MICHIGAN SEA GRANT PROGRAM

Reference Report

THE UNIVERSITY OF MICHIGAN MANUAL OF SAFE PRACTICES FOR SCIENTIFIC/ ACADEMIC SCUBA DIVING

by
Lee H. Somers

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FOREWORD

As part of the continuing effort to minimize the hazards of scientific/educational diving, the office of the Diving Safety Coordinator has prepared this concise guide for the conduct of scuba diving operations. Its content is based upon most frequently used information from diving manuals, federal and state regulations, and standards of Practice in the scientific/educational diving community.

The University of Michigan Manual of Safe Practice for Scientific/Academic Scuba Diving is designed for use as a quick reference by the diving team in the field. In addition, it may be used as an instructional text and guide to administration of scientific/educational diving programs.

The Manual's organization is analogous to an actual diving program or operation. Starting with personnel qualifications and training, it proceeds through the actual conduct of a dive to emergency procedures. Only open-circuit scuba diving is covered in this Manual. Separate manuals are available for surface-supplied diving and hyperbaric chamber operation.

This Manual complies with the requirement for a "safe practices manual" as specified in Part 1910 of Title 29 of the Code of Federal Regulations, Subpart T, Commercial Diving Operations.

Lee H. Somers, Ph.D.
Diving Safety Coordinator

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SECTION 1

INTRODUCTION

There are thousands of scientific/academic divers in the United States and abroad whose terms and conditions of employment fall outside the existing framework of military, commercial, and recreational diving. These people work in universities, research institutes, and government departments, and dive from time to time in the normal course of their work. Their diving must necessarily be carried out under acceptable standards of safety, and with professional efficiency.

The purpose of this document is to provide guidance in the training, qualification, responsibility, safety, maintenance of standards and conduct of operations for scuba diving in the course of research activities. The practices recommended in this document are intended to minimize the dangers to which scientific/academic divers are exposed.

NOTES:

SECTION 2

PERSONNEL: QUALIFICATIONS, TRAINING, CLASSIFICATIONS AND RESPONSIBILITIES

DIVER QUALIFICATIONS

All divers and applicants for diver training must meet prescribed medical, swimming and fitness standards. Candidates for training are required to pass a specific medical examination and swimming test prior to acceptance into the training program. University authorized divers are required to requalify annually. This requalification involves a medical examination and completion of a specified number of dives during the previous twelve month period. All divers are expected to maintain their swimming proficiency and a high level of physical fitness.

Medical Requirements

The University shall determine that persons who are, or are likely to be, exposed to hyperbaric conditions are medically qualified to perform assigned tasks in a safe and healthful manner. Prior to initial hyperbaric exposure all divers shall be examined by a physician familiar with the physical requirements and medical aspects of diving. In addition medical examinations are required:

1. At one year intervals from the date of the initial examination or last equivalent examination;
2. After any injury or illness requiring hospitalization for more than twenty-four (24) hours;
3. Following decompression sickness with vestibular or central nervous system involvement or pulmonary barotrauma; or
4. If the diving instructor, a University respresentative, or the Diving Safety Coordinator has doubts as to the individual's medical qualification to continue diving.

All applicants for University diver training must complete a specific diver medical examination. This medical examination includes special emphasis on the individual's medical history and ear, nose, and throat, pulmonary and cardiovascular scrutiny. The examining physician must consider the following (Nemiroff, Somers, and Anderson, 1975):

1. Diving involves heavy exertion. A diver must be in good health, be free of cardiovascular and respiratory disease, and have good exercise tolerance.

2. All body air spaces must equalize pressure readily. Ears and sinus pathology may impair equalization or be aggravated by pressure. Obstructive lung disease may cause catastrophic accidents on ascent.

3. Even momentary impairment of consciousness underwater may result in death. A diver must not be subject to syncope, epileptic episodes, diabetic problems, or the like.

4. Lack of emotional stability seriously endangers not only the diver but also his companions. Evidence of neurotic trends, recklessness, accident-proneness, panicky behavior, or questionable motivation for diving should be evaluated.

Disqualifications for scuba diver training are considered on the following basis (Nemiroff, Somers, and Anderson, 1975):

1. Pulmonary
    a. Asthma (requiring medications, wheezing on examination or within one year)
    b. Pneumonia - recurrent or present
    c. Pneumothorax (recurrent)

2. Cardiovascular
    a. Arrhythmias
    b. Aortic insufficiency
    c. Ventricular septal defect
    d. Cardiogenic syncope
    e. Hypertension

3. Otologic
    a. Perforated tympanic membrance
    b. Chronic sinusitis
    c. Mastoidectomy (double)

4. Metabolic
    a. Diabetes-mellitus (unstable)

5. Miscellaneous
    a. Osteogenesis imperfecta
    b. Vascular instability - Syncope
    c. Recent operations
    d. Infectious monoucleosis

Federal regulations specify that employees subject to provisions of Part 1910 of Title 29 of the Code of Federal Regulations, Subpart T must submit to the following initial medical examination:

1. Medical history review;

2. Diving-related work history review;

3. Basic diver's physical examination;

4. Test:

   a) Chest x-ray (PA projection);
   b) Visual acuity;
   c) Color blindness;
   d) Audiogram;
   e) Pulmonary function (VC and FEV_1);
   f) EKG: Standard;
   g) Hematocrit or hemoglobin;
   h) Sickle cell test;
   i) White blood count; and
   j) Urinalysis

5. Any additional test that the physician considers necessary.

The following disorders may restrict or limit occupational exposure to hyperbaric conditions depending on severity, presence of residual effects, response to therapy, number of occurrences, diving mode, or degree and duration of isolation:

1. History of seizure disorder other than early febrile convulsions.

2. Malignancies (active) unless treated and without recurrence for 5 years.

3. Chronic inability to equalize sinus and/or middle ear pressure.

4. Cystic or cavitary disease of the lungs.

5. Impaired organ function caused by alcohol or drug use.

6. Conditions requiring continuous medication for control (e.g., antihistamines, steroids, barbiturates, mood altering drugs, or insulin).

7. Meniere's disease.

8. Hemoglobinopathies.

9. Obstructive or restrictive lung disease.

10. Vestibular and organ destruction.

11. Pneumothorax.
12. Cardiac abnormalities (e.g., pathological heart block, valvular disease, intraventricular conduction defects other than isolated right bundle branch block, angina pectoris, arrhythmia, coronary artery disease).
13. Juxtra-articular osteonecrosis.
14. Pregnancy

The examining physician is provided with the following:

1. A diving medical examination form (Appendix A);
2. A summary of the nature and extent of diving conditions to which the diver will be exposed;
3. A summary of the diver's work history; and
4. A medical history of the diver.

The physician shall provide a written report of the examination to the University Diving Safety Coordinator and instructor. This report shall include the:

1. Date and location of the medical examination;
2. Results of the medical examination; and
3. Opinion of the individual's fitness to be exposed to diving (and hyperbaric) conditions, including any recommended restrictions or limitations to such exposure.

The University Diving Safety Coordinator or instructor shall provide the individual diver with a copy of the physician's report.

Swimming Requirements

Applicants for scuba diving training must successfully complete the following swimming test without the use of fins:

1. Swim 400 yards (360 meters) in less than 10 minutes;
2. Demonstrate proficiency in at least two basic swimming strokes (backstroke, breaststroke, sidestroke, crawl, etc.);
3. Swim underwater for a distance of 25 yards (22.5 meters) without surfacing;

4. Swim underwater for a distance of 40 yards (36 meters), surfacing not more than four times;

5. Remain afloat for 15 minutes using floating, drownproofing, or treading techniques; and

6. Surface dive to a depth of 10 fsw (3 msw), recover an inert swimmer, and tow the swimmer 25 yards (22.5 meters) at the surface.

The applicant must complete the above test without exhibiting signs of unusual fatigue or physical stress. Rest periods are allowed between tests; however, all six tests should be completed within a 90 minute period.

Certified (university authorized) divers are expected to maintain the above minimum level of swimming proficiency through their active diving career. The Diving Safety Coordinator/ Diving Safety Control Board may require periodic demonstration of swimming proficiency as a requalification requirement. Failure to meet a minimum proficiency level can be a basis for suspension or restriction of University diving authorization.

Physical Fitness

Flexibility, strength, and endurance are necessary for underwater swimming and diving. Good physical condition may prove to be the most important aspect of diving safety. The physically fit individual is able to withstand fatigue for longer periods and is better equipped to tolerate physical and emotional stress. Diving, particularly for novices, places severe stress on the entire body, especially the cardiovascular and respiratory systems. Anxiety, lack of skill (inefficiency), nonconditioned heart, hyperventilation, obesity, equipment restrictions, breathing resistance, and cold water are among the factors which cause increased heart rate and the onset of fatigue. As a general rule, average participation in diving activities is not sufficient in itself to develop and maintain a high level of physical fitness. Diving must be supplemented by a regular exercise program. This is especially true for persons who do not dive on a regular basis. Persons who participate only on a seasonal basis should exercise regularly when not diving, or at least initiate a conditioning program six to eight weeks prior to the diving season. Jogging is an excellent conditioner for divers.

One of the most widely accepted physical fitness or conditioning programs is the "aerobics" program (Cooper 1970). This program is based on exercises that stimulate heart and lung activity for a time period sufficiently long to produce changes in the body. Aerobics offers a variety of different forms of exercise including running, walking, cycling, swimming, handball, basketball, and squash. Each of these activities has one thing in common. They force the body to work hard and demand large quantities of oxygen.

The main objective of an aerobic exercise program is to increase the maximum amount of oxygen that the body can process within a given time. This is called the body's aerobic capacity. It is dependent upon an ability to (1) rapidly breathe large quantities of air, (2) forcefully deliver large volumes of blood and (3) effectively deliver oxygen to all parts of the body. Because it reflects the general condition of the respiratory and cardiovascular systems, the aerobic capacity is a good index of over-all physical fitness.

Although many exercise programs have been published and various authorities advocate various programs, the Cooper (1970) program has been selected as an "exercise program example" for the following reasons:

1. Apparent acceptance and use by a large population;
2. Detailed and simplified publication sold throughout the United States;
3. Specific programs for both men and women;
4. Age adaptable;
5. Simplified personal fitness testing scheme;
6. Variety of different forms of exercise including swimming;
7. Adaptable to a variety of life styles and living situations;
8. Simplified "point" system for measuring personal progress; and
9. It works!

Cooper has devised simple field tests to aid the individual in accessment of personal fitness. The test requires only a stopwatch and a place to run. One such test is the "12-Minute Test." This test involves covering the greatest distance you can in 12 minutes by running, walking, and/or a combination of both. An active diver should maintain a fitness level of Category IV (Good) for this test. This means that the male under the age of 30 should be able to cover 1.5 to 1.74 miles (2.4 to 2.78 kilometers) and the female diver should cover 1.35 to 1.64 miles (2.16 to 2.62 kilometers) in 12 minutes.

Since the heart rate and blood pressure cannot be monitored continuously during the field test, there is a certain degree of risk if one takes this test without having been properly conditioned by previous exercise. Cooper suggests the following precautions:

1. "Don't take a fitness test prior to beginning an exercise program if you are over 30 years of age."

2. "Be sure to have a medical examination (as outlined in Chapter 3 of his book) before you take the test. If you are over 30, it is still safer to postpone the test until you have completed the six-week 'starter program' as indicated in Chapter 6 (of his publication)."

3. "If you comply with the above, yet experience extreme fatigue, shortness of breath, lightheadness, or nausea during the physical fitness test, stop immediately. Do not try to repeat the test until your fitness level has been gradually improved through regular exercises."

All persons who are interested in starting an exercise program or modifying their existing program are encouraged to read Cooper (1970) or other similar publications recommended by a physician or fitness authority. For divers, the fitness program should include swimming.

DIVER TRAINING

Ideally, scientific/academic divers should be trained in special research diver courses. At a minimum this training shall include:

1. Scuba diving operations and emergency procedures;

2. Scuba diving techniques;

3. The use of equipment, systems and tools relevant to research diving tasks;

4. Diving related physics and physiology;

5. Knowledge of environmental factors and marine life relevant to dive planning, operations, and personal safety;

6. Field assembly, inspection, disassembly, and maintenance of scuba and associated diving equipment;

7. Use of U.S. Navy Standard Air Decompression and Repetitive Dive Tables;

8. Training in diving related lifesaving, first aid, and cardiopulmonary resuscitation; and

9. University safe diving practices and standards.

Detailed guidelines for diver training are included in Appendix B .

Scientific/academic scuba divers are frequently trained in recreational scuba diving courses. The scope of such courses is often limited in the areas of physical fitness/ watermanship requirements, dive operation planning and coordination, accident management, lifesaving techniques, decompression tables, and so on. Also, the recreational diver may acquire biased attidues towards equipment, diving procedures, etc., which are inconsistent with organized scientific/academic diving. The Diving Safety Coordinator and, later in the field, the Diving Supervisor must continue to assess the recreational trained diver for such inconsistencies.

PERSONNEL CLASSIFICATION AND RESPONSIBILITIES

Diving Supervisor

The Diving Supervisor (designated person-in-charge or Divemaster) is the person in immediate charge of a diving operation. He/she is generally a highly experienced diver or former diver designated by the employer, the University Diving Safety Coordinator, or by dive team agreement. The Diving Supervisor has complete authority and full responsibility in the conduct of the operation. All divers are in turn responsible to the Diving Supervisor for carrying out their assigned tasks according to preliminary planning and briefing and must adhere to specified safety requirements.

On major operations the Diving Supervisor will generally not enter the water. His/her usual post is on the surface where he/she is in full command of surface personnel and in a position to direct surface personnel and standby divers in an emergency situation. The Diving Supervisor may enter the water in an emergency situation, for predive and post dive inspections, and to give directions. In such situations, a responsible and qualified individual will be designated as temporary Diving Supervisor. It is absolutely necessary that a Diving Supervisor be in charge at the surface during all major diving operations. Whenever possible the Diving Supervisor should have a full supporting surface crew for timekeeping/recordkeeping, tending and other tasks.

On simple and limited research diving operations, the Diving Supervisor may also have to assume the roles of diver and scuba team leader or that of timekeeper/recordkeeper and tender. Unfortunately, large numbers of qualified personnel commonly used for military and commercial diving operations are not always available or feasible for research diving operations. Under acceptable environmental and operational conditions, a two-person land based or small boat scuba team may safely conduct a diving operation. Naturally, special considerations must be given to dive planning, boat mooring, diving procedures and so on. Generally, the most experienced member of the team will assume the role of Team Leader/Diving Supervisor.

For any diving operation, regardless of magnitude, the Diving Supervisor shall observe the following:

1. Plan the operation as completely as possible.
2. Survey the activity or task.
3. Evaluate the environmental conditions.
4. Select the proper diving technique.
5. Select and inspect the proper equipment.
6. Designate/approve scuba teams and team leaders.
7. Designate/approve surface crew.
8. Assign/approve task or responsibility for all dive operation personnel.
9. Brief divers and surface crew as fully as possible.
10. Brief the Captain of the support vessel.
11. Take all possible precautions against foreseeable contingencies.
12. When a scuba team is working from a shore base or a small boat, file a dive plan including exact dive location, members of team, and estimated time of return to base.

13. Supervise and direct all phases of the diving operation.

14. When working with an optimum surface crew, do not enter personally into any phase of the operation except to make the predive and postdive inspections, to give directions, or to handle an emergency.

15. Ensure that the operation is conducted in compliance with existing safety regulations.

16. Ensure that all divers have the required equipment with them before departing the staging area.

17. Conduct initial and periodic radio checks with the operations base and other stations in the area of operation; adhere to pre-arranged schedules.

18. Conduct pre-dive inspection of each diver; ensure that buddy pairs conduct mutual inspections and enter the water together; ensure that each diver fully understands the instructions before he/she enters the water.

19. Fill out all applicable information on the rough diving log at the dive site and/or review entries made by the designated recordkeeper.

20. Complete a smooth diving log or final record within 24 hours after completing the diving operation and submit it to the Diving Safety Coordinator.

21. Check with the divers for equipment malfunctions at the dive site; record malfunctions in log and "red tag" malfunctioning equipment.

22. Supervise cleaning and stowing of equipment; ensure that is is properly maintained and stored.

23. Take complete charge during any diving emergency and ensure that proper action is taken and reports made.

24. Ensure that all safety precautions and instructions are followed.

Diving Supervisors are designated/approved by the Diving Safety Coordinator. They are qualified to supervise diving operations only for the equipment in which they are already qualified, and may be required to take periodic courses or tests.

Scuba Diver

Each dive team member shall have the training and/or experience necessary to perform tasks assigned in a safe and proper manner. The classification system used for scientific/academic diving is based on initial scuba diver training, supervised environmental exposure/training, a controlled diving depth exposure progression, and recommendations of instructors or supervising divers. Detailed guidelines for training and classification of scientific/academic divers are given in Appendix B. The progressive depth rating system is summarized in Table I.

TABLE I - Open water diver requirments for scuba divers

Certification Depth (fsw/msw)	Total Minimum Number of Divers (2)	Total Minimum Underwater Time (Hr)	Depth Range of Qualification Advancement Dives (fsw/msw) (2) (3)
30/9	12(1)	4	
60/18	24	8	31-60/9.3-18
100/30	36	10	61-100/18.3-30
130/39	48	12	101-130/30.3-39
160/48	52	-	131-160/39.3-48
190/57	56	-	161-190/48.3-57

(1) Initial training dives completed under supervision of a diving instructor or approved certified diver.

(2) The minimum total number of dives required to receive a given depth certification. Dives for advancement in depth rating must be performed within the specified depth range. For example, to advance from a 30 fsw (9 msw) to 60 fsw (18 msw) rating requires 12 additional dives with a minimum total underwater time of 4 hours performed in the depth range of 30 to 60 fsw (9.3 -18 msw).

(3) All certification advancement dives or dives beyond current certification must be made under the direct supervision of an authorized diver already qualified to at least the next greater depth and validated by the signature of the diving supervisor, an approved instructor, or two authorized individuals who are divers and are themselves certified to the depth of certification advancement.

The Diver's Responsibilities

Each individual on the dive team has specific responsibilities to the other members of the team and, when applicable, to the employer. Willfully using faulty equipment, violating standard safe diving practices, diving when ill and so on, not only endangers the individual, but may also jeopardize the safety of other team members and the entire diving operation. The following is a list of individual "considerations" that each person should make when participating in a scuba diving operation:

1. I have the responsibility and privilege to refuse to dive if, in my judgement,:

    a) The conditions are unfavorable (including environment, personnel, planning, etc.);

    b) I am not qualified for the diving depth, environmental conditions, equipment, or procedures designated for this operation;

    c) I am not in proper physical or mental condition for diving (suffering from a cold, hangover, recent emotional trauma, etc.);

    d) I would violate the dictates of proper diving safety procedures or the governing standard;

    e) The equipment provided for the dive is, in my opinion, inadequate or malfunctioning; or

    f) A proper emergency procedure plan has not been determined.

2. I have the responsibility for reporting immediately to the designated person-in-charge and team members any equipment malfunction or discrepancy in safety procedures.

3. If I am providing my own equipment, it must be properly functioning, adequate for the diving conditions, and meet the acceptable standard for scuba diving. The following must be considered:

    a) Do I have the minimum necessary equipment for this scuba dive?

    b) Are my mask and fin straps in good condition and properly adjusted?

c) Is my buoyancy compensator properly fitted, equipped with a fully charged CO_2 or air cylinder, and completely functionable?

d) Are my depth gauge and timing device accurate?

e) Do I have proper thermal protection for the surface and water conditions?

f) Does my scuba cylinder have current hydrostatic test (within five years) and internal inspection (within one year) designation?

g) Is my scuba cylinder fully charged?

h) Is my scuba harness properly adjusted and fitted with a quick-release mechanism?

i) Is my scuba equipped with a submersible pressure gauge?

j) Is my scuba cylinder properly secured to the backpack/harness?

k) Is my weightbelt properly adjusted (amount of weight), equipped with a quick-release buckle, and fitted over all other straps in order to facilitate unrestricted release?

l) Is a surface float required for this dive? If so, is my float adequate for towing and emergency use?

m) Do I have an adequate sharp knife?

n) Are my scuba harness and weightbelt quick-releases fully exposed (not covered by BC or other equipment) in order to facilitate uninhibited release by myself or another person in an emergency?

4. Does my "buddy" know the location and operation of my CO_2 inflator, air power inflator (if so equipped), scuba harness/weight belt releases, and knife?

5. Do I have proper containers for transporting and stowing equipment (especially on vessels with large numbers of divers)?

Timekeeper/Recordkeeper

For operations involving several divers and repetitive dive schedules, a Timekeeper/Recordkeeper shall be designated by the Diving Supervisor. Whenever possible, this individual should have no other duties during the dive. The Timekeeper/Recordkeeper maintains worksheets and fills out the rough diving log for the operation, and records the diver's descent time, bottom time, ascent (decompression) time, and total dive time. In scuba diving operations, surface personnel can directly log times of starting descent and surfacing. However, the remaining dive time information must be supplied by the diver. The Timekeeper/Recordkeeper will keep stop-watch time on all divers and inform the Diving Supervisor of any irregularities, as well as keeping him informed at all times of the status of the dive. Other responsibilities include (1) knowning the probable diving depth and duration of the apparatus (air supply); (2) notifying the Diving Supervisor when the planned dive time is nearly up in order to facilitate diver pick-up or assistance; (3) providing the supervisor with assistance in figuring no-decompression schedules; and (4) foreseeing decompression requirments and warning the Diving Supervisor soon enough to make appropriate arrangements. Consequently, a dive status record (rough log) and standard decompression schedules must be available for immediate display to the Diving Supervisor.

If wireless communications (or wire type communications for tethered scuba divers) is used, the Timekeeper/Recordkeeper will generally operate the communications system. The Timekeeper/Recordkeeper should also be an administrative assistant to the Diving Supervisor for purposes of final record preparation, equipment records, personnel management, and so on. In limited scuba diving operations, the Diving Supervisor may assume the duties of Timekeeper/Recordkeeper. The Diving Supervisor shall have the following items available for timekeeping/recordkeeping:

1. Timekeeping device (ideally a standard watch and stopwatch);
2. Appropriate decompression tables;
3. Recordsheets (rough dive log and repetitive dive worksheets);
4. Clipboard and pencils/pens; and
5. Operations handbook or safe practice manual.

Standby Diver

A Standby Diver is required for line-tended scuba diving; and when scuba diving operations are conducted in caverns, under ice, or in submerged structures (pipelines, shipwrecks, etc.); and when divers are exposed to underwater situations in which there is a significant risk of entanglement (in and around fishing nets, etc.). The diver is fully qualified in the equipment to be used and holds the appropriate environment and depth ratings for the diving operation. He/she is prepared to back-up or to provide emergency assistance to the diver(s) in the water. The Standby scuba diver shall be dressed for quick deployment in all required equipment except fins, mask, and breathing apparatus. This equipment shall be ready and immediately accessible at the dive location. The weight belt may also be put on after the breathing apparatus if the scuba harness includes a crotch strap. A tending line should be available for use as required. The Standby Diver receives the same briefing and instructions as the working divers, and monitors the progress of the operation so that if called upon for assistance, he/she is fully prepared to respond. In some situations the Diving Supervisor may designate a two-person Standby Team instead of a single diver.

A Standby Diver is often used at the discretion of the Diving Supervisor, for openwater diving from vessels or shore bases. In this case, the Standby Diver functions in a lifeguard capacity ready to render aid to a distressed diver on the surface. The Standby Diver is stationed at a location where he/she can observe the entire operational area and quickly enter the water. When scuba diving operations are conducted from large vessels, a small boat (tending boat or chase boat) is often used to follow the divers or drift in their immediate vicinity. The Standby Diver would, of course, be stationed in this small boat. Although breathing apparatus shall always be available to this Standby Diver, it will generally not be used in surface rescue situations.

Tender/Diver Aide

A Tender or Diver Aide is a surface crew member who assists the divers as necessary in dressing, pre-dive equipment checks, leaving the boat or shore, and boarding the boat. The Tender assists the divers in equipment handling and inspection. In line-tended scuba diving operations, the Tender constantly tends the diver's line to eliminate excess slack or tension. The Tender exchanges line-pull communications with the diver, keeps the Diving Supervisor informed of the diver's status, and remains alert for any signs of an emergency.

Ideally, the Tender should be a qualified diver. When circumstances require the use of a non-diver as a Tender, it is the responsibility of the Diving Supervisor to ensure that he/she has been properly instructed in tender duties. As a minimum requirement the Tender should hold the following qualifications:

1. Familiarity with scuba apparatus and scuba diving procedures;
2. Trained in diving related first aid and cardiopulmonary resuscitation; and
3. Thorough knowledge of diving line-pull signals.

Emergency Medical Person

At least one member of the diving team should be qualified as an advanced first aider, emergency medical technician, diving medical corpsmen, or equivalent. Diving medical personnel aid the Diving Supervisor in assessing the fitness of divers before the operation begins and are prepared to handle any medical emergency which might arise. They maintain the first aid kit and oxygen inhalation apparatus in a "ready" status. In addition, they may also instruct members of the diving team in first aid and emergency medical procedures and provide personal medical advice. A specially qualified medical technician or physician is required for operations involving the use of a hyperbaric chamber.

Boat Operator/Crew

The number of personnel required for boat operation will depend upon the type and size of the craft. Ideally, Boat Operators should not dive. They are responsible for boat operation, navigation, proper mooring, boat safety, and emergency response. However, diving "qualified" boat crew-persons may be used as a Tender, Timekeeper/Recordkeeper, or Standby Diver provided that such action does not jeopardize the operation or safety of the boat. On limited scuba diving operations using small boats, at least one person should remain on the vessel at all times. This is a mandatory requirement for night diving operations.

THE BUDDY SYSTEM

The use of the buddy system is considered by some authorities as the greatest single safety factor in self-contained diving. Yet a review of Schenck and McAniff (1975) reveals that 92 percent of recreational scuba diving fatalities in 1973 occurred with the buddy system being used.

Only 8 percent of the fatalities involved solo divers. Since 1970, only 46 of 469 fatalities studied involved solo divers. Despite this alarming fact, authorities agree that no self-contained diving operation should be undertaken without the use of the buddy system. This safety procedure requires that the divers work as a single unit. Each member of the buddy team is responsible for his partner's safety throughout the dive. Both have a joint responsibility for completion of the task assigned.

What is wrong with the buddy system? Why do diver still die while using the buddy system? There is no single answer to these questions. In some cases, the accident would have occurred regardless of whether the buddy system was being used or not. However, many divers fail to understand what is meant by the buddy system. The buddy system is a "total commitment." Simply entering the water together or swimming in each other's presence is not the true buddy system. The buddy system is both physical and mental. Physical presence is, needless to say, a vital factor. However, the buddy system is also a state of mind. The buddy system attitude begins on your first day of scuba diver training and continues throughout your diving career. Your life, may indeed, depend on your choice of a buddy.

First, how do you choose a buddy? Unfortunately, this involves a rather haphazard approach by most divers. All too frequently, the selection of a buddy is based solely on "availability," not objective criteria.

Fead (1976) discusses buddy selection and describes four types of divers that may make undesirable buddies: (1) novice diver, (2) insulated diver, (3) subtle competitor, and (4) misunderstood diver. The novice diver is often awkward and unorganized. He is ashamed of his lack of ability and experience. The experienced diver may often be placed in a situation of diving with a novice and this experienced diver must recall that he was also once a novice. Time, patience, consideration, and guidance are needed to transform the novice into a qualified diver. The experienced diver that embarrasses the novice with regard to his capability, clumbsiness, and apparent lack of experience may well be producing an "anxiety factor" that will later affect the diver's performance. The novice diver may respond by attempting to "cover-up" his apparent short comings and may extend himself beyond both his physical and mental limitations during the dive. This spells trouble for both divers.

The insulated diver is the diver that feels that the rules of diving do not apply to him. Everyone else should dive by the rules; however, he is so good that nothing can happen to him. This type of diver often gets into serious trouble. His buddy must be prepared to rescue the insulated diver and may not depend on that diver to reciprocate in an emergency.

The subtle competitor is, in my opinion, one of the most awkward and potentially dangerous diving buddies. This diver is always challenging his buddies, especially novices. He commonly brags about his low air consumption. The minute he returns to the boat he immediately asks how much air you have left and boasts about his low consumption. If you use 15 lbs of weight on your belt, he finds competitive satisfaction in either using more or less. He prides himself on swimming further or faster than his buddy. Most frightening of all, this diver is generally a "deep freak." Life and diving are continously competitive events.

Do not accept the challenge of the subtle competitor. You cannot win! Such feats of competition tend to push you to and beyond your physical and emotional limits. Every diver has a reasonable and prudent safe limit. Remember that the subtle competitor is not only competing with his buddy, but also himself. As a buddy you must be ultimately prepared to rescue this diver when he exceeds his limit.

The misunderstood diver is the one who fails to communicate with his buddy before the dive. He assumes that every dive will be the same as the previous dive; consequently, there is no need for planning. This is the diver who always gets lost, swims the wrong way, leaves necessary equipment at home, and so on. He simply fails at "thinking." And "thinking" is the process in diving by which problems are avoided or solved. If the misunderstood diver thinks at all, he thinks alone.

The buddy must be selected several days before the dive. Each good diver will ultimately develop his own criteria for buddy selection; however, the following may serve as a guide:

1. Is the diver properly trained and experienced to participate in the proposed dive? Far too often divers are embarrassed to ask a new buddy for his C-card and logbook or to ask if he has ever dived under a particular environmental condition. Would you want to enter into a 4 ft surf and dive where there are strong currents with a diver who has only made 10 dives in a small midwest stone quarry? Above all, diving buddies must be honest with each other. If you are not qualified to make the dive, say so! Do not jeopardize the safety of yourself and your buddy.

2. *Is the diver physically fit to make this dive?* Strenuous dives require fit divers. If you select a buddy who is not fit, you may find yourself in a rescue situation. Furthermore, this unfit diver may be worthless to you if you get into trouble. A diver who was fit last year may be completely out of condition this year. A diver who has been recently ill or hospitalized may also be unfit for *this* dive. Again, honesty is a key to safety. If you know you are not "up to it", *decline* the invitation to participate in the dive.

3. *Is the diver properly equipped for this dive?* Evaluating a new diving buddy's equipment is part of the game of safe diving. Both his safety and your safety depend on that equipment. Does your buddy have a submersible pressure gauge on his regulator? If not, he is not an acceptable diving buddy. He is not properly equipped. Does your buddy have a proper buoyancy compensator? Is his suit acceptable for the water temperatures to be encountered? Are his fin straps showing signs of advanced deterioration? Does your buddy have a watch and depth gauge? Does he appear to have an "excessive" amount of weight on his belt? Is all equipment in good working condition?

Equipment does not make the diver; however, the quality, completeness, and condition of a diver's equipment is an important factor in evaluating a diver. A poorly equipped diver may be a poor buddy. If the diver's buoyancy vest doesn't function in an emergency, it may result in the loss of his life, your life, *or* both. Evaluate your own equipment! Are you properly equipped?

4. *Is the diver a "good" buddy?* Don't be afraid to ask fellow divers about a new diving buddy. Reputation is a key factor. Poor diving buddies are soon identified in the diving community.

5. *How will the diver respond in an emergency?* Exactly how a diver will respond under the stress of an actual emergency is difficult if not impossible to assess. However, you can identify if your responses and your buddy's responses will be *compatible* through discussion of training and personal diving philosophy.

As a buddy team, what will you do if one diver's air supply suddenly fails at depth? Evaluation of a group of midwest divers revealed that about 50% would make an emergency swimming ascent and 50% would make a buddy breathing ascent. What would you do? What would your buddy do? It is too late to work this out at the time of the emergency. Unfortunately, there are other factors to consider. Let's assume that your buddy is a "free ascender" and you are a "buddy breather." Before the dive you collectively decide that you will "buddy breathe" if such an emergency arises. Under the stress of a real emergency, each of you will most likely revert to the procedure that you have learned or practiced in training. The "most learned" skill or procedure will dominate. There is no easy solution. Ideally, you should select a buddy that has the same training and emergency procedure orientation as yourself. If you are an individual that is in a position of diving with "new" and unfamiliar buddies most of the time, consider an auxiliary breathing system ("pony bottle").

Do not assume that your buddy will respond the same as you would in an emergency. Practice with your buddy prior to the dive. A good buddy team will develop a routine of periodic emergency procedures and rescue practice.

PERSONNEL CREDENTIALS

All divers must have a current letter of University diving authorization or a diver certification card and a recognized form of official identification (driver's license, staff or student identification card, etc.) in the immediate vicinity of the diving location. When traveling to dive at marine laboratories, other universities, and some resorts a copy of a current diver medical examination may be required. The diver's personal logbook should also be available for review by the Diving Supervisor. All documents and logbooks should be placed in a protective waterproof case. They should be carried in the diver's luggage, a camera bag, or brief case, not a dive bag.

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SECTION 3

DIVING EQUIPMENT

SELF-CONTAINED UNDERWATER BREATHING APPARATUS

Self-contained underwater breathing apparatus (or scuba) is the most common type of diving apparatus used in recreational and scientific diving today. Generally, only open-circuit type scuba is used. This means that no breathing gas is recycled in the system. The diver simply inhales air from the scuba cylinder and all exhaled gas is released into the water. Consequently, open-circuit scuba is very inefficient from a standpoint of breathing gas economy. A large volume of air is required for a relatively short duration dive. However, this low gas economy factor is more than compensated for by the simplicity, low cost, limited maintenance requirements, and lack of physiological problems commonly associated with recirculating type scuba.

Open-circuit scuba components include a high pressure cylinder with valve, a pressure reduction regulator with mouthpiece assembly and a submersible pressure gauge, and a backpack/harness assembly. Some scuba are also equipped with a buoyancy regulation system and auxiliary breathing equipment. Two or more cylinders may also be manifolded together. In this handbook only a generalized description of scuba components and specifics on preventive maintenance will be given. Consult a diving manual or textbook for details.

Regulator

The open-circuit scuba regulator reduces high-pressure air from the cylinder to ambient or breathing pressure. Air flow in initiated by a slight inhalation pressure and continues only as long as the diver inhales. The volume of air delivered is regulated by the diver's inspiratory requirements. The exhaled gas is released directly into the water through a non-return valve located in the mouthpiece assembly. Today, most scuba regulators are of the two-stage, single hose type. In the two-stage regulator air is reduced from cylinder pressure to ambient pressure through two reduction stages. The first - and second-stage reduction mechanism are separated by a length of hose, and the second stage is part of the mouthpiece assembly. One-stage and double-hose models are available; however, because of their limited use and availability, they will not be discussed here.

The first stage is depth compensated and designed to maintain a constant intermediate pressure ranging from about 120 to 180 psig (8.4 to 12.7 kg/cm^2) above ambient pressure depending on the make. Most intermediate pressure reduction valve systems use a piston-type mechanism or a balance diaphragm/valve mechanism to control release of high pressure air from the cylinder. The second stage is a demand-lever-activated unit designed to reduce intermediate pressure to ambient pressure. Inhalation by the diver causes a pressure reduction within the second-stage air chamber with respect to ambient pressure and a flexible low-pressure diaphragm is deflated inward. This activates the second-stage demand lever which opens the low-pressure valve assembly. Air enters the second-stage chamber until demand ceases and the internal pressure equals ambient pressure. As air is released from the intermediate-pressure chamber, the high pressure valve opens and allows air from the cylinder to enter the intermediate-pressure chamber. When pressures are balanced, the valves close to stop air flow until the next inhalation. In single-hose regulators, the low-pressure diaphragm may be depressed manually to activate the demand lever and start air flow.

The exhaust valve port in a single-hose regulator is located in the lower or side portion of the second-stage air chamber (mouthpiece assembly). A non-return valve prevents water from entering through this port. The exhaled air is deflected away from the diver's face through a special rubber/plastic assembly.

All scuba must be fitted with a submersible pressure gauge that enables the diver to monitor cylinder pressure while swimming underwater. Generally, the gauge assembly is attached to the intermediate-stage regulator housing. The gauge is fitted with a length of high-pressure hose, which enables the diver to place the gauge in a position for easy monitoring. Always select a pressure gauge that reads 500 to 1000 psi (35 to 70 kg/cm^2) higher than the maximum cylinder working pressure.

Some divers use regulators with dual second-stage assemblies to facilitate supplying air to another diver in an emergency situation. Consequently, the diver does not have to remove his/her mouthpiece as in conventional buddy-breathing. This procedure is simpler and safer. Although there is no standardization of carrying position or use of the auxiliary mouthpiece assembly, many divers attach it to their scuba harness with a quick-release mechanism and simply pass it to a distressed diver as needed. A longer, brightly marked hose is often used on the auxiliary unit. Diving teams generally standardize position, attachment, and use procedures on an individual team basis. Procedure and position must be established between buddy pairs in pre-dive preparation. Do not let the auxiliary mouthpiece assembly drag unattached beside the swimmer. It is vulnerable to damage and filling with debris.

Some scuba regulators are equipped with low-pressure warning devices. The most common type uses a spring activated valve with a manual override. This mechanism permits air to flow freely until the cylinder pressure falls to a predetermined level (generally 300 psig or 21 kg/cm^2). At this pressure, a spring forces a flow check valve against the port orifice and restricts the air flow. Initially, the diver notices an increase in breathing resistance followed quickly by complete obstruction of air flow. The remaining air in the cylinder, approximately 9 cf (255 liters), is released by manually activating the override located on the first-stage assembly.

An audible low-pressure warning system is used on some regulators. In this system an audible signal automatically sounds when the cylinder pressure drops to a predetermined level (generally, 300 psig or 21 kg/cm^2). The signal continues during inhalation until the air supply is exhausted or dive terminated.

The use of low-pressure warning devices other than submersible pressure gauges on regulators has not gained universal popularity. In practice, many divers now reject the spring-loaded mechanism (J-valve type) even on cylinder valves. The submersible pressure gauge is universally accepted by American divers and is mandatory under some safety and health regulations.

Single-Hose Regulators in Cold Water

Single hose regulator malfunctions are relatively common in cold climates and/or cold water. University of Michigan divers have experienced single hose regulator malfunctions while diving in the Arctic and in the Great Lakes area during the winter. Fortunately, the single hose regulators malfunctioned in a free-flow or open mode. It was noted that precooling of the regulator by prolonged exposure to extreme cold before use contributed considerably to the chances of a freeze up. Also, residual moisture accidentally introduced during removal of the regulator from the cylinder valve assembly or in rinsing appears to be a significant contributing factor.

Cooling of the air due to adiabatic expansion from high pressure to low pressure causes moisture in the air or water in the regulator mechanism to cool significantly.

Because of the compact design of the first stage of single hose regulators heat is actually absorbed from the metal and even in very cold water the temperature within the regulator housing itself may be well below freezing. Consequently, water in liquid or vapor form will freeze. Ice crystals may plug orifices or interfere with the movement of regulator parts. Nearly all such internal freezing appears to cause the regulator to malfunction in an open or free-flow position.

External freezing may also occur. Ice crystals have been observed to form around both the first- and second-stage assemblies. These ice crystals may interfere with the proper movement of regulator parts and cause either loss of depth compensation, free-flow, or restricted breathing. Generally, ice forms around the large first stage spring which is exposed to the water resulting in jamming or excessive friction. This produces an increase in intermediate air pressure and causes the down-stream second demand valve to open and free-flow results. Freezing, internal or external has resulted in malfunction of both piston and diaphragm type single hose regulators.

Some manufacturers of single hose regulators have designed an antifreeze cup to place over a portion of the first stage assembly. The cup is filled with an antifreeze liquid (i.e. alcohol compound or equivalent). This insures that fluid in contact with the first stage diaphragm does not freeze. In another design the first stage of the regulator is fitted with a depth compensating oil-filled chamber over the diaphragm. The use of the antifreeze cup concept has reduced regulator malfunction due to freezing.

To date, there is no valid research data available to show that the single hose regulator freezing problems have been solved. Although the antifreeze cups and oil-filled first stage chambers apparently eliminate the first stage freezing problems, regulator malfunction as a result of second stage freezing still exists. Probably many of the malfunctions previously attributed to freezing of the first stage were, in fact, second stage freezing or both. Following hard inhalation and/or depressing of the purge button to activate high air flow, ice crystals apparently form in the second stage valve assembly. Consequently, the valve cannot close properly and air continues to free flow. Free flow at high rates only complicates the situation by promoting further ice crystal formation. The ice crystals form from moisture in the diver's exhaled breath plus free water in the second stage chamber. Divers are cautioned against letting water enter the second stage chamber before, during and between dives. Special care is required to completely dry all residual moisture after post-dive rinsing.

All divers and instructors are encouraged to stay abreast of current developments in diving through reading of periodicals such as "Sport Diver" and "Skin Diver Magazine."

It has been shown that breathing from a single-hose regulator in 32^{o} F (0^{o} C) water will not normally cause freezing of the second stage. However, free-flowing the regulator for more than 5 seconds may cause freezing. In one test situation, free-flowing through the second stage yielded a 5.4^{o} F second stage temperature drop within 30 seconds. Thereafter the temperature remained constant. Therefore, it is estimated that in water temperatures below 37.4^{o} F (3^{o} C) in fresh water and 34.2^{o} F (1.2^{o} C) in salt water, potential single hose regulator freezing is a significant problem.

Years of diving experience with the double hose, two stage regulator have passed with relatively few reported regulator freezing problems. In two hose, two stage regulators the high-pressure reduction mechanism is protected from contact with the water by the large metal case. The high pressure diaphragm is surrounded by air, not water. The larger mass of metal also alters the heat transfer characteristics.

Although some diving equipment retailers claim that "their" single hose regulators do not freeze and apparently many divers have participated in ice diving without experiencing the regulator freezing, the beginning ice diver must be aware of the possibility of a regulator malfunction and take precautions against it. The following precautions apply to both single hose and double hose regulators:

1. Be certain that scuba cylinders are completely dry inside. Frequent internal visual inspection by qualified persons is recommended.

2. Be certain that only moisture free air is used to fill scuba cylinders. Particular attention must be given to compressors. Some groups advocate the use of elaborate moisture separator-filter units; special desecant may be used to remove moisture.

3. Take special precautions when removing the regulator form the scuba cylinder, replacing the dust cap, and rinsing the regulator. Water introduced into the regulator following pool or open-water diving activities prior to the ice diving trip can cause trouble. This water may freeze inside the regulator and cause serious malfunction. Avoid the use of dust caps with hollow cores and be certain that all water is removed from the cap prior to emplacement.

4. If an antifreeze cap is available for your model of regulator, use it. However, even the antifreeze cap will not be an adequate precaution if there is water in your cylinder

or regulator prior to the dive.

5. Avoid prolonged exposure of the regulator to extreme cold prior to the dive.

6. A dual regulator-cylinder system should be used to provide an adequate emergency air supply and regulator in the event of freeze up. Small auxiliary scuba units may be used for this purpose, providing that the penetrations under the ice are not extensive or the water depth too great (less than 60 feet, 18 meters).

7. It appears that double hose, two-stage regulators are more dependable for ice diving. The users of single hose regulators should take special precautions.

8. Breathing from the regulator in a sub-freezing atmosphere prior to submergence also adds to the freezing probabilities. I recommend that the diver not inhale from the regulator until it is just below the surface of the water when diving under sub-freezing conditions. Also, do not let water enter the regulator.

Regulator Preventive Maintenance

Open-circuit scuba regulators are durable, but they can be damaged and malfunction unless given reasonable care. Simple preventive maintenance will ensure maximum operating efficiency with minimum repair requirements. Scuba regulators are built extremely rugged externally but are relatively delicate internally. The clearance between parts is close and foreign material or rust and salt corrosion can cause inefficient operation and malfunction. Observe the following preventive maintenance procedures for open-circuit scuba regulators:

1. Never stow or transport scuba cylinder with the regulator attached.

2. Do not lubricate your regulator; only proper lubricants should be applied by qualified regulator service persons. Silicone spray, commonly sold in dive shops, can cause the rubber parts such as exhaust valves and diaphragms to warp. Sprayed into the second stage of a regulator, silicone can be quite dangerous. It can seep under the diaphragm retaining ring and possibly cause the diaphragm to "pop out" during use. Underwater the consequences could be serious. Breathing excessive quantities of silicone mist can also be hazardous to your health.

3. In single hose regulators avoid sharp bends or tight loops that can seriously weaken the internal nylon or

cotton braid of both second-stage and pressure gauge hoses. Store with hoses straight or supported. Use stress relieving sleeves on all hoses at the point of connection with the second-stage housing.

4. Do not leave the regulator attached to a standing cylinder following the dive. The weight of the second stage can cause excessive stress on the regulator hose. Also, the unit may be severely damaged if it is knocked over.

5. Do not allow the second-stage to "drag" when snorkel swimming. This places excessive, potentially damaging strain on the regulator hose where it attaches to the second-stage and can seriously weaken hose fibers. The regulator second-stage may also catch on kelp or in rock crevices during surf entries/exits. Pressure gauge and auxiliary second-stage hoses are subject to the same type of damage.

6. Keep the scuba out of direct sunlight because it causes rubber products to deteriorate rapidly.

7. Do not allow water or foreign matter to enter the high-pressure inlet of the regulator. Dry and insert the protective cap into the yoke to seal the high-pressure inlet immediately after detaching the regulator from the cylinder. When water (salt or fresh) evaporates, it leaves a residue of salts or minerals.

This residue can accumulate on internal parts of the regulator, resulting in friction, decreased funtional efficiency, and excessive wear. Chlorinated swimming pool water is nearly as harmful to regulator parts as salt water. Use only plastic or rubber protective caps with a solid core and fitted with an o-ring to ensure a more positive seal. Avoid metal protective caps since electrolysis corrosion may result from the reaction of contact between two different metals and salt water. Rubber ball type caps are difficult to center and may not seal. Placing excessive pressure on the ball with the yoke screw can cause damage to the filter.

Rinse regulator thoroughly with fresh water following each use. The procedure for rinsing single-hose regulators is given below:

1. With the dust cap securely in place, flow fresh water gently, preferably warm, into all parts; a 2-minute warm water rinse is recommended to dilute saltwater accumulations and remove all foreign matter. This is extremely important for a regulator

with the piston-type first stage since salt and sand deposits can interfere with the movement of the piston.

2. Wash the second-stage assembly by flowing water into the mouthpiece and out the exhaust tee for about 3 minutes to thoroughly remove sand and salt. Do not depress the purge button while washing the second-stage assembly. This action opens the second-stage valve and will allow salt, foreign matter, and water to enter the valve assembly, hose, and possibly the first stage. If there is any possibility of the purge button having been depressed during washing, place the regulator on a scuba cylinder and allow air to flow through it. Rinse the outside of the second-stage housing and run water across the diaphragm.

3. Shake excessive water from the regulator and hang it by the yoke to dry; be sure the hoses are straight or supported, avoid sharp bends.

Occasionally, a regulator may be accidentally submerged in pool, salt or even polluted lake water without the protective cap in place. If this does occur, the interior of the regulator can be washed with fresh, warm tap water or, preferably, distilled water. Do not attempt to disassemble the regulator! On a single-hose unit, run water into the high-pressure inlet and hold the purge button down so water will run through the entire regulator for several minutes. Then, with the purge button still depressed, shake the water from the regulator. Place the regulator on a cylinder and free flow air through the regulator for several minutes to complete the drying.

Regulators may be washed by immersing them in a bucket of fresh water. Single-hose regulators may be completely submerged.

During storage and transport, protect regulators from abuse, physical damage and exposure to high ozone levels in surrounding air (produces rubber deterioration). A protective container is recommended for carrying regulators in the field. Regulators should be stored in a cool, dry, dark place. Placing the regulator in a plastic bag will protect the regulator's rubber parts from ozone.

Careful inspection of the high-pressure inlet filter is an excellent indicator of potential type and source of foreign material that may be entering the regulator. This filter is designed to exclude large particles of foreign material (generally 40 microns and larger); however, it will not prevent all materials from entering the regulator. The following indicators are noted:

1. A black, wet substance is an indicator of salt water inside the cylinder.
2. A black dust or powder may indicate contamination of the cylinder interior with activated charcoal from the compressor filter.
3. A reddish-brown accumulation indicates fresh water inside the cylinder; dry accumulations are indicative of rust and wet materials suggest the presence of fresh water in the cylinder.
4. A greenish or turquoise accumulation indicates that salt water has come into contact with the filter and suggests potential internal contamination of the regulator. This is usually a result of carelessness.
5. A white crystal accumulation indicates that salt water, possibly from the dust cap, has evaporated and left a deposit of salt.
6. Small flakes of paint-like substance may indicate that the interior lining of the cylinder is coming off.
7. Sand and dirt indicate abusive handling of the regulator by dragging it through sand or dirt and/or that the dust cap fits improperly.

Any of these particles can enter the regulator and impair performance or possibly cause serious malfunctions. Particles smaller than 40 microns may actually pass through the regulator to the diver's lungs. If these substances are present, have the regulator inspected, and if indicated, the cylinder inspected by a professional scuba service person.

Scuba regulators should be inspected by a qualified technician annually. In the event of even minor malfunction, immediate repair is indicated. Annual maintenance procedures involve inspection (and possible replacement) of all rubber parts, pressure-setting adjustments, and evaluation of the internal condition of the regulator. Periodically, the regulator must be completely overhauled, including disassembly, cleaning, and replacement of worn or defective parts. If the regulator has been subjected to abuse or physical shock, it should be inspected by a qualified technician prior to use in open water. A record of all inspections and repairs should be kept in the diver's logbook.

High-Pressure Cylinder

The compressed-air supply for open-circuit scuba is contained in steel or aluminum alloy cylinders. Scuba cylinder capacity will generally range from 38 to 100 standard cubic feet (scf) or 1075 to 2831 liters at pressures ranging from 1800 to 440 psig (126 to 359 kg/cm^2). A standard cubic foot is air capacity expressed at atmospheric pressure equivalent instead of compressed pressure. A standard steel cylinder used in scuba will have a rated capacity of 71.2 scf (2015 liters) at a pressure of 2475 psig (174 kg/cm^2). The working pressure is stamped near the neck of the cylinder. The normal working pressure of the cylinder is 2250 psig (158 kg/cm^2); however, under Department of Transportation regulations, steel cylinders bearing a "+" symbol after the hydrostatic test date may be filled and transported with a 10% overpressure. This generally applies only to new cylinders. After 5 years or retesting the "+" symbol is seldom placed beside the new test date and the cylinder may only be filled to a pressure of 2250 psig and the free air capacity is, in the standard cylinder, 64.7 scf (1831 liters). The standard scuba cylinder with valve and backpack weighs approximately 35 lbs (16 kg).

Cylinders constructed of aluminum are now commonly used for scuba in the United States and Canada. The corrosion resistance properties of aluminum alloy are far superior to steel; consequently, both internal and external corrosion problems are minimal. However, steel cylinders are still in common usage. Aluminum cylinders are generally available in 50, 71.2, and 80 scf (1415, 2015 and 2264 liter) capacities with a rated pressure of 3000 psig (211 kg/cm^2). The "+" symbol for allowable overpressure does not apply to aluminum cylinders.

The exterior of steel cylinders must be protected against rust and corrosion. Galvanized exteriors are recommended for durability against abrasion. Epoxy paint over zinc-galvanized surfaces prevents electrolytic corrosion of the zinc by salt water. However, with proper preventive maintenance, electrolytic corrosion is relatively insignificant.

High-pressure cylinders are stamped with letters, numbers, and symbols near the neck, giving certain specifications. The following is an example of the markings found on a standard scuba cylinder:

DOT 3AA2250
K7422
USD
1 ⊘ 78+

The DOT designates that the cylinder is manufactured in accordance with requirements for interstate transport. The type of metal alloy used is designated by 3AA (chrome molybdenum); the 2250 psig working pressure follows the material specification. In the above example, K7422 is the cylinder serial number and USD is the distributer's symbol. The hydrostatic test date is indicated by 1 ⊘ 78+ where " ⊘ " is the registered symbol of the tester and the "+" following the test date designates that the cylinder may be charged to 10% over the rated working pressure. Most cylinders also have a manufacturer's symbol.

The bottoms of scuba cylinders are often fitted with a rubber or plastic boot for protection and to facilitate holding the cylinder in an upright position. However, scuba cylinders should not be left unattended or unsecured in an upright position. The boot must also be removed periodically to inspect for corrosion.

The cylinder valve assembly is primarily a slow-turn on/off valve to control the flow of air from the cylinder and is designed to facilitate attachment of a regulator or cylinder charging device. The valve assembly is equipped with a thin, metallic safety disk designed to rupture at a given pressure as a measure to prevent cylinder damage from excessive pressure. The valve assembly may also include a spring-loaded, low pressure air warning mechanism. See regulators for a brief description of this mechanism. The valve assembly may be incorporated into manifold units for use with multiple-cylinder scuba.

Scuba Cylinder Preventive Maintenance

Air cylinders and high-pressure manifolds should be rinsed thoroughly with fresh water after each use to remove all traces of salt and other deposits. The exterior of the cylinder should be inspected for abrasion, dents, corrosion, and rust. If the cylinder has been subjected to severe damage resulting in deep abrasion or denting, it should be hydrostatically tested before refilling. External rust and corrosion should be removed and a protective coating applied to these areas to prevent further deterioration of the cylinder wall. The cylinder boot should be removed periodically. The portion of the cylinder under the boot is particularly subject to corrosion and rusting since the boot retains moisture next to the cylinder. Occasional application of protective coatings to this area may be required. Also, periodically inspect the area under the cylinder harness bands for rust and corrosion.

Internal rusting and corrosion are problems that have become more apparent in recent years. Some scuba repair facilities claim that approximately 80 percent of all steel cylinders received for hydrostatic testing have to be tumbled to remove excessive rust from the interior of the cylinder.

Care must be taken to prevent moisture accumulations in high-pressure cylinders. When a cylinder is completely drained of air while using a single-hose regulator, water may enter the cylinder through the regulator if the purge button is depressed, allowing the second-stage valve to open. The obvious solution to this problem is never to allow the cylinder to be completely drained of air. Always terminate the dive with a small amount of air remaining in the cylinder (Approximately 300 psi is sufficient to keep water from entering the cylinder). Never depress the purge button underwater when the cylinder is empty.

Moisture may enter the cylinder during charging. The cylinder should never be completely submerged prior to attachment of the filler assembly. Small amounts of water may be trapped in the valve orifice and injected into the cylinder. Inadequate removal of moisture from air by high-pressure compressor filter systems is another source of internal moisture. Be certain that the compressed air filter system has an adequate moisture separator.

All scuba cylinders, steel or aluminum, should be internally inspected at least once a year for rust and corrosion. A special rod-type light that illuminates the entire inside of the cylinder should be used for this visual inspection. Most diving equipment suppliers and repair facilities provide this service.

The internal visual cylinder inspection program began about a decade ago in the recreational diving community. There is, to my knowledge, no local, state, or national laws at the time of this publication, that require personally owned cylinders to be inspected. However, the diving community has voluntarily imposed this safety standard on itself. Internal corrosion and rusting in steel cylinders is serious and dangerous. People have been killed when filling apparently unsafe, rusted cylinders.

Some divers have stated that aluminum cylinders do not need to be inspected annually since they do not rust. Aluminum cylinders may, however, develop an oxide compound on the inside. If this oxide becomes loose in the cylinder, it may pass through the valve and regulator as fine chalk-like powder. Most authorities now recommend annual inspection.

If internal inspection reveals rust and corrosion, the steel cylinder should be cleaned by tumbling. The tumbling process involves filling the cylinder approximately one-half full with an abrasive material such as palet abrasive, carbide chips, or zinc oxide chips and allowing the cylinder to rotate. The abrasive materials remove rust and polish the inside surface of the cylinder. The cylinder is then rinsed to remove loose material and dehydrated internally to remove all traces of moisture. Aluminum cylinders should not be tumbled.

Rust chips may be detected by rocking the cylinder through its horizontal axis while pressing it next to the ear and listening for foreign matter. Also gently tapping an empty cylinder with a hammer may reveal internal rust and corrosion. A clean cylinder will have a clear metallic ring and a corroded or structurally weak cylinder gives a dull wooden sound. These procedures are useful when selecting rental or loan cylinders. They are not, however, to be considered as a substitute for visual internal inspection.

High-pressure cylinders are subject to Department of Transportation regulations. These regulations require that high-pressure cylinders transported from state to state be hydrostatically tested at least once every five years. Most states and cities have ordinances that cover transportation of high-pressure cylinders requiring adherence to Department of Transportation regulations. Diving equipment suppliers and air station personnel will generally not recharge out-of-date cylinders.

There are several methods of hydrostatic testing of cylinders including direct expansion, pressure recession, pressure and water jacket. The water jacket method is commonly used. In this method the valve is removed and a special test fitting inserted. The cylinder, filled with water, is placed in a water-filled pressure chamber and all air is evacuated. A high-pressure water line is attached to the test fitting and pressure is applied to the inside of the cylinder using a high-pressure hydraulic pump. Before pressure is applied, a burette reading is taken. The burette, attached to the test chamber by a water line, allows the tester to measure the amount of cylinder expansion in terms of water column displacement.

The pressure is increased to one and two-thirds the rated pressure of the cylinder, or in the case of the standard scuba cylinder with a rated pressure of 2250 psi, the test pressure is 3750 psi. This pressure is held for 30 seconds. A second burette reading is taken under full pressure. The water column rises due to expansion of the cylinder. The hydraulic pressure is released and the water column starts to drop, indicating that the cylinder is returning to its original diameter. After all pressure is released, a third burette reading is taken. Based on these burette readings, the permanent expansion of the cylinder is determined. According to DOT regulations, permanent expansion of 10 percent or more of total expansion indicates that the cylinder is unsafe for use. Cylinders that fail hydrostatic testing and show signs of structural damage must be condemned. This can be accomplished by stamping out the DOT (or ICC) specification symbols and figures or boring a hole in the cylinder. A cylinder cannot be restamped for a lower pressure.

The cylinder valve assembly and reserve mechanism must be periodically inspected. Immediate repair is necessary if it is determined that assembly is malfunctioning or faulty. Routine valve inspection and preventive maintenance includes checking and replacing, if necessary, o-rings and packings. The proper operation of the low-pressure warning valve is verified. Divers are discouraged from disassembling the valve mechanism and applying any lubricants. The entire valve assembly should be rinsed with fresh water after diving, and protected from unusual abuse. Frequently, the reserve lever is damaged when hit against the roof of a cave or a ship's hull, or when the cylinder assembly is left unsecured on a boat deck in rough seas. Use a protective shield for cave diving and properly secure cylinders at sea and during transport. Cylinders should be tied down, blocked, or otherwise fastened to prevent shifting during transport in vehicles.

The diver must be certain that no water enters the cylinder during filling procedures or as a result of improper use. When cylinders are being filled, be certain that the filler attachment is not submerged in the water container prior to attaching it to the cylinder. Water trapped in the filler assembly will enter the cylinder during filling. Even letting air out of the cylinder too rapidly can cause moisture to condense from the cooled air in the cylinder. The air remaining in the cylinder and the cylinder are cooled as a result of expansion. You can check for moisture in your cylinder as follows:

1. Open valve, discharge air, and inspect the air stream for a whitish mist; dry air is clean;

2. Smell the air; moist rust has a damp and metallic odor;

3. Listen for sloshing water as you tip the cylinder back and forth.

It is extremely important that the cylinder interior remains absolutely dry. Rust and corrosion are obvious problems. Regulator malfunction as a result of particle contamination is possible. The cold water diver faces the additional hazard of internal regulator freezing and subsequent malfunction.

When not in use, the valve orifice should be covered with masking tape to prevent loss of rubber o-ring and accumulation of foreign material. Divers should carry extra cylinder valve orifice or-rings attached to the regulator or in the diving equipment bag.

Cylinders containing high-pressure compressed gas can be extremely dangerous if abused or misused. If the pressure of 2250 psi (158 kg/cm^2) is multiplied by the number of square inches (square centimeters) of surface inside a standard cylinder, the force is found to be approximately 433.3 tons (176,440 kg). Property damage, physical injury, and even death have resulted from the explosion of high-pressure cylinders. A faulty cylinder is a potential bomb and if a valve is broken off of a cylinder, it is a potentially deadly missile.

High-pressure cylinders used with open-circuit scuba should be filled only with pure compressed air. The rated pressure should not be exceeded by more than 10 percent if over pressure is indicated by a plus (+) following the hydrostatic test date; otherwise, never exceed the pressure stamped on the cylinder. Overfilling places extreme stress on the cylinder walls and may result in metal fatigue. Never allow the cylinder to overheat during charging. Excessive heat, especially involving temperatures above 500° F (260° C), can result in significant structural damage.

Scuba cylinders may be stored at full pressure for short periods of time. However, most authorities suggest that the pressure be reduced to about 100 to 300 psi (7 to 21 kg/cm^2) for storage periods exceeding a month or so. In the event that there is moisture in the cylinder, the higher pressures (high partial pressure of oxygen) accelerate rusting and corrosion. Leaving some air in the cylinder with the valve closed in the best protection against contamination of the cylinder interior. The cylinder should be stored in a vertical position. The thicker metal at the bottom is less likely to be damaged by corrosion. Strap or secure the cylinder.

If a cylinder containing some water is stored at high pressure, the oxygen in the air may be depleted to a significantly low level by the corrosion process since oxygen is consumed in the chemical reaction. At least one scuba diving fatality has been attributed directly to this cause. The scuba cylinder was filled about three months prior to its use on the fatal dive. The victim apparently lost consciousness and drowned approximately 5 minutes after entering the water. Analysis of the residual air in the cylinder revealed an oxygen concentration of only 2 to 3% instead of the normal 20%. Inspection of the interior of the cylinder revealed significant corrosion. The investigators concluded that the oxygen concentration had been depleted as a result of corrosion.

BASIC EQUIPMENT

Mask

The face mask provides increased clarity and visibility underwater by placing an air space between the eyes and the water. Face mask selection is a matter of individual preference, fit, comfort, and the diver's requirements. The scuba diver's mask covers only the eyes and nose portion of the face. It consists of a safety-glass face plate, rubber body with a metal or plastic structure to hold the face plate, and a wide adjustable head strap. Many mask designs incorporate nose pockets to facilitate grasping the nostrils and equalizing pressure during descent. A purge valve, although not necessary, may be installed to facilitate purging water from the mask. Prescription lenses may be bonded to the face plate or fitted into a special frame which is inserted into the mask.

The mask must fit comfortably and form a water tight seal on the face. To test for proper fit, the mask is placed in position without securing the head strap. The mask is properly sealed if and when the diver inhales through the nose, it will remain in place without being held or leaking air.

Fins

Swim fins increase the propulsive force transmitted from the legs to the water. Used properly, the swim fins conserve the diver's energy and facilitate all underwater movement. Swim fins are availabe in a variety of sizes and designs. Selection of fins is a matter of individual preference, swimming requirements, fit, and physical condition. The type of fin commonly used today is an open-heel model with an adjustable heel strap. These fins are availabe in two or three different sizes and are generally worn over a protective foamed neoprene boot. The straps are secured with buckles and often taped to prevent loss. Avoid oversized fins that place excessive stress on the leg muscles and undersized fins that require excessive kicking and give limited progress in the water.

Snorkel

The snorkel is a J- or L-shaped rubber or rubber/plastic combination tube which enables the diver to breathe while swimming on the surface, without moving his/her head. For efficient and easy breathing, the tube diameter should be about 7/8 in. (22mm). The mouthpiece should be pliable and nonrestrictive with an opening cross-section that is approximately equal to the inside diameter of the tube. The snorkel is generally attached to the mask strap with a rubber or plastic retainer. Most scuba divers carry a snorkel to facilitate surface swimming when scuba air is depleted.

Buoyancy Unit

A self-contained, inflatable buoyancy unit is mandatory for all skin and scuba divers. It is one of the diver's best safeguards against drowning, especially in rough seas or when highly fatigued. Scuba diver buoyancy units may be yoke-type vest independent of the scuba or a vest/bladder attached directly to the scuba backpack. Each design has its own merits. The inflatable yoke-type vest remains as the most commonly used design today.

In addition to surface lifesaving and dive convenience applications, the buoyancy unit is used to compensate for buoyancy variations resulting from wet suit compression as the diver descends. However, the unit must not be used as a substitute for fitness, swimming ability and proper weight belt adjustment. The unit is used to adjust minor variations in buoyancy.

There is considerable variation in buoyancy unit design with little or no standardization in inflation systems. The following should be considered in selecting and using a vest-type unit:

1. Proper fit (not cover scuba waist strap buckle or weight belts);
2. Comfortable, adjustable straps to secure the vest and prevent "riding up" when inflated;
3. Carbon dioxide or small air cylinder inflation system independent of scuba for emergency use;
4. Inflation system connected to scuba air supply with single hand operation of inflator/deflator;
5. Long, large diameter hose attached in neck portion of vest;
6. Over-pressure valve (in some models this valve is designed to allow rapid discharge of vest contents, a good feature) and;
7. A minimum of 25 pounds surface flotation.

Compact type swimmer vests with small inflation hoses are used by some skin divers. Many scuba diver buoyancy compensators are bulky and cumbersome. Compact designs are increasing in popularity. Most vests are equipped with a "pocket" to carry decompression tables, a small slate, pencil, etc. Avoid using the vest as a lifting device or to facilitate carrying heavy equipment underwater. Use special flotation devices for lifting and equipment handling so that loss of the equipment will not result in momentary loss of diver buoyancy control.

Knife

The diver's knife is essentially a piece of emergency equipment used in the event of entanglement in lines or nets. It may also serve as a valuable tool for minor cutting. However, it is not generally acceptable to use it as a collecting tool, pry bar, and so on. Special pry bars and collecting devices are available. Unfortunately, most knives for divers have heavy 6 to 8 in. (15 to 20 cm) blades. Often they are made of poor quality stainless steel that is difficult to maintain sharp. Smaller, high quality stainless steel knives seem more preferable. The knife must be contained in a sturdy scabbard that can be attached to the diver's belt, scuba harness, buoyancy compensator, leg, or arm.

Weight Belt

A weight belt is frequently required to offset natural buoyancy or the buoyancy of a diving suit. For scuba diving, the belt is generally constructed of 2-in. (5 cm) nylon webbing with a quick release buckle. Molded lead weights, generally in 2, 3, or 5 lbs (.91, 1.4, or 2.3 kg), are attached to the belt.

The amount of weight required to offset the buoyancy of a foamed-neoprene wet suit is primarily determined by the depth of the dive. Foamed-neoprene rubber compresses as pressure is increased and, thus, the flotation, or buoyancy factor is decreased. Several methods may be used to determine the amount of weight necessary to achieve neutral buoyancy. To determine the surface buoyancy, the diver must don all of the equipment which he plans to wear during the dive. Wearing a weight belt with clip-on lead weights or carrying weights in a net bag, he enters the water and adds or subtracts weights until he achieves a state of neutral buoyancy. At neutral buoyancy, he should sink slightly with exhalation and rise with inhalation. This amount of weight is generally satisfactory for diving in depths of less than 30 ft (9.4 m). Remember that a full, standard, 71.2 ft^3 (2020 l) scuba cylinder contains approximately 5 lb (2.3 kg) of air; consequently, the diver can expect to be about 5 lb (2.3 kg) more buoyant at the end of the dive when his air has been depleted. Minor buoyancy compensations may be made using the diver's buoyancy compensator.

The density difference between fresh and salt water has only a slight effect on the suit's buoyancy. Remember, however, that the diver must add weight when he makes the transition from fresh water to salt water to compensate for his body's displacement. For example, if a 180 lb (82 kg) individual dressed in a bathing suit is neutrally buoyant in fresh water without the addition weight, he will displace approximately 2.88 ft^3 (81.5 l) or 180 lb (82 kg) of fresh water. This same individual will displace about 184 lb (83.5 kg) of salt water. Since he weighs only 180 lb (82 kg), approximately 4 lb (1.8 kg) of weight must be added to achieve neutral buoyancy in salt water.

Frequently, novice divers will find that they will reduce their weight belt requirements by 4 to 5 lb (1.8 to 2.3 kg) during the first year of diving. Certainly part of this reduction is due to improvement in skill, relaxation, and breathing characteristics. However, about half of this reduction is due to wet-suit deterioration through normal useage.

A rapid alternate, but less accurate, method of determining the amount of weight required by a diver wearing a wet suit to achieve neutral buoyancy at the surface is the formula of 1 lb (.454 kg) of lead for each 10 lb (4.5 kg) of body weight.

Care of Basic Equipment

All equipment must be thoroughly rinsed in fresh water after diving in salt water or chlorinated water. In fresh water diving, a careful rinse is also recommended to remove sand or mud. The face plate of the mask should be periodically cleaned with soap. All straps and harness components must be periodically inspected and replaced if signs of deterioration are evident.

The buoyancy unit requires considerable maintenance. It must be inspected prior to each dive to insure that it isn't damaged and that both the primary and emergency inflation systems are operational. At least every 30 dives (or six months, whichever comes first) a CO_2 cylinder should be discharged to insure continuing function. The CO_2 inflation system must be rinsed after each dive and periodically cleaned with penetrating oil to remove corrosion and lubricated with silicone compound. Proper maintenance will insure years of satisfactory service. The buoyancy bag should be periodically inflated to full capacity to inspect for leaks. It should hold full inflation for at least 2 hours. Replace components or the entire buoyancy system as required.

The knife must be maintained sharp and free of corrosion. Sharpen as needed with a good stone and coat blade with a light oil if rust/corrosion appears.

INSTRUMENTS

Depth Gauge

Self-contained divers must continuously monitor their depth to determine proper dive limits. Generally, scuba divers move around an underwater area, and the depths at which they work may vary considerably during a single submergence.

This necessitates the use of a self-contained depth gauge, generally worn on the wrist or attached to the submersible pressure gauge.

Depth gauges available at present are generally of the open or sealed bourdon tube, diaphragm or capillary type. The bourdon tube is currently used in the majority of gauges. In this type of gauge the ambient pressure is transmitted to a hollow c-shaped spring; pressure variations change the curvature of the spring. Many better quality gauges house this mechanism, the gears, and pointer in an oil-filled container. Since water acts on the housing (flexible portion or plastic face cover) to transmit pressure, it does not enter the mechanism and corrosion is not a problem. Also, the oil-filled housing tends to protect the delicate gauge mechanism by dampening shock.

Depth gauge accuracy will vary with make/model, use, and abuse. Some new gauges are marketed with a tolerance of ± 5% of full scale. Divers must check the accuracy tolerance prior to purchase; ± 2% accuracy within the normal diving range is condidered maximum for a satisfactory gauge. The gauge must be periodically calibrated against a precise master test gauge or a marked chain. Remember that the gauge registers water pressure converted to feet of seawater. Therefore, 34 feet of freshwater will give a gauge reading of 33 feet. The simplest and least expensive depth gauges are of the capillary type. This type of gauge consists of a small diameter clear plastic tube that is open at one end and closed at the other. The tube is secured to a calibrated dial. As the diver descends, ambient pressure forces water into the tube, compressing the entrapped air. The leading edge of the water column indicates the depth. The diver must be certain that the tube end point is properly positioned, that there are no air bubbles in the water column, and that the tube is free of debris. The capillary depth gauge is relatively accurate at shallow depths, generally less than 60 fsw.

Watch/Timer

A watch or dive timer is essential to the scuba diver for determining bottom time, controlling rate of ascent, and navigation timing. The diver's watch must be pressure proof and waterproof; a screw-type sealing crown is recommended. It should have a heavily constructed case, be highly shock resistant, self-winding (or battery powered) and nonmagnetic. A black, blue or orange face with large, luminous hands and dial is necessary for utmost visibility underwater. An external, self-locking bezel is required for registering elapsed time. A heavy-duty band of plastic, rubber, or metal is necessary.

An underwater stop watch or dive timer is also an excellent timing device for scuba divers. One model automatically starts timing when the diver descends below a depth of about 5 fsw (1.5 msw) and stops when the diver ascends to depths less than fsw (1.5 msw). The diver must be certain to wind the stopwatch and set it on zero before diving.

Watches and timers must be rinsed after each dive and operated and maintained in accordance with manufacturer's recommendations.

Compass

Self-contained divers commonly use a liquid-filled magnetic compass for underwater research and navigation. Generally, the compass is secured to the diver's wrist; however, it may be fastened to a compass board or carried in the diver's hand. A diver's compass should have the following features: (1) fluid filled, (2) the compass rose marked in degrees, (3) a line showing direction of travel over the face, (4) a course setting line, and (5) a moveable bezel. A good compass will respond rapidly to even slight course changes and have a high degree of luminescence for use at night.

When using a compass, the diver will first obtain a bearing in degrees to a target relative to magnetic north. While sighting on the target, the diver rotates the bezel until the parallel lines on the compass face are aligned with the North needle. The bearing, in degrees, will be read at the direction of travel line or the end of the North needle, depending upon the make of compass. To maintain proper direction while swimming, the diver must keep the North needle aligned with the parallel lines on the compass face.

An inexpensive, accurate hand held compass for underwater use is the simple hiker's compass mounted on a plastic base plate (for example, the Silva Polaris Type 7). The compass can be carried in the BC pocket when not in use.

Either the diver's wrist compass or hiker's base plate type compass can be mounted on an 8 x 10 in. (20 x 25 cm) sheet of 1/4 in. (6.35 mm) thick plastic. The compass board system greatly improves accuracy on long underwater swims.

The diver must keep the center line of the compass parallel to the longitudinal axis of the body and sight over the compass, not look down at it. The diver must swim in straight lines and keep his/her body straight in order to achieve accurate underwater navigation.

DIVING SUITS

Wet-Type Diving Suit

The foamed-neoprene, wet-type diving suit is probably the most widely used suit today due to its availability and simplicity. With a properly fitted suit, only a small quantity of water is able to enter and this water is quickly warmed by the body. Under ideal conditions in shallow water, dive durations of up to two hours have been recorded in 29° F (-1.7° C) water. Heat loss is restricted by the insulating properties of the closed-cell, foamed-neoprene material. Unfortunately, this material is subject to compression under pressure and its insulating effectiveness decreases with depth.

Insulation is primarily dependent on suit quality and foamed-neoprene thickness. Better quality wet suits are constructed of "gas-blown" neoprene. Chamber tests show that "gas-blown" neoprene compresses slightly less with increased pressure and thus retains more insulating qualities. The rate of neoprene deterioration and the breakdown of gas spaces is also less than with the cheaper suits constructed of "chemically processed" neoprene. Wet suits are commonly available in 1/8 in., 3/16 in., 1/4 in., and 3/8 in. (3.8 mm, 4.8 mm. 6.35 mm, and 9.5 mm) thickness. Selection of suit thickness depends on water temperature, diving requirements (continuous swimming or limited underwater activity), dive duration, and individual comfort preference (thicker suits are more restrictive). The following are suit thickness recommendations for various temperature ranges:

1. 70° F (21° C) and above: 1/8 in. (3.8 mm) jacket
2. 60° F to 70° F (15.5° C to 21° C): 3/16 in. (4.8 mm) suit (standard)
3. 40° F to 60° F (4.4° C to 15.5° C): 1/4 in. (6.35 mm) suit (standard)
4. Below 40° F (4.4° C): 1/4 in. or 3/8 in. (6.35 mm or 9.5 mm) (custom)

The standard wet suit consists of a jacket with zippers in the front and arms, pants with leg zippers, a hood, boots, and glove-mitts (3-finger type). Various design modifications and accessories are used to increase thermal comfort and protection. Suspender-type pants ("bib" type or "Farmer John" type) which resemble sleeveless coveralls are commonly used to provide added thermal protection to the diver's torso, an area of great heat loss. The 1/8 in. or 3/16 in. (3.8 mm or 4.8 mm) hooded vest is highly recommended for increasing thermal protection and allowing for seasonal variation. This vest prevents significant water seepage to the chest area (through zipper) and the back of the neck. It is extremely important to protect the head and back of the neck from cold-water exposure since these areas are highly sensitive to cold and have significant effects on the body's thermal balance.

Standard suits are equipped with leg, arm, and chest zippers backed with a neoprene overlap strip to minimize water seepage. Zippers facilitate easy and rapid dressing and undressing. Unfortunately, they also constitute a weakness in the insulation barrier and allow cold-water seepage. Zippers are frequently eliminated from suits designed for extremely cold-water diving or are backed with special backing pieces (gussets) glued and sewn to both sides of the zipper opening. If zippers are used, heavy-duty nickel-silver models are currently recommended. However, most cold-water divers consider it desirable to eliminate zippers.

Hands and feet are subject to the most rapid cooling rates. In moderate temperature waters and when finger dexterity is required for manual skill performance, divers frequently wear 1/8 in. (3.8 mm) or 3/16 in. (4.8 mm) five-finger, foamed-neoprene gloves. Unfortunately, gloves offer only minimal thermal protection. The three-finger glove-mitt, 3/16 in. (4.8 mm) or 1/4 in. (6.35 mm), is most commonly used in cold water. For extremely cold water, a gauntlet type, 1/4 in. (6.35 mm) or 3/8 in. (6.35 mm) mitt designed to reach to just below the elbow is recommended. Gloves and mitts must be carefully fitted since the slightest restriction in the fingers will impair circulation and cause cold and numb fingers.

Footwear must be properly fitted to keep the diver's feet warm, yet prevent cramping and circulation restrictions. Foamed-neoprene boots with a hard rubber or felt sole are designed to minimize wear (damage to bottom surface) and to protect the diver's feet when walking. The neoprene sock, without a hard sole, is designed to fit the foot snugly like a regular sock. Some sort of overboot or shoe is required to protect the foot and soft neoprene when walking on rough surfaces.

A hood must be designed to give maximum protection to the head, neck, and face; however, it should not intefere with proper fitting of the mask and scuba mouthpiece. Proper sizing can be extremely important because the skull is rigid and requires more accurate fitting than other suit parts. A poorly fitted hood can cause severe jaw fatigue, a chocking sensation, a headache, dizziness, and coldness. An extremely tight-fitting hood and suit neck could cause unconsciousness by restricting blood flow to the head. This condition is known as carotid sinus reflex. Pressure on the carotid arteries in the neck region can stimulate the heart to reduce blood flow to the cerebral area. Consequently, symptoms similar to those of hypoxia will be evident and eventually the diver will lose consciousness. A special cold-water hood which extends well over the shoulder area is available. The special cold-water hood may be worn over a hooded vest, a high neck vest with separate 1/8 in. (3.8 mm) hood, or a vest without a hood. Recent improvements in wet suit design have proven that the separate cold-water hood is relatively effective when used in conjunction with high top, over the shoulder, bib-type pants. The pants, hood, and separate outer jacket must be custom fitted.

Most wet suits are currently lined with four-way stretch nylon fabric. This nylon lining facilitates dressing and retards tearing. There is a slight reduction in suit flexibility, and some divers claim that thermal protection is reduced. The nylon lining also serves as a base for sewn seams. The sewn seam is desirable since it virtually eliminates tearing at seams. One must be cautious with regard to sewn seams on lower quality suits. Improperly sewn seams admit large quantities of water and cause significant cooling. The advantages of nylon lining appear to outweigh the disadvantages; consequently, nylon lining is recommended. The outer surface of the suit may be smooth or textured rubber or nylon covered. Some manufacturers claim that the textured surface increases flexibility and is more resistant to abrasion. Most suits are currently manufactured with textured surfaces, although distinct advantages of textured surfaces relative to smooth surfaces are not clearly defined. A nylon outer surface significantly increases suit durability. A slight decrease in flexibility is evident; however, the nylon surface is desirable for the working diver.

Other factors to consider when selecting a wet suit include color, crotch strap snaps, and spine pad. Black rubber is preferable since coloring compounds may tend to weaken material and lower elasticity. Twist-lock fasteners are commonly used to secure the crotch. Some manufacturers are now successfully using a specially designed velcro fastener for crotch straps. The shoulder straps of suspender-type pants should be secured with large velcro strips. Spine pads are used to reduce the flow of water in the spinal area and provide additional insulation of this critical area.

On custom suits the diver may get a variety of pockets on arms or legs for carrying slates, knives, snorkels, or other items. Special seam trim or tape is also available in a variety of colors; however, the overall long term advantages of the trim relative to the cost are questionable. At least one major manufacturer of wet suits provides, at extra cost, a waterproof-zipper fly in the pants to facilitate the diver in relieving himself.

Although production model wet suits are available in a wide range of sizes, including longs, regulars, and shorts, custom-tailored suits are recommended. A custom suit is tailored to 20 or 30 personal measurements and various modifications may be specified by the diver. Fit is extremely important! A wet suit should fit snugly; not so tight as to restrict circulation, yet not so loose as to allow excess seepage and accumulation of water. Too tight of a fit in the chest area can result in restriction to breathing with subsequent respiratory fatigue. A good quality suit will fit snugly and comfortably but will stretch with body movement.

Most divers will not be fortunate enough to have two or more wet suits to use for various water temperature ranges. Taking into consideration comfort, thermal protection, versatility, and cost, the following suit and accessories are recommended for the 40° F to 70° F (4.4° C to 21° C) temperature range:

Shirt: 1/4 in.(6.35 mm); no zippers in arms

Pants: 1/4 in.(6.35 mm); no zippers, high bib type

Vest: 1/8 in.(3.8 mm); hooded (for exceptionally cold water)

Boots: 1/4 in.(6.35 mm); hard sole

Mitts: 1/4 in.(6.35 mm); glove-mitts

Hood: 1/4 in.(6.35 mm); cold-water type

Stock sizes acceptable, custom preferable.

The following cold-water wet suit (custom tailored) has been proven satisfactory for water temperatures of 40° F to 50° F (4.4° C to 10° C) (moderate activity level):

Shirt: 1/4 in.(6.35 mm) with attached hood, no zippers in sleeves; front inverted zipper optional

Pants: 1/4 in.(6.35 mm), high bib type, cut high in neck

Vest: 1/8 in.(3.8 mm), hooded or turtle-neck, neoprene

Boots: 1/4 in.(6.35 mm), hard sole

Mitts: 3-finger glove-mitts

For arctic diving conditions and where most diving is in water temperatures of 28° F to 40° F (-2.2° C to 4.4° C), the following wet suit (custom tailored) is recommended:

Shirt: 3/8 in. (9.5 mm), with attached hood, no zippers

Pants: 3/8 in. (9.5 mm), suspender type

Vest: 1/8 in. (3.8 mm), hooded

Boots: 3/8 in. (9.5 mm), foot with 1/4 in. (6.35 mm) upper to just below knee

Mitts: 1/4 in. (6.35 mm), or 3/8 in. (9.5 mm), gauntlet type extending to just below elbow.

The 3/8 in. (9.5 mm) suit is extremely buoyant and requires considerably heavy weight belts and a buoyancy compensator. One should seriously consider a variable volume dry suit at this point. However, with the wet suit there is virtually no danger of material failure allowing sudden flooding as in the dry suits.

Variable-Volume Dry-Type Suit

The variable-volume, dry suit most commonly used by University of Michigan research divers (Unisuit) is a flexible, lightweight, one piece, dry-type suit with integral boots and hood, and separate glove-mitts. It is generally constructed of 1/4 in. (6.35 mm), closed-cell, neoprene rubber with nylon-lined interior and exterior. The seams are stitched and large kneepads are affixed. The suit is entered through an opening that extends from the breast bone down around the crotch and up to the nape of the neck in back. A waterproof, pressure-proof zipper completely seals the opening and permits the diver to dress and undress in approximately 5 min. The suit is designed to be worn with light or heavy underwear and may be used with scuba or surface-supplied mask or lightweight helmet. However, extensive horizontal swims are somewhat fatiguing due to suit bulk and air migration characteristics.

The suit is fitted with inlet and outlet valves to permit diver control of inflation and deflation of the suit, thus permitting control of displacement and buoyancy. Air supply for the suit is taken from the diver's air supply through a hose attached to a low-pressure outlet on the regulator or from a small auxiliary cylinder. The common practice is for divers to attach the suit inflator hose to their breathing regulators. Controlled inflation produces only limited local ballooning, and squeeze is minimized since the elasticity of the suit material facilitates equalization of pressure differential over the entire body. While the neoprene rubber is compressed with increasing depth, the insulation properties of the underwear and the air envelope surrounding the diver are relatively unimpaired.

The diver may utilize the variable-volume factor to control buoyancy. Approximately 24-30 lb (11.4 -13.6 kg) of weight are required to neutralize the buoyancy of the suit. For normal diving the diver should use only the amount of weight required to achieve neutral buoyancy at the surface at normal inflation level. Overweighting can be dangerous.

The suit is also effective as a life preserver. Inflation of the suit allows a surfaced scuba diver to float on his back above wave action. Divers are warned against misue of this type of suit. Some use the suit as a lift bag and carry heavy anchors, etc. to the surface. This is abuse of a piece of life-support equipment and the practice should be avoided.

The variable-volume suit is not without some disadvantages. One of the primary hazards of using this type of suit is the possibility of blow-up. In the event of an inlet valve malfunction excessive air may enter the suit and cause overinflation with subsequent uncontrolled ascent. If this occurs, the diver must disconnect the air source immediately and vent the suit by depressing the suit exhaust buttom. In the event that the air doesn't dump rapidly enough, additional air may be vented through the wrist seal cuffs or by unzipping the suit. The air will not satisfactorily vent automatically through the wrist cuffs as claimed in previous manufacturer's literature. Tests at the University of Michigan have proven this fact and shown that blow-up is a problem for which the diver must be prepared.

Accidental release of a weight belt can also lead to an uncontrolled ascent. Weight belts used with variable-volume suits should have a secure quick release mechanism and the use of an over the shoulder harness is highly recommended.

Also, the suit must be sized properly. In one test a diver wore a suit that was too long for him. On the bottom during the suit evaluation test, he was asked to invert and practice righting himself. The air rushed from the upper portion of the suit and lifted the suit boots, fins and all, off of his feet. Essentially, he now had two balloons holding him upside down. Fortunately, being a skilled and experienced diver, he survived the 80 ft (24.4 m) upside down, uncontrolled ascent without adverse effects. This is apparently not as much of a problem in properly fitted suits.

Divers must be trained and practice under close supervision in shallow water in the use of these suits. They must experience blow-ups and learn the techniques of righting themselves in case they invert. Simply tuck the knees to the chest, roll, and snap the body into a straight upright position. Do not use so much weight that you have to overinflate the suit to remain neutral. Master the use of the suit in shallow open water before venturing to deep water or under the ice.

There are also reports of zipper or seam failure in a few incidents. Remember that the suit provides only limited insulation. The underwear and the trapped air are the prime insulators. If the undergarment becomes soaked with water and the suit floods, the diver must be surfaced immediately. Exposure to 33° F (5.6° C) water can render the diver virtually helpless in minutes. Also, the diver loses the buoyancy characteristics of the suit.

Using heavy underwear (a knitted nylon-fur or wool suit, the Swedish Navy has tested the suit in water temperature of 37° F to 50° F (2.8° C to 9° C) at depths of 197-138 ft (60 - 100 m). Tests conducted in my presence on an arctic expedition included a 2.5 hr dive in shallow (to 30 ft or 9 m) water with a temperature of 29° F to 30° F (-1.7° C to 1.1° C).

The variable-volume suit also provides superior protection during pre- and post-dive surface exposures since the diver is dry and the suit acts as an excellent windbreaker. The diver is more comfortable while on the surface than in any other type of diving suit.

Under conditions of extremely low atmospheric temperature, if at all possible, the Unisuit should not be exposed to the outside temperature prior to the dive. Resulting cooling of the inlet and exhaust valves can cause icing upon immersion in water. The icing will render the valves inoperable until they have warmed to ambient water temperature. Also, icing of the inlet valve in an open position can be caused by using long bursts of air; use short bursts to inflate the suit. Icing of the inlet valve could lead to overexpansion of the suit and loss of buoyancy control.

ACCESSORY EQUIPMENT

Surface Floats

Many skin and scuba divers tow surf mats, surf boards, inner tubes, or similar floats when swimming offshore. The float is used for carrying equipment and samples or as an object on which to rest. It is a very useful item of rescue equipment. The float is generally towed on a nylon or plastic line which is coiled on some sort of reel or line retainer. The float is fitted with a pole and diver's flag that extends at least one meter above the water's surface.

Slate

A sheet of 1/8 to 1/4 in. (3 to 6 mm) thick plastic with both surfaces roughened with fine sandpaper serves as a writing slate. Size is a matter of personal preference. An ordinary #2 pencil is secured to the slate with a length of line. The slate may be carried in the BC pocket or secured to the diver by a lanyard.

Gloves

Gloves/mitts for thermal protection are discussed in that section. However, tropical divers will want to include a pair of snug fitting vinyl gloves in their equipment bag to facilitate handling marine life.

Numerous items of accessory equipment are available for special applications. In this handbook only basic equipment essentials are discussed. Space does not permit a description of such items as:

1. Reels and lines;
2. Underwater lights;
3. Photographic equipment;
4. Flares/emergency flashers;
5. Wireless communications systems;
6. Special bags and boxes for diving equipment;
7. Diver propulsion vehicles;
8. Shark defense devices; and
9. Decompression meters.

The reader is referred to the numerous text/manuals and equipment supply stores for detailed information on these and other accessory equipment items.

NOTES:

SECTION 4

OPERATIONS PLANNING

Careful and detailed planning and preparation is the key to diving safety. First, all aspects of the diving operation must be evaluated to determine if scuba diving techniques are acceptable or if the surface-supplied diving technique should be used. Open-circuit, demand type scuba is the simplest and most frequently used type of diving apparatus employed by the modern scientific/academic diver. The apparatus does have certain advantages and limitations that must be taken into consideration when planning diving operations. Open-circuit scuba has the following advantages:

1. Underwater mobility;
2. Portability;
3. Adaptability to small boat operations (requires minimum support equipment); and
4. Readily available training for civilian diver.

On the other hand, open-circuit scuba has a number of limitations or disadvantages:

1. Limited depth;
2. Limited dive duration (air supply);
3. Limited to low or moderate exertion level diving;
4. Inefficient utilization of gas supply;
5. Inefficient utilization of personnel in that two divers are required underwater for safety purposes;
6. Limited communication capability;
7. Limited to self-contained thermal protection systems; and
8. Relatively unsafe for limited visibility diving conditions.

Environmental conditions unfavorable for self-contained diving include extremely poor underwater visibility, strong currents, exceptionally cold water, ice cover, and contaminated water. Self-contained diving is also more limiting in operations where heavy work must be accomplished underwater. Under the above conditions surface-supplied diving is considered more desirable. In addition, the self-contained diver should avoid dives requiring decompression; surface-supplied diving is preferable for decompression dives.

Dive planning and procedures are subjects that are frequently ignored in sport diving manuals wich are used for many research diving training programs. Since diving operations must be conducted at the highest possible level of efficiency and safety, it is necessary that all personnel have a knowledge of standard operational procedures.

PRELIMINARY DIVE PLANNING

Preliminary planning is vital for the success of any diving operation. Without adequate preparation the entire diving operation may fail and, even more seriously, the safety and well-being of the divers may be jeopardized. The diver must be placed in the water under optimum conditions, including sufficient knowledge, training, experience, equipment, and safety. Surface support must be capable and well organized. Although the diving supervisor is responsible for preliminary planning and organization, the diving team and ship's crew must render all possible assistance. A Diving Supervisor's Checklist is included in Appendix E.

The preliminary planning phase of a diving operation is divided into the following steps:

1. Survey of activity or task;
2. Evaluation of environmental conditions;
3. Selection of diving techniques;
4. Selection of diver teams and assignment of task;
5. Selection of equipment;
6. Fulfillment of safety precautions and emergency assistance plan; and
7. Establishment of procedures and briefing of all personnel.

Survey of Activity or Task

The first step in planning a diving operation is to assess the activity or task and to formulate a general approach. In a working dive, it must be determined if the job is feasible and if the proper equipment and personnel are available to undertake the job. All factors that might constitute a specific hazard must be noted.

Evaluation of Environmental Conditions

Diver safety, especially for self-contained divers, is influenced considerably by environmental conditions. Careful consideration must be given to both surface and underwater conditions and appropriate arrangments made for diving under these conditions. Surface conditions to be considered include sea state, weather (present and predicted), tides, currents, ship traffic, etc. Underwater conditions include depth, bottom type or condition, visibility, and temperature.

Weather conditions will generally be the first factor to consider in planning a dive. When possible, diving operations should be cancelled or delayed during bad weather. Generally, rough seas can be expected during storms and high winds. Weather forecasts must be reviewed to determine if proper weather conditions will last for a sufficient amount of time to complete the mission. Critical weather changes and a wind shift can jeopardize safety of personnel and vessels. Conditions must be such that adequate mooring may be maintained for the duration of the operation. Do not attempt self-contained or surface-supplied diving in rough seas (Sea State 4: 5 to 8 ft waves; 1.5 to 2.4 meters), and when possible, avoid or limit diving in moderate seas (Sea State 3: 3 to 5 ft waves; .9 to 1.5 meters). Naturally, sea-state limitations will be dependent to a large degree on the type and size of diving vessel. Diving operations may be conducted in rougher seas from properly moored, larger vessels or fixed structures. Land-based self-contained divers should avoid entering a lake or ocean in heavy surf.

Current and tidal conditions must be considered before commencing with diving operations. Current direction and magnitude are important considerations when mooring a diving vessel. When currents exceed 1 knot, self-contained diving operations should be avoided unless absolutely necessary and adequate provisions are made for diver control and safety. A pick-up boat is a desirable factor. Some divers prefer to carry smoke flares to signal for pick-up in an emergency or if carried away from the boat by the current. Heavily weighted surface-supplied divers are frequently required for work in currents. Tidal currents may prohibit diving at some locations except during periods of tidal current direction change. Consult tide tables when necessary and determine magnitude of tidal currents prior to diving.

Self-contained diving operations should not be conducted during periods of low visibility (fog, snow, rain, etc.). Self-contained divers are particularly vulnerable during periods of low visibility since they may lose orientation and be unable to relocate the diving vessel or shore base. Also, the diving vessel may be in danger when anchored during periods of limited visibility.

Ship traffic may constitute a hazard to divers, particularly self-contained divers. It is necessary to display proper visual signals in a prominent location on the diving vessel during operations in order to notify approaching vessels that divers are in the water. The following signals are appropriate:

1. U.S. Diver's Flag: This is a red flag 4 units wide by 5 units long with a one-unit wide white diagonal from the upper-left to lower-right corners. Sizes are not standardized and will vary with the size of the vessel.

2. United Nations Maritime Group International Divers Flag: The single-letter signal "A" or alpha flag (blue and white) is recommended for international waters and is currently used by the U.S. Navy and the major nations of the world.

3. International Code of Signals: The two-letter signal "HD" has the meaning, "I am engaged in submarine survey work; you should keep clear."

4. Underwater Task Shapes: A "red ball - white diamond - red ball" shape display spaced 6 ft (1.8 meters) apart may denote diving operations.

Self-contained divers must tow a float on which a diver's flag is displayed or be accompanied by a chase boat with a diver's flag if they operate out of the immediate vicinity of the support vessel. The flag must be 3 ft (.9 m) above the water. Divers must consult local authorities for regulations on diver's flags since these regulations are designated on a state to state basis.

Diving personnel must be protected from excessive exposure to adverse surface weather conditions. When working in tropical areas, the staging area should be shaded to prevent overexposure to sun. During cold weather in northern waters, divers and surface personnel must be protected from cold air temperatures and wind. Divers should not be expected to dress in an open, unprotected area. When working from small craft, divers should dress prior to leaving the shore base. If under-ice dives are required, dress in heated, shore facilities or heated, portable structures on the ice. Do not submit divers to excessive exposure prior to the dive. Heated quarters and warm showers should be available immediately after surfacing.

The selection of diving dress and equipment will depend on the activity, weather conditions, and type of vessel. For example, even though water temperatures may permit the use of wet-type suits, cold air temperature and wind would dictate a variable-volume dry suit (or equivalent) when diving from an open or unheated vessel.

The type of bottom affects the diver's ability to work and is a factor in determining visibility. Consequently, this must be considered in the preliminary dive plan and certain precautionary measures may be necessary to ensure the diver's safety and efficiency. Mud (silt and clay) bottoms are generally the most restrictive for divers. The slightest movement will stir sediment into suspension and restrict the diver's visibility. The diver must orient himself so that the current, if any, will carry the suspended sediment away from the work area, and he must use a distance line. Since the self-contained diver is more hampered by the limited visibility, surface-supplied diving techniques should be considered for this activity. For general survey work, self-contained diving techniques have certain advantages. The diver can weight himself to be neutral at survey depth and move about without touching the bottom.

Sand bottoms present little problem for divers. Visibility restrictions from suspended sediment are less and footing is firm. In marine areas the diver must be alert for sting rays buried in the sand.

Coral reefs are solid with many sharp protrusions. The diver should wear gloves and coveralls or a wet suit for protection if the mission requires considerable contact with the coral. Proper buoyancy control is extremely important. Survey divers and photographers have to be cautious to avoid injury. Learn to identify and avoid corals and any marine organisms that might inflict injury.

Water depth is a basic consideration in the selection of personnel, equipment, and techniques. When possible, determine the depth accurately prior to diving and plan the dive duration, air requirements, and decompression schedule accordingly.

Water temperature is a major factor to be considered in dive planning since it will determine the type of equipment (diving suits) and, in some cases, the practical dive duration. Cold-water diving procedures and equipment are discussed elsewhere.

Underwater visibility depends on time of day, locality, water conditions, season, bottom type, weather, and currents. Dark or murky water is a disadvantage in all underwater operations. Self-contained diving should be avoided under zero to limited visibility conditions when possible and a surface-supplied diver used. If self-contained divers must work in limited visibility water, a "buddy" line is recommended.

Self-contained divers are at a considerable disadvantage especially if decompression is required. In addition to a descent (shot) line, a distance line carried on a reel is required. This enables the divers to return to the shot line for controlled ascent. Short distance lines are also desirable for surface-supplied divers in limited visibility. An alternate method of controlling ascent and decompression is by the use of an inflatable float with a line marked at

10 ft (3 m) intervals below the float and which is twice as long as the diving depth. At the end of the dive, the diver releases the float and secures the line to an object on the bottom with a releasable knot. He may then ascend to the appropriate decompression level, unreeling the remaining line below him. When he surfaces, the diver simply tugs on the free end of the line to release the knot and to retrieve the line. This technique is not recommended for diving in currents or high wave activity. Caution must be observed to avoid becoming tangled in the line. Do not leave lines and floats attached to submerged structures. Decompression dives should be avoided by self-contained divers.

Self-contained divers must establish a procedure for reunion of separated divers. Generally, the best procedure is to surface or return to a predetermined bottom location if separated. Striking the scuba cylinder with a rock or knife has only limited value in reuniting separated divers. The use of a buddy line or common float line is encouraged.

Selection of Diving Techniques

The proper diving technique, scuba or surface-supplied, is based on the activity requirements, environmental conditions, and available personnel. It is the responsibility of the diving supervisor and divers to review the situation and determine which technique to use. The advantages and limitations of various techniques have been summarized previously.

Selection of Divers and Assignment of Jobs

The diver must be qualified and designated in accordance with the depth, equipment and environmental rating required for the activity or underwater task. The diving supervisor is responsible for determining the qualifications of a diver before assigning him to an activity. In addition to the diver, the diving supervisor must designate qualified tenders or aides, timers, and stand-by divers.

Selection of Equipment

The diving supervisor and divers will determine whether to use scuba or surface-supplied diving equipment for a particular activity based on a review of the activity requirements, personnel available, and environmental conditions. The diver must be outfitted with the proper equipment to complete the activity or task assigned. When selecting equipment, the diver should not overburden himself with accessories. Use only the equipment required for safety and completion of the activity or task. When the diver is encumbered with excess equipment, the possibility of entanglement and fatigue increases.

The minimum equipment for a scuba diver consists of:

1. Swimsuit;

2. Buoyancy unit;
3. Knife;
4. Swim fins;
5. Face mask;
6. Watch or timer;
7. Depth gauge;
8. Thermal protection (as required considering environmental conditions); and
9. Scuba with submersible pressure gauge.

Most scuba divers prefer to carry a snorkel to facilitate surface swimming when returning to the boat or shore with exhausted air supply. A waterproof watch and depth indicator (gauge) are now considered as required equipment on all dives. A weight belt is required when wearing an exposure suit. The submersible pressure gauge is mandatory for all scuba and many authorities suggest that auxiliary breathing equipment (octopus) be required.

Fulfillment of Safety Precautions

All personnel associated with the diving operation are responsible for maintaining proper safety standards. Ultimately, the diving supervisor (or team leader) must assume responsibility for the safety of the divers. He must evaluate each and every aspect of the operation. Safety is considered in all aspects of preliminary planning. Divers must not be committed to a task or activity which is unreasonably hazardous or for which they are not sufficiently trained or equipped. In evaluating environmental conditions and the dive site, the diving supervisor must train himself to anticipate potential hazards and take appropriate measures to protect the divers from these conditions. Naturally, all hazards cannot be eliminated from any diving operation; however, they can be minimized. If a particular hazard is foreseeable, it can usually be eliminated. The diving supervisor may wish to prepare a list of potential hazards, including precautionary measures to use when setting up the operation and briefing the personnel.

The diving supervisor must verify that there are appropriate emergency first aid supplies (including oxygen inhalation equipment) available. He must establish an emergency protocol for diver and/or aide injuries that includes emergency transportation, communications, medical attention (personnel and source), and recompression facilities (location and availability).

Establish Procedures and Brief Personnel

The diving supervisor, dive master, or team leader, after careful evaluation of the above factors, will establish the operational procedure and brief all personnel. The procedure and briefing should include:

1. Objectives and scope of the operation;

2. Conditions in the diving area;

3. Dive plans and schedules;

4. Assignment of personnel: buddy teams, divers, aides, tenders, and specific tasks for each;

5. Safety precautions; and

5. Special considerations.

The Underwater Team

A scuba diving underwater team must consist of no less than two divers. Diving alone should not be permitted, and all team members must hold a valid diving certificate. A leader will be designated for each diving team prior to entering the water, and it will be the responsibility of the other divers to stay in visual or physical contact with the leader. If a diver becomes separated, he should promptly surface or return to a previously designated location.

The maximum size of a diving team depends upon the diving activity and environmental conditions. Generally, two-person teams are more desirable in poor visibility waters. More than two divers seem to easily become separated. For specialized activities such as cave diving, many persons prefer to use three person teams. It is assumed that two divers can better handle a third "victim" diver in an emergency situation. Large teams of four to ten divers can work under good visibility conditions. The diving supervisor will stipulate the dive area boundaries or require that all members of the team stay within visibility range of a given central bottom feature, descent line (with a highly visible submerged marker), or "lead" person (designated by a specific feature such as a special color cylinder, a colored hood, etc.). Under these conditions the large team generally sub-divides into two-person swimming groups. For underwater tours, a guide system has proven quite successful. Ideally, this system utilizes a team leader and an assistant. The leader (or assistant) enters the water first followed immediately by various team members. The assistant (or leader) enters last. The team assembles on the bottom at the anchor or shot line and the leader then leads the diving team or party on an underwater swim. The assistant (and one other team member) swims at the end of the line of divers to keep them from dispersing or falling behind. The team maintains a close but comfortable spacing between divers. In this case, the buddy pairing of divers may or may not be required. Any person in the team may respond to the needs of another member. However, generally the leader or the assistant is the focus for emergency assistance. These persons are generally the most skilled and are to be equipped with auxiliary breathing equipment. The leader judges the dive/air supply duration and makes every effort to return the team to the starting point (under the boat) before any member has depleted the air supply. As the members deplete their air supply, they are escorted to the surface by the assistant or sent to the surface by buddy pairs. Water conditions must be such that the leader and assistant can maintain good visual contact. This technique works well in clear tropical waters; however, its use is discouraged in poor visibility water.

A diving supervisor will be designated for each diving operation. His/her qualifications and responsibilities are in accordance with those previously described.

A scuba diver's aide or tender may be used on scuba diving operations. He/she must be qualified to independently aid divers and operate all surface-support equipment. From a standpoint of efficient manpower utilization, the aide may be a qualified diver and used in a diver-aide rotation system. However, there is no specific requirement that the aide must be a qualified diver. He/she may be trained in theory and operational aspects by the divers and diving supervisors. Ideally, aides should be previously trained by instructors and assigned to diving operations by the diving supervisors. He/she may receive instruction in proper procedures during field operations. An aide may be assigned to be a time keeper, record keeper, and diver's surface assistant.

Frequently, scuba diving operations will involve only two divers and one surface crewman. It is unwise to conduct any diving operation without at least one person remaining on the surface to aid divers before and after the dive and to tend the surface vessel.

Equipment Requirements

All scuba divers must be adequately equipped for safe diving. The exact equipment requirements depend upon the underwater task, environmental conditions, dive depth, dive duration, safety requirements, and personal preference. Scuba divers should avoid wearing/carrying non-essential equipment. The following items are considered as a basic minimum for scuba diving operations:

1. Face mask;

2. Fins (additional foot protection such as a sock or neoprene boot may also be required to prevent fins from chafing the foot);

3. Buoyancy unit (vest, stabilizer jacket, back-mounted unit or other approved designed/personal preference; inflation from scuba commonly used; emergency inflator separate from scuba; not required with some variable; volume suits);

4. Self-contained underwater breathing apparatus (must include submersible pressure guage).

Additional items of equipment that may be required depending on the environment and diving conditions include:

1. Snorkel (required for any scuba dive where surface swimming is anticipated);

2. Knife* (required on any scuba dive where the possibility of entanglement in lines, nets or marine plants exists);

3. Environmental protection (the type and amount of protection depends upon atmospheric and water conditions; ranges from a cloth shirt for pre-post dive sun protection to heavy-duty variable-volume dry suit; gloves may be required for handling marine life);

4. Watch/dive timer* (required to be worn by at least one member of a buddy team for dives below 30 fsw (9 msw); required for all scuba divers below 80 fsw (24 msw));

5. Depth gauge* (required to be worn by at least one member of a buddy team for scuba dives below 30 fsw (9 msw); required for all scuba divers below 80 fsw (24 msw));

6. Waterproof decompression tables (to be carried by at least one member of buddy team for all scuba dives below 50 fsw (15 msw); generally carried in buoyancy vest pocket; a slate with appropriate dive schedule data is an acceptable substitute);

7. Compass (for dives in limited underwater and/or surface visibility, at night, or where conditions preclude unaided return to vessel or staging area; wrist compass for occasional use, compass board for precise navigation);

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* Required for all scuba divers who must comply with MIOSHA, OSHA, or U.S. Coast Guard diving operations standards, regardless of depth. These items are highly recommended for all divers regardless of depth.

8. Whistle (for emergency signaling; frequently attached to buoyancy vest);

9. Underwater light (for night dives, diving in caverns, etc.);

10. Slate/pencil (small slate and attached pencil in vest pocket; larger slate or clipboard system if extensive data recording);

11. Surface float/diver's flag (required in navigable waters; include tow line and line reel or retainer; float anchoring device optional; minimum 14 x 16 inch flag elevated 3 feet above water);

12. Weightbelt (properly adjusted for type of dive and suit buoyancy);

13. Auxiliary breathing equipment (second mouthpiece unit for single hose regulator or "octopus"/auxiliary small scuba or "pony" unit; highly recommended for dives below 60 fsw (18 msw); discretionary based on environmental conditions and personnel; required in caves and under ice); and

14. Buddy line (for limited visibility diving).

All scuba divers are encouraged to include a small spare parts/tool kit in their personal equipment:

1. Spare mask strap
2. Spare fin strap
3. Spare CO_2 cylinders (2)
4. High-pressure port plug for regulators
5. Spare bulbs/batteries for underwater light
6. Spare "O" rings (4)
7. Adjustable wrench (6-inch)
8. Spare pencils (2)

These items may be placed in a small, waterproof container and carried in the diving equipment bag. Be careful to protect bulbs.

Each diver must provide his/her personal swim suit, towel(s), and adequate protective clothing to wear on the surface. In tropical areas this will include lightweight sun blocking garments, deck, beach, or coral shoes, and a hat. In colder climates this will include wool and down or fiber filled garments, wind/rain protection outer clothes, gloves, and cold weather boots. A diver is also expected to have in his/her possession, at or near the dive location, a certificate of scuba diver training (C-card); a copy of his/her most recent medical diver examination results; a personal log/record book; and an information card specifying medications currently being taken, medication allergies, and relative(s) to contact in the event of an emergency.

Other items of equipment including photographic equipment, special lights, special surface floats, underwater propulsion devices, signal flares, coral/beach shoes, lines, pry tools, collecting equipment/containers, thermometers, and so on will depend upon the underwater task, diving conditions, and diving procedures. All divers must have adequate equipment containers or bags to transport and stow equipment. Also, include a hanger for drying wet suits.

The Diving Supervisor or other designated person is responsible for providing <u>dive team</u> equipment. Naturally, the team equipment requirements will depend upon the dive location, environmental condition, underwater task, and diving technique/procedures. The following items are considered as minimum for all organized diving operations:

1. First aid kit approved for diving (OSHA requires approval by a physician);
2. Oxygen inhalation unit (at least 30-minute oxygen supply);
3. First aid manual (OSHA requirement);
4. Diving manual/handbook;
5. Decompression/repetitive dive tables;
6. Dive record sheets/repetitive dive worksheets;
7. Emergency information and procedures sheet;
8. Pencils/pens/note paper;
9. Clipboard;
10. Cylinder "O" rings;
11. Cylinder pressure gauge;
12. Neoprene cement for wet suit repairs;
13. Stopwatch or watch for dive timing;
14. Whistle and/or other appropriate signaling equipment;

15. Light (for use at surface during night operations; include extra bulbs and batteries);
16. Communications unit (if no ship or land communications system is available at dive location; CB radio may be used; OSHA requirement); and
17. Backboard/stretcher (recommended).

The Diving Supervisor may also wish to include a stretcher/ backboard and a blanket. All items should be stowed in substantial weatherproof containers and be available at the dive location for routine or emergency use.

The Diving Supervisor may also include a Carbon Monoxide Test Kit with his/her equipment.

Preparation Prior to Diving Trip

In preparing for any diving project or trip it is necessary to complete certain portions of the dive plan and equipment inspection before leaving for the dive location. Generally, the Diving Supervisor will prepare a specific "checklist" for each trip. The following items must be considered:

1. Personnel availability and qualifications;
2. Emergency procedures and contact numbers for specific dive location;
3. Air source in field or portable compressor requirements;
4. Scuba cylinders/regulators required (many divers are issued a regulator for personal use or use their own; some divers prefer to use their personal backpack; cylinders often furnished by laboratory or sponsoring agency); and
    a. Cylinders within hydrostatic test date;
    b. Cylinders internally inspected within past year;
    c. Scuba regulator inspected and approved for use within past year;
    d. All valves and regulators functioning properly; and
    e. Cylinders charged.
5. Team/equipment transportation.

The individual diver must consider the following:

1. Diving equipment and personal items checklist (equipment requirements previously stated; special request by Diving Supervisor; environmental conditions; living conditions);

2. Personal "fitness" and qualifications for specific diving operations (discuss with Diving Supervisor; disqualify self if physically unfit or if you feel you are not qualified);

3. All equipment operational;

4. All equipment properly packed; and

5. Travel funds/advances;

Packing individual diving equipment and personal items is generally a matter of personal preference. However, the diver must consider transportation arrangements, space, weight (especially on overseas flights) and so on. Most divers prefer a roomy, heavy-duty soft vinyl, nylon or canvas equipment bag instead of hard cases or containers. Soft, lightweight bags for both diving equipment and personal items save space and weight in vehicles, aircraft and diving vessels. In addition, a net bag ("goody bag") is desirable for stowing fins, mask, snorkel, buoyancy vest, regulator, gauges, and other small items on boats. Naturally, delicate instruments such as depth gauges, compasses, watches, and masks should be placed in a padded protective case and/or carried in a camera bag. Regulators may be wrapped in a wet suit for protection.

One exception to this is the diver who has ample transportation space (pickup or van) and dives from a large vessel. In this case the large plastic heavy-duty trash container with a cover has gained significant popularity. This container serves for transport, stowing on board vessel, and washing equipment.

Comments for the Traveling Diver

Divers, both scientific and recreational, often travel to distant and remote diving locations. Since most modern travel is by air, the traveling diver must consider compactness, weight, and durability among the criteria for selecting a diving outfit. Generally, the scientific diver working at tropical marine laboratories and the recreational diver vacationing at resorts will be provided with a scuba cylinder/ backpack, compressed air, lead weights, and a suitable dive boat. In any case, the diver must be aware of what equipment will be provided and what equipment must be brought from home. In the case of marine laboratories it is frequently best to consult with others who have visited the laboratory recently or communicate directly with the laboratory's diving officer regarding the immediate "condition" of laboratory equipment and/or special requirements. The scientific diver may occasionally find it necessary to transport all diving equipment, including compressor, to facilities where scuba diving is not considered as a part of the daily routine of the laboratory.

The following should be considered when traveling to tropical research or recreation facilities for scuba diving:

1. Regulator: The regulator should include a pressure gauge and auxiliary breathing unit (octopus). Many marine laboratories and resorts now require the pressure gauge. The use of the "octopus" will depend on the diving situation. Scientific divers will find regulator repair services generally "unavailable" on islands. Consequently, when projects rely heavily on diving, a second regulator system should be taken. Also, the scientist may wish to select a regulator which is "easily" repaired with a minimum of tools and parts. At least one manufacturer supplies an overhaul kit. The diver should consult with a diving equipment supplier/service facility for further information and seek special instruction in advanced regulator maintenance. Do not attempt to repair or overhaul a regulator unless specially trained.

2. Backpack: Some divers prefer to supply their own backpack with padded shoulder straps.

3. Fins, Mask, and Snorkel: Each item is a matter of the diver's personal preference. It is advisable to carry an extra mask lens, especially if a prescription lens is required for diving. Some divers simply take a spare mask. Extra fin straps and a mask strap should be included.

4. Buoyancy Vest/Unit: The buoyancy vest is a matter of personal preference. However, since many individuals do an extensive amount of skin diving during visits to tropical reef areas, they may wish to include both the smaller "swimmer" vest and a standard buoyancy compensator. Several spare cylinders, patch materials, silicone grease, and penetrating oil are important in vest maintenance. The more compact model buoyancy compensators are most desirable for packing and general use.

5. Weightbelt: Lead weights are generally available at the laboratory or resort. However, be certain to take a proper belt.

6. Tool/Spare Parts: In addition to the tools and spare parts previously listed, the diver should also include the following:

    a. Screwdriver (size depends upon equipment such as lights, camera housings, etc.);

    b. Slip-joint pliers;

    c. Long-nosed pliers;

    d. Allen head wrenches (as required for special equipment)

    e. Other special tools, extra "O" rings, and so on as required for lights, camera gear, regulators, etc.;

    f. Silicone grease;

    g. Penetrating oil; and

    h. Extra instrument strap.

7. <u>Environmental Protection Equipment</u>: Even in the tropics where water temperatures exceed 75^{o} F (24^{o} C) some divers still prefer to wear a 3/16 in. (.47 cm) or 1/4 in. (.63 cm) wet suit for both thermal and physical protection, especially on long dives. However, on the surface the suits are hot and difficult to put on and take off on small boats. Others use a 1/8 in. (.31 cm) or 3/16 in. (.47 cm) short sleeve jacket. Many divers wear close-fitting long or short sleeve shirts and old denims (straight leg, not bell-bottom) for protection from corals and to reduce chafing from backpack straps and the buoyancy compensator. The clothing also provides sun protection on the surface. Leotard bottoms are also used. Avoid bulky, heavy clothing! The increased drag can cause serious fatigue problems; even tight denim jeans have a significant drag factor.

    Sun protection is extremely important. The divers should have lightweight long sleeved shirts, long pants, and sun hats (with chin strap) for surface wear. Protect the feet also if open sandals are worn. A high collar or bandana may be required to protect the neck. Sun lotions will be discussed later.

    Generally foot protection is necessary to prevent chafing. Neoprene boots or socks are commonly used. Do not swim without boots if you normally wear boots in colder waters. Blisters can lead to serious infected wounds. Many persons will walk on rocky beaches or wade in shallow waters. An old pair of canvas or nylon sneakers with a sturdy sole will provide good foot protection; high tops are desirable.

Complete sun protection is extremely important for the surface swimming skin diver.

In addition to sun protection clothing include a good pair of dark and/or polarized sunglasses. When working in remote areas, take a spare pair. If you wear prescription glasses, include a spare pair or at least a pair of clip-on type for your regular glasses.

No matter how good you think your suntan is, you will still burn in the tropics if you do not take proper precaution. An ample supply of suntan lotion and/or sunburn prevention lotion should be included with your personal equipment. The following have been found to be satisfactory:

Sun block: U-Val
Sundown (good in water)
Sun screen: PreSun
Sun Tanning: Bain de Soleil
Hawaiian Tropic (Professional)

8. Instruments: All divers should have a watch/dive timer, depth gauge, and compass. Transport these items in your camera bag or carry-on luggage, not in the dive bag. Some instruments (depth gauges) are sensitive to reduced pressures and may be damaged during air transport. Consult manufacturer's manual for information and special precautions. A pressure-tight container may be required to protect the equipment. Underwater light housings with batteries removed make satisfactory pressure-tight housings.

9. Underwater Lights: Spare bulbs and batteries for dive lights will not be available on most islands. Always include spares. If extensive night diving is anticipated, take two or more lights in case one floods. Consider the new compact lights. Rechargeables are excellent if a proper power source is available. Transport with switch taped in "off" position or with batteries removed. A high intensity light accidentally turned on in a dive bag can produce enough heat to ignite fabric. This could be critical in the luggage compartment of an airplane.

10. Personal First Aid Supplies: It is wise to pack a few personal first aid supplies since they will be limited or unavailable in some areas. Cuts, abrasions,

and sunburns are common in tropical diving. The kit should include:

a. Alcohol;

b. Assorted bandaids;

c. Antibacterial soap;

d. Antibiotic ointment;

e. Pain relief tablets;

f. Sunburn cream;

g. Decongestant (spray or tablet);

h. Ear rinse (if you have a history of external ear infection);

i. Motion sickness tablets; and

j. Personal routine medications (if any).

A bottle of isopropyl alcohol may be used for cleaning ears as well as first aid for flooded cameras. Use unbreakable plastic containers.

11. Miscellaneous: A number of items can be included to add to your comfort and convenience while diving in remote locations. However, these items must be selected with discretion. Avoid excessive weight and bulk. The following may be considered:

    a. Clothes line (25 feet of lightweight multipurpose cord with a few small plastic clothes pins);

    b. Towel (beach size is useful; may be used for packing protection);

    c. Plastic bags (sealable; useful for packing; larger heavy duty bag to protect surface camera on dive boat and keep clothing dry);

    d. Camera first aid supplies (alcohol, jeweler's tools, silicone spray, and reprint of article on how to do it).

12. Identification of Equipment: All equipment must be marked for personal identification.

13. Personal Papers: All divers must have a C-card. It is advisable (required at some facilities) to have a logbook and copy of your most recent medical examination. When traveling outside of the United States,

You should carry a passport. However, a voter registration card or birth certificate will suffice in some foreign countries. Requirements range from visas to passports to none at all. Check with travel authorities prior to traveling to a foreign country. Proof of U.S. Citizenship will also be required when re-entering the United States. Be certain to document all foreign made cameras, strobes, lightmeters, tape recorders, watches, etc. on a Certificate of Registration at a U.S. Custom's Office prior to leaving the United States. Otherwise you might have to pay duty when returning the equipment to the United States.

14. Tricks of the Trade: Many divers experience difficulties when traveling by air to foreign countries. The following are a few helpful hints for traveling divers:

    a. Do not carry CO_2 cylinders in carry-on luggage. To an uninformed inspector they look like miniature bombs.

    b. Do not carry a bang stick or shark dart or diver's knife in carry-on luggage unless you want to be the center of attention at the baggage inspection counter and spend some anxious moments in a small room explaining that you have no interest in acquiring your own scheduled aircraft.

    c. Purchase a moderate size, heavy-duty carry-on camera bag, brief case or bag. Be certain that the handles or carry straps are extremely sturdy and well secured to the bag. Some people have extended their overseas weight limit from the allowed 44 pounds (19.8 kilograms) to in excessive of 88 or more pounds (39.6 kilograms). You will probably not want to be carrying the bag when you check your other luggage. Do not appear "strained" as you board the plane and avoid dropping it on another passenger's foot.

A SCUBA DIVE

Individual Preparation and Dressing for the Dive

In addition to general planning, the following procedures should be carried out prior to the dive:

1. Attend dive briefing/planning session (understand task, procedures, personnel assignments, depth/time limits, etc.);

2. Physically/mentally "fit" and qualified for dive;

3. Personal analysis of environmental conditions, staging area, etc.;

4. Understand emergency procedures (especially buddy separation and emergency ascent);

5. Buddy selected/appointed and approved (buddy qualified);

6. Entry and exit plans (2 exit locations if shore diving, primary and alternate);

7. Review standard, special, and emergency signals;

8. Gauge cylinders immediately before entering the water to ensure that there is sufficient air for the dive;

9. Attach regulator and open cylinder valve to determine if there are any leaks in the scuba;

10. Inhale and exhale through the mouthpiece (or mask) to ascertain that the scuba is functioning properly;

11. Inspect breathing tubes, harness, etc., to ensure that the unit is properly assembled;

12. Close the air reserve mechanism (if used) ;

13. Don diving suit (if surface temperatures are high, do not zip up jacket or put on hood until last possible moment; if overheating, pour some water inside suit and stand in shade);

14. Don watch, depth guage, compass, knife, and buoyancy compensator;

15. Inspect buoyancy unit and its gas cartridge (and/or injection system) to ensure readiness for operation;

16. Select a safe location to don scuba (many prefer to don fins before scuba, others prefer to not walk on decks with fins and wait until just before entering the water to don them; the exact procedure depends on the vessel or dive location; the diver must be able to move safely to the entry point without tripping over equipment or people when wearing fins; manuevering to put on fins with scuba on your back and on a rocking boat can also lead to injuries; evaluate each situation individually);

17. Don scuba and secure harness properly to ensure quick release in an emergency. Diving partner and/or surface personnel will aid with donning scuba;

18. Don weight belt (generally the weight belt is put on last to be certain that the weight belt is not placed under the BC straps or under scuba harness straps; it must be in a position to drop without obstruction);

19. Check diving partner's equipment and finalize (or review) dive plan:

    a. Air supply;

    b. Location and operation of BC power inflator/deflator, CO_2 discharge mechanism, weight release, scuba harness release, and knife;

    c. CO_2 cylinder charged and discharge mechanism operational;

    d. Gauges, watch, and compass available and properly placed;

    e. Straps properly secured;

    f. Weight belt free of obstruction.

20. Have scuba, mask, snorkel, and fins ready to don just before entering water;

21. Prepare to enter the water after clearance from the Diving Supervisor.

The Dive

Both divers will enter the water at the same time or one immediately after the other. Entry techniques will depend on staging area or type of vessel. Upon entering the water, the divers will stop at the surface, unless prohibited by current or surface conditions, to:

1. Make a final equipment check;

2. Adjust buoyancy if necessary;

3. Check scuba operation and inspect partner's scuba for leaks;

4. Check to ensure that your partner's reserve mechanism is closed if scuba is so equipped (lever in up position); and

5. Report any inadequacies or malfunctions of equipment to your partner and the Diving Supervisor. Correct any deficiencies before making the descent. If deficiencies cannot be corrected simply and immediately, abort the dive.

Upon completion of the final equipment check, the divers will signal each other and the Diving Supervisor that they are ready to descend. When the divers are ready, the Dive Supervisor will signal them to commence the dive. The divers will observe the following procedures during descent and while swimming underwater:

1. Descend together. If one diver experiences difficulty equalizing pressure, the other diver should stay with him/her. Although the divers will set their own rate of descent, exceeding 75 ft/min (22.5 m/min) is not recommended.

2. A descent line or anchor line should be used when possible even in clear water. This aids the diver in maintaining depth and controlling descent for pressure equalization purposes.

3. When descending without something to facilitate orientation, occasionally a diver will experience vertigo and severe disorientation. If these conditions develop, it may be necessary to abort the dive.

4. As the divers descend in clear water they should take the opportunity to get a visual overview of the bottom topography and establish an orientation pattern. This will enhance underwater navigation and safe diving.

5. Upon reaching the bottom, the divers must confirm that everything is satisfactory and immediately establish orientation. Previously, one diver will have been designated as leader.

6. If there is a current, swim against it initially so that returning to the boat or starting point may be facilitated by drifting with the current at the end of the dive.

7. If visibility is limited, the divers may wish to use a "buddy line" and/or a distance line (on a reel) to facilitate return to the descent line. This is especially necessary for proper decompression procedures.

8. Proceed with the activity or task and avoid excessive exertion. At the first sign of increased breathing rate, fatigue, etc., stop, rest, and ventilate!

9. Observe proper buddy procedures and follow the dive plan.

10. The diver should monitor his/her air supply pressure gauge throughout the dive. Terminate in accordance with the pre-dive plan, if not before. Begin ascent with not less than 300-500 psig depending on depth and conditions. Always have at least 200 psig remaining in the scuba when you reach the surface. Completely exhausting the air supply in the water can lead to awkward if not hazardous situations.

11. When the activity or task is completed, air supply depleted, or the dive time is up, the divers should acknowledge to each other that it is time to terminate and then proceed to the line or ascend directly at a rate of 60 ft/min (18 m/min). Both divers must ascend together. Never leave one on the bottom to complete the task even though he/she may have sufficient air.

When diving in a strong current, it may not be possible for the divers to make a final in-water equipment check and adjustment at the surface. In this case, added precaution is taken in onboard preparation and the divers will check each other below the surface during descent.

There is no such thing as a "routine" dive. Every dive is unique and requires individual planning and execution. It is impossible to develop a rigid list of dive preparation and procedural requirements that can be applied to all situations. Rather, the above list is general in nature and must be modified as required to fit the diving situation. The dive team must take time to discuss and re-evaluate procedures especially after diving at the same location and using the same procedures day after day. <u>Over-familiarity breeds over-confidence and carelessness</u>.

COMPUTING AIR REQUIREMENTS

The scuba diver must be provided with a sufficient air supply in order to complete the underwater task. In many cases the dive and work task will be planned in accordance with the available air supply. Air consumption is a function of depth, exertion level, water temperature, and individual physiological/ psychological variables. In some situations high air supply requirements will preclude the effective use of scuba and surface-supplied diving equipment will be required.

In the past, considerable emphasis has been placed on "exact" calculation of scuba diver air requirements. Today, most authorities find such precise calculations impractical because of the wide range of variables. Realistically, the diver can only roughly estimate the underwater time for a given amount of air on a basis of theoretical calcuation and/or past experience. The dive duration will ultimately be determined by observing a timing device (or watch) in order to remain within the proper dive time limits and the submersible scuba pressure gauge to insure that the air supply isn't depleted before the diver is prepared to surface. As a general rule, the diver should begin ascent at a pressure of 300 to 600 psig (28 to 56 kg/cm^2) depending upon depth and dive conditions (assuming no-decompression and depth not exceeding 130 fsw (39 msw)). As a general University policy, all scuba divers are required to have 200 psig (14 kg/cm^2) of air remaining in their cylinders when they return to the boat or staging area. This policy discourages "thoughtless running out of air" and reduces the likelihood of emergency situations.

Approximate air requirements for a given depth and exertion level may be calculated using the formula

$$\frac{D + 33}{33} C_s = C_d,$$

where D is the depth in feet, C_s is the surface consumption at a given exertion level, and C_d is the consumption at depth expressed in standard units (volume of air consumed from scuba converted to measurement at one atmosphere). The term standard cubic foot (scf) is frequently used to designate consumption. For practical purposes, assume that a standard cubic foot is that volume of air reduced to atmospheric pressure. On the other hand, the term actual cubic foot refers to the volume of air measured at a higher or ambient pressure. For example, a standard scuba cylinder has a measured internal volume of only approximately .5 cubic feet (14 liters). This is actual cubic feet. Yet the volume of air in a filled cylinder is expressed as 71.2 cubic feet (2015 liters) at 2475 psig (165 atm). This is standard cubic feet.

The average surface consumption (C_s) for various exertion levels is:

Light exertion/warm water	.5 cfm
Moderate exertion/warm water	1 cfm
Heavy exertion/warm water	2 cfm
Moderate exertion/cold water	2 cfm
Heavy exertion/cold water	3 cfm

For example, a scuba diver working at moderate exertion level in warm water at 99 fsw (30 msw) would calculate air consumption as,

$$\left(\frac{99 + 33}{33} \right) 1 = 4 \text{ scfm}$$

However, a diver performing heavy work in cold water at a depth of 132 fsw (40 msw) might require,

$$\left(\frac{132 + 33}{33} \right) 3 = 15 \text{ scfm}$$

A simplified procedure for rapid calculation of air consumption at depth (C_d) is given by the formula

$$P_a \ (C_s) = C_d ,$$

where P_a is ambient pressure at diving depth expressed in terms of the nearest atmosphere. For example, air consumption under heavy exertion in warm water at a depth of 60 fsw (18 msw) is,

$$3(2) = 6 \text{ scfm}$$

Total dive time (T_t) for a given volume of air is calculated using the formula

$$\frac{V}{C_d} = T_t ,$$

where V is the volume of air available. To simplify calculations, "total dive time" is often used instead of "bottom time". Remember that total dive time infers a total dive profile, surface to surface.

Many divers calculate air consumption in terms of "psi" consumed per minute. A diver can compute his/her psi consumption at surface pressure (P_s) for a given set of conditions using the following formula:

$$\left(\frac{P_c}{T}\right)\left(\frac{33}{33 + D}\right) = \frac{33 \ P_c}{33T + DT} = P_s$$

where P_c is psi consumed in a timed swim at a constant depth, T is the duration of the timed swim, and D is the depth of the timed swim. For example, a diver swims at a depth of 10 fsw (3 msw) for 10 minutes and consumes 300 psig of air. Determine surface consumption,

$$\frac{33 \ P_c}{33T + DT} = \frac{(33)300}{33(10) + 10(10)} = 23.02 \text{ psig/min}$$

Therefore, the same diver swimming at 99 fsw (30 msw) under similar temperature and exertion conditions would consume

$$23 \ (4 \text{ ata}) = 92 \text{ psig/min}$$

Occasionally, scuba divers are required to dive with a partially filled cylinder. For dive planning, the exact volume of air available may be determined using the formula

$$\frac{P_g}{P_r} \ (V_r) = V_a ,$$

where P_g is the cylinder gauged pressure, P_r is the rated pressure, V_r is the rated volume, and V_a is the volume of air available expressed in standard units. For multiple cylinder scuba, multiply V_a by the number of cylinders. For example, the volume of air contained in a standard 71.2 cf <u>steel</u> cylinder (rated pressure: 2250 psig plus 10% overfill since the cylinder is date 79+) at a gauge pressure of 1600 psi is

$$\frac{1600}{2475}(71.2) = 45.6 \text{ scf.}$$

To simplify the calculation of available volume, a "constant" (K) may be determined for any given cylinder using

$$\frac{V_r}{P_r} = k.$$

For the above steel cylinder k = .0288. Approximate values, generally adequate for most scuba diving calculations, may be determined by using k rounded to the nearest .01, i.e., .0288 = .03.

A simplified calculation of dive duration on a given air supply may be completed as follows:

1. Standard steel 71.2 cf cylinder pressurized to 2000 psig.
2. Diver must have 200 psig remaining in cylinder when he/she surfaces, therefore, only 1800 psig available for use.
3. Diving depth is 65 fsw.
4. Exertion level is moderate in warm water.
5. Calculation:

$$\frac{P_g(k)}{P_a(C_s)} \quad \text{or} \quad \frac{1800\ (.03)}{3(1)} \quad = 18 \text{ minutes } \underline{\text{total}} \text{ dive time.}$$

HAND SIGNALS

Hand signals (Appendix D) are used by scuba divers to convey critical information rapidly. Eleven hand signals were approved as a national standard for scuba divers by the American National Standards Institute. These signals are marked with an asterisk(*) in Appendix. Unfortunately, there are still divers who learned and use non-standardized signals. Dive team members must agree on a set of signals prior to the dive. This is best accomplished by the Diving Supervisor during briefing sessions. The national standard signals will be designated for University diving operations. Special signals may be designed to meet specific requirements. Remember that most signals will be given with a gloved or mittened hand.

POST DIVE PROCEDURES

1. Personnel should be available to help divers from the water and remove diving apparatus.

2. The divers should avoid excessive exertion such as hauling the anchor.

3. All divers must be observed for signs of sickness or illness resulting from the dive.

4. Commence warming procedures as soon as possible.

5. Secure equipment to prevent damage or injury to personnel while the boat is underway.

6. Record any equipment defects or operational problems.

7. Prepare/complete entries in a rough field log, both supervisor's and diver's, as soon after the dive as possible. Transfer data to permanent logs as soon as possible.

8. Undertake preventive maintenance of equipment, dry suits, and stow equipment for transport/protection.

9. The Diving Supervisor will inform the diver of:

    a. The location of the nearest chamber and medical assistance;

    b. Hazards and rules regarding flying after diving; and

    c. Necessity of reporting symptoms of potential diving injuries.

10. The diving team should stay together for at least one hour after a dive for medical reasons.

11. All divers should carry an information card for 24 hours in the event of delayed symptoms of decompression sickness/air embolism.

BOAT DIVING

General

Frequently, divers will be required to use a boat as a diving platform. Diving vessels range in size from small, inflatable rubber boats to large research vessels or charter boats. The type and magnitude of diving operation, environmental conditions, distance offshore, number of personnel, amount of support equipment, etc. will dictate the type and size of vessel. For nearshore, scuba diving in relatively calm water a small 14 to 18 ft (4.2 to 5.4 m) outboard motorboat is commonly used. More extensive offshore diving operations must be undertaken from a larger vessel with adequate deck space and seaworthiness. The following factors must be considered:

1. Adequate size to comfortably accommodate divers, surface personnel, and equipment;

2. Sufficient stability and seaworthiness to function as a platform for diving operations;

3. Vessel well-maintained, in satisfactory operating condition, and equipped with proper safety equipment as required by state and/or federal laws (Certificate of Inspection, if applicable);

4. Large, open, work area;

5. Mooring capability (3- or 4-point moorings may be required for large boats);

6. Adequate protection from sun or cold;

7. Sufficient storage space to accommodate diving equipment when not in use;

8. An adequate ladder and staging area to facilitate entering and leaving the water;

9. Diving personnel and/or professional crew trained in boat handling, seamanship, etc. (licensed crew when applicable); and

10. Ship-to-shore communications (marine radio with Federal Communications Commission Station license posted; CB may be used in some small boat operations).

A satisfactory diving ladder/exit platform is an extremely important safety consideration. Most boats, unless specifically designed and equipped for diving, will not have a ladder that is safe for use by divers. Serious injuries have resulted from the use of inadequate ladders. The ladder should include the following features:

1. Solid construction;
2. Rungs wide enough to allow comfortable use with bare feet and stability with fins;
3. Hand rail extending the full length of the ladder to give the diver a "hand hold" until he is completely on deck;
4. Inclination of about 10-15 degrees relative to the side of the vessel; and
5. Secure enough to avoid movement when the diver is on it.

Small Boat Diving

Choice of Craft - Features to consider in selecting a small boat for diving include seaworthiness, stability, space, and carrying capacity. The boat may be of rigid construction or an inflatable design. Good quality inflatable boats are excellent diving crafts if protection from surface exposure is not required.

Propulsion - Most small boats are powered by outboard engines. The engines must be serviced and in good working order. A rigid, comprehensive service/maintenance program should be established. Engine operation must be verified prior to leaving for the dive area. Avoid outdated, poorly maintained outboards.

Be certain to secure the engine to the vessel with a safety chain. Generally, a gasoline-oil mix will be required. Use appropriate mix proportions and oil. Be certain that you have sufficient fuel for all requirements plus reserve fuel for an emergency.

A spare parts/tool kit must be included as standard boat equipment. The kit must include spare plugs, shearpins, and a starter rope plus the appropriate tools to replace them. Ideally, an engine trouble-shooting chart with correction procedures should be included in the kit. The kit should be fully waterproof and stowed in a secure location. At least one member of the dive team must know the function of the engine and how to make field repairs.

Always carry an auxiliary pair of paddles or oars; they could be your only means of propulsion in an emergency.

Many divers prefer the use of twin-outboards. This means you will generally have propulsion if one engine fails. Others use a small auxiliary engine that is exclusively for emergency use.

Safety Equipment - In addition to the spare parts/ tool kit standard boat equipment must include a bailing device or container, a flashlight, emergency flares, and approved lifejackets. The diver's inflatable vest is not an approved flotation unit for boating. Ideally, a lifeline/ float for throwing rescues should be available. A first aid kit is standard equipment. Ship-to-shore communications is required for all diving operations covered by federal/state occupational safety and health regulations and are recommended for all offshore diving operations. A diver's flag and adequate support must be available. All boats must be equipped with a fire extinguisher; even gasoline outboards can present a hazard if fuel is mishandled. A megaphone is useful for warning approaching boaters or recalling divers on the surface. An underwater diver recall/signalling device is also desirable.

Navigation Equipment - The amount and type of navigation equipment will depend upon the diving location, distance offshore, landmarks, and so on. Ideally, a waterproofed chart, or chart in a waterproof case, of the area should be on board. Even if you navigate by landmarks and buoys a compass must be available. Fog, forming while you are offshore, can necessitate the use of a compass for safe return to port. A sextant, pencils, and instruments should be included as required.

Knots for Line Handling/Attachment - All boat divers must be able to tie the following knots:

Bowline
Square Knot
Clove Hitch
Two Half Hitches
Sheet Bend

Lines must be coiled in a fashion to prevent snagging when being deployed. Coiling the anchor line into a locker or container is a good practice. The line may also be figure-eighted on the deck to minimize snagging during rapid deployment.

Preparation of Boat - Pre-launching preparation procedures will depend upon the boat itself. In general, inspect the boat to assure that no damage has occurred during transport, secure drain plugs, secure engine, ready mooring and anchor lines, and stow safety equipment. Do not bury the anchor and anchor line under diving gear. Do not load heavy equipment into the boat until it is afloat. Be certain that inflatable boats are assembled in accordance with the manufacturer's instructions.

Launching - When launching from a trailer, make sure that someone is holding onto the mooring lines while the boat is being pushed off the trailer. Be certain that the trailer is parked in a proper location so as not to interfere with the launching of other boats. Load heavy equipment while the boat is moored. Be assured that the water depth is adequate to prevent damage to the engine. Install or lower engine, connect and prime fuel system, start engine, check for cooling water coming from engine, and allow sufficient time for the engine to warm up before proceeding to sea. Be cautious to avoid engine damage in shallow water.

Handling Under Way - All boat operators, regardless of the size of the boat must be familiar with boating "rules of the road," local rules, speed regulations, and so on. Pamphlets and manuals relating to these subjects are available from the U.S. Coast Guard, state agencies such as the Department of Natural Resources, and some sheriff's departments. A variety of boating manuals are available in book stores. Each operator should be provided with appropriate information. Speed is one of the greatest hazards. Avoid unnecessary speed, particularly in confined water. Avoid sudden bursts of speed and tight turns under full power. The latter can cause a capsizing, and if not expected by those in the boat, can pitch people overboard. In addition, equipment may move around causing damage or injury.

The operator must be in total control of the vessel at all times. This requires, among other things, constant and uninterrupted attention to the boat and surrounding water. Always be alert for other craft or persons in the water (swimmers, waterskiers, etc.). Do not allow a person under the influence of alcohol or drugs or a person suffering from motion sickness to operate a boat.

Hopefully, a diving team will not put to sea in adverse rough water conditions. However, such conditions can develop quickly and a team in a small boat can be "caught out" by bad weather conditions. The general rule is, "Keep the boat headed into the sea and proceed at slow speed." When it is necessary to go with the sea, allow the waves to overtake you; to travel faster than the sea means that the boat is more likely to suddenly swing off course and be hit broadside by the waves. Watch waves approaching from the stern and control speed in order to minimize water flood over the stern. If your course is across the direction of the seas, it may be necessary to alternately "almost" head into the sea for some distance and then change course so that the sea is "almost" astern. If the distance between wave crests is large, it may be possible to run at speed along the trough and turn the bow into the crest at the last minute. In rough seas all persons in small boats must wear lifejackets, or at least the diver's inflatable vest. Ideally, all persons, both tenders/operators and divers, should wear diving suits or waterproof exposure suits, especially if the water is cold. Not only does this allow for greater thermal comfort and reduce the discomfort of wetting spray, but greatly enhances survival if the boat capsizes.

When going alongside a dock or object or picking up a diver in the water, approach against the wind or tide, whichever has the greatest effect on the boat, and on the sheltered side if possible. Use reverse gear to "brake", if necessary. The idea is to come to a halt within reaching distance of the dock, object, or diver. The most common fault when going alongside or picking up is to approach too fast. Do not hurry! When moving off from alongside a pier or boat, back off first if possible.

Anchoring and Mooring - The anchor must be of adequate size for the boat. A Danforth or grapnel (wrecks/rock bottom) with approximately 12 ft (3.6 m) of chain is recommended. The heavy-duty anchor line should be at least three times the maximum water depth. Many divers secure a buoy near the upper end of the anchor line. In the event that the boat must be moved quickly (such as picking up a distressed diver), the anchor line can simply be thrown off and later retrieved. Mooring lines, twice the length of the boat, should be available at the bow and stern.

Always anchor clear of other craft, and not in an area designated as prohibited or restricted on a chart. Be sure that the anchor line is clear. Stop the boat into the wind or current and let the anchor go, allowing the boat to drop astern. Pay out plenty of line. Make sure the anchor is holding before stopping the engine. Always make sure the anchor line is secured in the boat. When retrieving the anchor, start the engine first. The engine can be used "slow ahead" to assist in breaking out the anchor and while the anchor is being hauled in. Immediately prepare the anchor line so that the anchor is always ready for use. It may save you from disaster in the event of engine failure or other emergency.

The anchor line is often used as a descent-ascent line. Often this practice encourages divers to use less "scope" or adequate length of line for anchoring. Such practices can lead to dragging the anchor or place unusual stress on the line or boat hardware, especially in rough seas. Use of a specific weighted ascent-descent line secured to the stern is more acceptable. Some divers use a separate ascent-descent system. Once the vessel stabilizes after anchoring, a heavy weighted line with a surface float is placed directly off the stern of the vessel. The line is generally equal to the water depth so it remains taut. The size buoy will depend upon the bottom weight; however, both should be of adequate size to allow the divers to pull down or up on the line without affecting the position of either. A short length of line generally leads from the boat to the ascent-descent line.

When the anchor line is used for descent and ascent and a current is running, a length of line is secured from the stern to the anchor line. The diver holds this line as he/she enters and pulls hand over hand to the anchor line. In all current diving a brightly colored floating line with a float or floats must be trained behind the boat. If a diver enters and is carried away by the current, he/she can grab the trail line and pull hand over hand back to the boat. These lines are 100 to 300 ft (30 to 90 m) long.

Boat Maintenance - Following a dive, completely clean and inspect the boat. When working in salt water, wash the boat down with fresh water, particularly the engine. Make minor repairs (tighten screws, hardward, etc.) and carefully/ correctly stow all gear. Dry out lifejackets and other moisture absorbing equipment. Carefully inspect for damage, especially after operating in a rough sea or "hitting" an object. Routine professional maintenance schedules must be developed.

Safety Procedures

Common sense and good judgement are the keys to diving/ boating safety. Safety considerations are dictated by the personnel, environment, and type of boat. For example, John Dorr, University of Michigan, Great Lakes Research Division developed the following guidelines for small boat operations (16 to 21 ft outboards):

1. Loads will be anticipated so as to avoid exceeding the capacity of the boat.

2. Operations will not be conducted during marginal weather conditions.

3. Boats will be anchored or moored from the bow only.

4. The anchor line will be attached to the boat and retained in a ready position.

5. An anchor will be set in addition to mooring lines (to fix anchorage buoys), especially for night operations.

6. Two buckets or bailing devices will be carried in the boat.

7. Emergency equipment (including flares, horn, whistle, and first aid kit) will be placed in a floatable container and secured to the boat in a manner to allow access in the event that the boat overturns.

8. Paddles will be secured to the boat.

9. Ideally, a radio telephone should be carried if the boat cannot be visually monitored from shore.

10. If extended offshore operations are anticipated, a means of receiving continuous weather advisories should be available.

11. Do not "overpower" small boats or place too heavy of engine on the stern.

12. No more than 6 scuba will be carried at any time (4 for diving, one for standby diver, and 1 extra; assume single cylinder type).

13. Equipment will be carried for a maximum of 3 divers (2 divers and one standby diver).

14. All dives will be conducted with a minimum of 4 persons (2 divers, 1 standby diver, and 1 boat handler/tender).

15. During January to May and September to December all personnel will wear full diver type exposure suits.

16. Standby equipment and the standby diver will be in a ready status (suit and buoyancy system on; scuba assembled; mask, fins, snorkel and weight belt readily accessible).

17. A strobe light will be displayed from the boat mast during night diving operations.

18. Arrangements will be made to have all dives, especially night dives, monitored by onshore personnel. Specific emergency procedures will be provided in writing in accordance with location and situation. A beachmaster should be designated.

19. A contingency plan will be established in the event that the divers are separated from the boat. This plan will be established prior to the divers leaving the boat for every dive.

20. Flare/smoke distress signals will be carried by divers, especially at night or in adverse weather.

21. Only the equipment and personnel necessary to complete the given task should be carried on the boat.

22. After each dive, the boat should return to shore to drop off unneeded equipment and samples and to exchange personnel as required.

SCUBA DIVING AT NIGHT

Night diving can be both exciting and scientifically rewarding. In the ocean, many nocturnal animals emerge shortly after dusk and feed throughout the night. For example, some striking differences between day and night fish populations can be noted on tropical coral reefs.

Novice scuba divers are discouraged from participating in open ocean night dives. Only through considerable daytime diving experience can the diver gain the necessary ability to maintain orientation. It is vital for the diver to return to a designated point. Orientation underwater and on the surface must be considered. When the scuba diver must contend with currents and poor visibility, underwater or on the surface, diving operations should be suspended. These two factors can make maintaining orientation questionable if not impossible.

Night diving sites must be considered on an individual basis and the dives planned accordingly. Dives may be conducted from both boats and shore stations. The following is a list of considerations which the diver should take into account when planning and executing a night dive:

1. Do not dive at an unfamiliar site. Daytime underwater reconnaissance is necessary to gain familiarity with underwater topography and features. Such familiarity is vital to maintaining night time orientation. Prepare and study sketch maps of the dive site.

2. Be certain to avoid ship traffic routes. A diver is difficult to spot on the surface at night, especially if his light has failed. He may be in immediate danger from both large commercial vessels and pleasure craft. If it is necessary to anchor and work at night in a ship's channel, use a large vessel, display proper night anchoring and work signals, and execute radio security calls to warn ship traffic. When possible, surface-supplied divers should be used instead of scuba divers.

3. Any boat, whether large or small, must be securely moored. This is especially significant when working near reefs and in even slight currents. If the mooring breaks, the boat could drift a considerable distance before the divers surface. The vessel could be destroyed if it drifts onto a reef.

4. Anchor precisely over the underwater site and work as close to the boat as possible. Long underwater swims are both unsafe and unnecessary at night.

5. Use a weighted descent line with a large light colored, reflective marker suspended about 10 feet above the bottom.

6. Secure an underwater light pointing downward at 10 to 20 feet below the surface on the descent line. Some divers use flashing strobe lights; however, a constant light is easier to orient on than a flashing light.

7. The divers should descend and ascend on the line and use the light and bottom marker as the primary orientation point.

8. Unless the underwater task requires that the divers move some distance from the boat, work close to the descent line with the operational range determined by the distance at which the underwater marker light is visible.

9. The surface vessel should never be left unattended. At least one person must be assigned as surface tender/boat operator. This person must have a high intensity light and a whistle or loud-hailer. In the event that divers become disoriented and surface away from the boat, the surface tender can direct them back to the boat with both light and noise signals. Ideally, there should be a standby diver <u>and</u> a boat operator stationed in the surface craft.

10. A prominently displayed white anchor light should be used as both a warning to other boats and an orientation point if divers accidentally surface away from the boat.

11. Avoid night scuba dives when surface visibility is limited by fog or inclement weather.

12. Each diver must be equipped with at least one underwater light and a compass. Many carry a compact model light as a spare.

13. Special effort may be required to maintain the buddy system.

14. In cold weather or when diving in cold water, surface personnel in small boats should wear a protective type diver's suit (wet or dry suit) or have a cold water survival suit available.

LINE TENDING A SCUBA DIVER

Line tended scuba diving is an accepted practice in commercial diving. However, it is currently an uncommon practice in scientific/educational diving and must be used with considerable discretion on the part of the Diving Safety Coordinator and Diving Supervisor. Generally, the University will limit a single scuba diver being line tended from the surface to depths of about 15 to 30 fsw (4.5 to 9 msw) providing that the water is clear enough for the diver to be seen from the surface. Line tended scuba diving may be approved for low visibility water if a full face mask system with communications and an emergency air supply are used. Life lines used by scuba divers should be equipped with a quick release device which enables the diver to disengage himself/herself quickly in an emergency (exclusive of ice and cave diving).

A standby diver should be used for line tended scuba diving. Frequently, when working in shallow, clear water where the diver is always visible, the tender can double as a standby diver providing that he/she is equipped with mask and fins (and diving suit/weights, if cold water) and is capable of easily breathhold diving to the diver's work site. Line tended scuba diving (single diver) is questionable for working in enclosures or where the risk of entanglement/ entrapment is high.

Surface tenders should be experienced divers or especially trained as tenders. The most effective assistance can be given only by a tender who is familiar with equipment procedures, safety precautions, underwater conditions, and difficulties that are inherent in diving. It is the tender's responsibility to see that the diver receives proper care both topside and underwater. He/she must check all equipment before sending the diver down.

When the diver is ready, the tender assists in dressing, checks equipment, and assists the diver to the entry point. The tender handles the line and allows for proper slack (if the diver jumps into the water) or strain (if the diver descends the ladder). While the diver is submerged, the tender handles the line and maintains line pull communications (or voice communications if available). It is important that the loose line signals be memorized and practiced so they will be recognized instantly. The following line signals are commonly used by the U.S. Navy:

Tender-to-Diver

1 pull	Are you all right? (When the diver is descending, 1 pull means stop.)

2 pulls	Go down. (During ascent, you have come up too far. Go back down until I stop you.)
3 pulls	Standby to come up.
4 pulls	Come up.

Diver-to-Tender

1 pull	I am all right.
2 pulls	Give me slack.
3 pulls	Take in my slack.
4 pulls	Haul me up.

Emergency Signals: Diver-to-Tender

2-2-2 pulls	I am fouled and need the assistance of another diver.
3-3-3 pulls	I am fouled but I can clear myself.
4-4-4 pulls	Haul me up immediately.

Special signals may be prepared to meet diving requirements.

In tending the diver, the tender must not hold the diver's line so taut as to interfere with the diver's work or movements. The diver should be given 2 to 3 ft (.6 to 1 m) of slack when he/she is on the bottom, but not so much that he/she cannot be felt from time to time. Signals cannot be received on a slack line. Line pull signals consist of a series of sharp, distinct pulls, strong enough for the diver or tender to feel but not so strong as to pull the diver away from his/her work or the tender from the ship. When sending signals, take the slack out of the line first. Repeat signal until answered. The only signal not answered when delivered is the emergency "haul me up" and "come up" is delayed until the diver is ready. Continued failure to respond to signal may indicate that there is too much slack in the line, the line is fouled, or the diver is incapacitated. Be prepared to dispatch a standby diver.

The tender may also serve as timekeeper/recordkeeper. The tender assists the diver in post-dive procedures.

The tending line is a 100 to 150 ft (30 to 45 m) heavy duty line, at least 3/8 in. (9.5 mm) in diameter to facilitate handling. Although it is unlikely that conditions will be such that heavy stress is placed on the line, it should have a minimum breaking strength of 1200 lbs (545 kg). Many divers choose synthetic polypropylene or polyethylene (polyolefins) braided or 3-strand twist rope. This rope is advantageous in that in most varieties it floats and it is available in bright colors. A floating line will float above the diver and is less likely to interfere with kicking or become entangled in equipment. A quick-release survival snap hook should be spliced to the diver's end of the line. The rope should be marked at approximately 3 ft (1 m) intervals.

Most line tended divers prefer to use some type of body harness for securing the line to the body. A common harness assembly is constructed of nylon webbing with heavy "D" rings for attachment and securing to the body. It consists of two over the shoulder straps and a mid-chest strap.

DIVING UNDER ICE

Diving under ice is particularly hazardous and should only be undertaken when absolutely necessary. The diver is subjected to severe cold stress, emergency procedures are complicated, and the scuba may be adversely affected by severe cold. The effects of cold on scuba regulators are discussed in Section 3.

In addition to previously discussed procedures, the following should be considered when working under ice:

1. Use ample protective clothing and do not commit a chilled diver to an under-ice mission.

2. Always have a stand-by diver ready to enter the water immediately.

3. Cut a hole large enough to accommodate 2 or 3 divers even though one diver is under the ice at a time. (Be sure to mark the hole clearly following ice diving to warn fisherman and snowmobile riders of the hazardous opening.)

4. Limit dive duration and provide sufficient facilities for immediate warming.

5. Never rely on a compass; the safety line is the only way to insure relocation of the hole.

6. The safety line must be secured to the diver, not his equipment. A trained tender must handle the safety line or umbilical hose. Secure the line to a fixed object on the surface.

7. Avoid long excursions under the ice. If it is necessary to cover large areas when under the ice, cut several holes and make a series of dives.

8. Avoid having more than one scuba team in the water at a time.

9. Divers must have considerable open-water experience and special training prior to diving under the ice.

10. Carry an auxiliary breathing unit. Do not inhale from regulators above water, wait until you submerge.

Specific procedures for under ice diving and training of ice divers are to be in accordance with those given in:

> Somers, L., "Cold Water and Under Ice Scuba Diving", NAUI Technical Publication No. 4 (Colton, Calif: National Association of Underwater Instructors, 1973).

CAVE DIVING

Diving in water filled caverns is a specialized scuba diving activity requiring special training, equipment, and procedures. All University cave diving will require special approval of the Diving Safety Committee and the Diving Safety Coordinator. Specific procedures and requirements will be specified for individual situations. In general, equipment and procedures will be in accordance with those recommended in the following or an equivalent publication:

> Mount, T. (ed.), Safe Cave Diving (The National Association for Cave Diving, 1973).

SECTION 5

AIR DECOMPRESSION*

GENERAL

When air is breathed under pressure, the inert nitrogen diffuses into the various tissues of the body. Nitrogen uptake by the body continues, at different rates for the various tissues, as long as the partial pressure of the inspired nitrogen is higher than the partial pressure of the gas absorbed in the tissues. Consequently, the amount of nitrogen absorbed increases with the partial pressure of the inspired nitrogen (depth) and the duration of the exposure (time).

When the diver begins to ascend, the process is reversed as the nitrogen partial pressure in the tissues exceeds that in the circulatory and respiratory systems. The pressure gradient from the tissues to the blood and lungs must be carefully controlled to prevent too rapid an outward diffusion of nitrogen. If the pressure gradient is uncontrolled, bubbles of nitrogen gas can form in tissues and blood, resulting in the development of decompression sickness.

To prevent the development of decompression sickness, special decompression tables have been established. These tables take into consideration the amount of nitrogen absorbed by the body at various depths for given time periods. They also consider allowable pressure gradients which can exist without excessive bubble formation, and the different gas elimination rates associated with various body tissues.

Stage decompression, requiring stops of specific durations at given depths, is used for air diving because of its operational simplicity. It will be found that the decompression tables require longer stops at more frequent intervals as the surface is approached due to the higher gas expansion ratios which occur at shallow depths.

The USN decompression tables are the result of years of scientific study, calculation, animal and human experimentation, and extensive field experience. They represent the best overall information available, but as depth and time increases, they tend to be less accurate and require careful

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*This explanation of decompression tables is taken in part from the _U.S. Navy Diving Operations Handbook_ (NAVSHIPS 0994-009-6010) and the _U.S. Navy Air Decompression Table Handbook_ (NAVSHIPS 0994-015-9010). Tables are in an Appendix of this handbook.

application. Lacking the presence of trained medical staff personnel, or someone otherwise qualified, the tables must be rigidly followed to ensure maximum diving safety. Variations in decompression procedures are permissible only with the guidance of qualified medical staff personnel in emergency situations.

Definition of Terms

Those terms which are frequently used in discussions of the decompression tables are defined as follows:

Depth - When used to indicate the depth of a dive, means the maximum depth attained during the dive, measured in feet of seawater (FSW).

Bottom Time - The total elapsed time from when the diver leaves the surface in descent to the time (next whole minute) that he begins his direct ascent, measured in minutes.

Decompression Stop - Specified depth at which a diver must remain for a specified length of time to eliminate inert gases from his body.

Decompression Schedule - Specific decompression procedure for a given combination of depth and bottom time as listed in a decompression table; it is normally indicated as feet/minutes.

Single Dive - Any dive conducted 12 hours or more after a previous dive.

Residual Nitrogen - Nitrogen gas that is still dissolved in a diver's tissues after he has surfaced.

Surface Interval - The time which a diver has spent on the surface following a dive; beginning as soon as the diver surfaces and ending as soon as he starts his next descent.

Repetitive Dive - Any dive conducted within a 12-hour period of a previous dive.

Repetitive Group Designation - A letter which relates directly to the amount of residual nitrogen in a diver's body for a 12-hour period following a dive.

Residual Nitrogen Time - An amount of time, in minutes, which must be added to the bottom time of a repetitive dive to compensate for the nitrogen still in solution in a diver's tissues from a previous dive.

Single Repetitive Dive - A dive for which the bottom time used to select the decompression schedule is the sum of the residual nitrogen time and the actual bottom time of the dive.

USE OF DECOMPRESSION TABLES

Variations in Rate of Ascent

The rate of ascent for Standard Air Decompression Table dives is 60 feet per minute. Since conditions sometimes prevent these ascent rates from being maintained, a general set of instructions has been established to compensate for any variations in rate of ascent. These instructions, along with examples of their application, are listed below:

Condition No. 1 - Rate of ascent less than 60 fpm, delay occurs greater than 50 fsw.

Procedure - Increase BOTTOM TIME by the difference between the actual ascent time and the time if 60 fpm were used.

> A dive was conducted to 120 feet with a bottom time of 60 minutes. According to the 120/60 decompression schedule of the Standard Air Decompression Table, the first decompression stop is 30 feet. During the ascent the diver was delayed at 100 feet and it actually took 5 minutes for him to reach his 30 foot decompression stop. If an ascent rate of 60 fpm were used, it would have taken him 1 minute 30 seconds to ascend from 120 feet to 30 feet. The difference between the actual and 60 fpm ascent times is 3 minutes 30 seconds. Increase the bottom time of the dive from 60 minutes to 63 minutes 30 seconds and continue decompression according to the schedule which represents this new bottom time ... the 120/70 schedule. (Note from the Standard Air Decompression Table that this 3-minute, 30-second delay increased the diver's total decompression time from 71 minutes to 92 minutes 30 seconds - an increase of 21 minutes 30 seconds.)

Condition No. 2 - Rate of ascent less than 60 fpm delay occurs less than 50 fsw.

Procedure - Increase TIME OF FIRST DECOMPRESSION STOP by difference between the actual ascent time and the time if 60 fpm were used.

> A dive was conducted to 120 feet with a bottom time of 60 minutes. From the Standard Air Decompression Table the first decompression stop is 30 fsw. During

the ascent, the diver was delayed at 40 feet and it actually took 5 minutes for him to reach his 30-foot stop. As in the preceding example, the correct ascent time should have been 1 minute 30 seconds causing a delay of 3 minutes 30 seconds. Increase the length of the 30-foot decompression stop by 3 minutes 30 seconds. Instead of 2 minutes, the diver must spend 5 minutes 30 seconds at 30 feet. (Note that in this example, the diver's total decompression time is increased by only 7 minutes; the 3-minute, 30-second delay in ascent plus the additional 3 minutes 30 seconds he had to spend at 30 feet.)

Condition No. 3 - Rate of ascent greater than 60 fpm, no decompression required, bottom time places the diver within 10 minutes of decompression schedule requiring decompression.

Procedure - Stop at 10 feet for the time that it would have taken to ascend at a rate of 60 fpm.

A dive was conducted to 100 feet with a bottom time of 22 minutes. During ascent, the diver momentarily lost control of his buoyancy and increased his ascent rate to 75 fpm. Normally, the 100/25 decompression schedule of the Standard Air Decompression Table would be used, which is a no-decompression schedule. However, the actual bottom time of 22 minutes is within 10 minutes of the 100/30 dive schedule which does require decompression. The diver must stop at 10 feet and remain there for 1 minute and 40 seconds, the time that it would have taken him to ascend at 60 fpm.

Condition No. 4 - Rate of ascent greater than 60 fpm, decompression required.

Procedure - Stop 10 feet below the first decompression stop for the remaining time that it would have taken if a rate of 60 fpm were used.

A diver ascending from a 120/50 scheduled dive takes only 30 seconds to reach his 20-foot decompression stop. At a rate of 60 fpm his ascent time should have been 1 minute 40 seconds. He must return to 30 feet and remain there for the difference between 1 minute 40 seconds and 30 seconds, or 1 minute 10 seconds.

The rate of ascent between stops is not critical, and variations from the specified rate require no compensation.

Selection of Decompression Schedule

The decompression schedules of all the tables are given in 10- or 20-foot depth increments. Depth and bottom time combinations from actual dives, however, rarely exactly match one of the decompression schedules listed in the table being used. As assurance that the selected decompression schedule is always conservative - (A) always select the schedule depth to be equal to or the next depth greater than the actual depth to which the dive was conducted, and (B) always select the schedule bottom time to be equal to or the next longer bottom time than the actual bottom time of the dive.

If the Standard Air Decompression Table, for example, was being used to select the correct schedule for a dive to 97 feet for 31 minutes, decompression would be carried out in accordance with the 100/40 schedule.

NEVER ATTEMPT TO INTERPOLATE
BETWEEN DECOMPRESSION SCHEDULES

Cold/Strenuous Dives

If the diver was exceptionally cold during the dive, or if his work load was relatively strenuous, the next longer decompression schedule than the one he would normally follow should be selected. For example, the normal schedule for a dive to 90 feet for 34 minutes would be the 90/40 schedule. If the diver were exceptionally cold or fatigued, he should decompress according to the 90/50 schedule.

In scuba diving, dives are planned to remain within a no-decompression limit. Consequently, the appropriate schedule for a cold/strenuous scuba dive may be selected by advancing to the next deeper dive depth. For example, the normal limit for a 60 fsw dive is 60 minutes. If the diver is cold or fatigued, the maximum limit selected from the 70 fsw schedule is 50 minutes. For a repetitive dive, the appropriate group designation would be selected as if the previous dive were to 70 fsw.

Rules During Ascent

After the correct decompression schedule has been selected, it is imperative that it be exactly followed. Without exception, decompression must be completed according to the selected schedule unless the directions to alter the schedule are given by a diving medical officer.

Ascend at a rate of 60 feet per minute when using all Standard Air Decompression Tables. Any variation in the rate of ascent must be corrected in accordance with the earlier instructions. The diver's chest should be located as close as possible to the stop depth. A pneumofathometer is the most practical instrument for ensuring proper measurement.

The decompression stop times, as specified in each decompression schedule, begin as soon as the diver reaches the stop depth. Upon completion of the specified stop time, the diver ascendsto the next stop, or to the surface, at the proper ascent rate. DO NOT INCLUDE ASCENT TIME AS PART OF STOP TIME.

Exceptional Exposure

The exceptional exposure air decompression schedules are for dives which expose the diver to oxygen partial pressures, environmental conditions, and bottom times considered extreme. The prolonged decompressions, which must be carried out in the water, impose exceptional demands on the diver's endurance. Because of this, decompressions conducted according to these schedules have limited assurance that they will be completed without an incidence of decompression sickness. For this reason, the Diving Supervisor must fully justify the need for conducting an exceptional exposure dive. Exceptional exposure tables are not included in this handbook.

Repetitive Dives

During the 12-hour period after an air dive, the quantity of residual nitrogen in a diver's body will gradually reduce to its normal level. If, within this period, the diver is to make a second dive - called a repetitive dive - he /she must consider his/her present residual nitrogen level when planning for the dive.

Upon completing the first dive, the diver will have a Repetitive Group Designation assigned by either the Standard Air Table or the No-Decompression Table. This designation relates directly to his/her residual nitrogen level upon surfacing. As nitrogen passes out of the tissues and blood, the repetitive group designation changes.

The Residual Nitrogen Table permits this designation to be determined at any time during the surface interval.

Just prior to beginning the repetitive dive, the residual nitrogen time should be determined using the Residual Nitrogen Table. This time is added to the actual bottom time of the respective dive to give the bottom time of the equivalent single dive. Decompression from the repetitive dive is conducted using the depth and bottom time of the equivalent single dive to select the appropriate decompression schedule. Equivalent single dives which require the use of exceptional exposure decompression schedules should, whenever possible, be avoided.

To assist in determining the decompression schedule for a repetitive dive, a systematic repetitive dive worksheet may be used.

If still another dive is to follow the repetitive dive, the depth and bottom time of the first equivalent single dive should be inserted in the second repetitive dive worksheet.

AIR DECOMPRESSION TABLES

USN Standard Air Decompression Table

This handbook contains the Standard Air Table (Appendix H). If the bottom time of a dive is less than the first bottom time listed for its depth, decompression is not required. The diver may ascend directly to the surface at a rate of 60 feet per minute. The repetitive group designation for no-decompression dives is given in the No-Decompression Table.

As will be noted in the Standard Air Table, there are no repetitive group designation for exceptional exposure dives. Repetitive dives following an exceptional exposure dive are not permitted.

Example 1 - Diver Bowman has just completed a salvage dive to a depth of 133 feet for 37 minutes. He was not exceptionally cold or fatigued during the dive. What is his decompression schedule and his repetitive group designation at the end of the decompression?

Solution - Select the equal or next deeper and the equal or next longer decompression schedule. This would be the 140/30 schedule.

Action	Time (min:sec.)	Total Elapsed Ascent Time (min:sec.)
Ascend to 20 feet at 60 fpm	1:13	1:13
Remain at 20 feet .	5:00	6:13
Ascend to 10 feet .	0:10	7:23
Remain at 10 feet .	21:00	28:23
Ascend to Surface .	0:10	28:33
Repetitive Group Designation	"K"	

No-Decompression Limits and Repetitive Group Designation Table for No-Decompression Air Dives

The No-Decompression Table serves two purposes. First, it summarizes all the depth and bottom time combinations for which no decompression is required. Secondly, it provides the repetitive group designation for each no-decompression dive. Even though decompression is not required, an amount of nitrogen remains in the diver's tissues after every dive. If he/she dives again within a 12-hour period, the diver must consider this residual nitrogen when calculating decompression.

Each depth listed in the No-Decompression Table has a corresponding no-decompression limit given in minutes. This limit is the maximum bottom time that a diver may spend at that depth without requiring decompression. The columns to the right of the no-decompression limits column are used to determine the repetitive group designation which must be assigned to a diver subsequent to every dive. To find the repetitive group designation, enter the table at the depth equal to or next greater than the actual bottom time of the dive. Follow that column upward to the repetitive group designation.

Depths above 35 feet do not have a specific no-decompression limit. They are, however, restricted in that they only provide repetitive group designations for bottom times up to between 5 and 6 hours. These bottom-times are considered the limitations of the No-Decompression Table and no field requirement for diving should extend beyond them.

Any dive below 35 feet which has a bottom time greater than the no-decompression limit given in this table is a decompression dive and should be conducted in accordance with the Standard Air Table.

Example 2 - In planning a dive, the Diving Supervisor wants to conduct a brief inspection of the work site, located 100 feet below the surface. What is the maximum bottom time which he may use without requiring decompression? What is his repetitive group designation after the dive?

Solution - The no-decompression limit corresponding to the 100 foot depth in the No-Decompression Table is 25 minutes. Therefore, the Diving Supervisor must descend to 100 feet, make his inspection and begin his ascent within 25 minutes without having to undergo decompression.

Following the 100 foot depth row to the 25 minute column, the repetitive group designation at the top of this column is H.

Residual Nitrogen Timetable for Repetitive Air Dives

The quantity of residual nitrogen in a diver's body immediately after a dive is expressed by the repetitive group designation assigned to him by either the Standard Air Table or the No-Decompression Table. The upper portion of the Residual Nitrogen Table is composed of various intervals between 10 minutes and 12 hours, expressed in hours: minutes (2:21 = 2 hours 21 minutes). Each interval has two limits; a minimum time (top limit) and a maximum time (bottom limit).

Residual nitrogen times, corresponding to the depth of the repetitive dive, are given in the body of the lower portion of the table. To determine the residual nitrogen time for a repetitive dive, locate the diver's repetitive group designation from his previous dive along the diagonal line above the table. Read horizontally to the interval in which the diver's surface interval lies. The time spent on the surface must be between or equal to the limits of the selected interval.

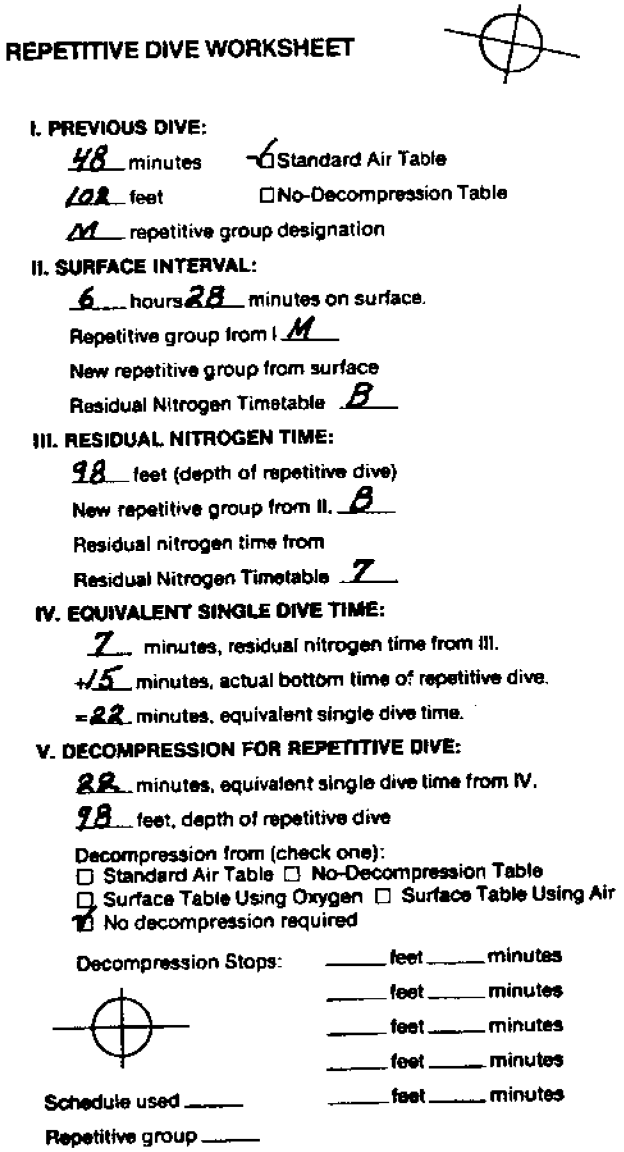
Next, read vertically downwards to the new repetitive group designation. This designation corresponds to the present quantity of residual nitrogen in the diver's body. Continue downward in this same column to the row which represents the depth of the repetitive dive. The time given at the intersection is the residual nitrogen time, in minutes, to be applied to the repetitive dive.

If the surface interval is less than 10 minutes, the residual nitrogen time is the bottom time of the previous dive. All of the residual nitrogen will be passed out of the diver's body after 12 hours, so a dive conducted after a 12-hour surface interval is not a repetitive dive.

There is one exception to this table. In some instances, when the repetitive dive is to the same or greater depth than the previous dive, the residual nitrogen time may be longer than the actual bottom time of the previous dive. In this event, add the actual bottom time of the previous dive to the actual bottom time of the repetitive dive to obtain the equivalent single dive time.

Example 3 - A repetitive dive is to be made to 98 fsw for an estimated bottom time of 15 minutes. The previous dive was to a depth of 102 fsw and had a 48 minute bottom time. The diver's surface interval is 6 hours 28 minutes (6:28). What decompression schedule should be used for the repetitive dive?

Solution - Using the repetitive dive worksheet -



REPETITIVE DIVE WORKSHEET

I. PREVIOUS DIVE:
48 minutes ☑ Standard Air Table
102 feet ☐ No-Decompression Table
M repetitive group designation

II. SURFACE INTERVAL:
6 hours 28 minutes on surface.
Repetitive group from I M
New repetitive group from surface
Residual Nitrogen Timetable B

III. RESIDUAL NITROGEN TIME:
98 feet (depth of repetitive dive)
New repetitive group from II. B
Residual nitrogen time from
Residual Nitrogen Timetable 7

IV. EQUIVALENT SINGLE DIVE TIME:
7 minutes, residual nitrogen time from III.
+15 minutes, actual bottom time of repetitive dive.
=22 minutes, equivalent single dive time.

V. DECOMPRESSION FOR REPETITIVE DIVE:
22 minutes, equivalent single dive time from IV.
98 feet, depth of repetitive dive
Decompression from (check one):
☐ Standard Air Table ☐ No-Decompression Table
☐ Surface Table Using Oxygen ☐ Surface Table Using Air
☑ No decompression required

Decompression Stops: _____ feet _____ minutes
_____ feet _____ minutes
_____ feet _____ minutes
_____ feet _____ minutes
_____ feet _____ minutes

Schedule used _____
Repetitive group _____

OMITTED DECOMPRESSION

Certain emergencies may interrupt or prevent specified decompression. Blow-up, exhausted air supply, bodily injury and the like constitute such emergencies. If the diver shows any symptoms of decompression sickness or gas embolism, immediate treatment using the appropriate oxygen or air recompression treatment table is essential. Even if the diver shows no symptoms of ill effects, omitted decompression must be made up in some manner to avoid later difficulty.

Use of Surface Decompression Tables

The Surface Decompression Table Using Oxygen or The Surface Decompression Table Using Air may be used to make up omitted decompression only if the emergency surface interval occurs with no water stops required by these tables, or if required, the water stops have already been completed.

Surface Decompression Tables Not Applicable

When the conditions which permit the use of the surface decompression tables are not fulfilled, the diver's decompression has been compromised. Special care must be taken to detect signs of decompression sickness, regardless of what action is initiated. The diver must be returned to pressure as soon as possible. The use of a recompression chamber is strongly preferred over in-water recompression.

When a Recompression Chamber is Available

Even if the diver shows no ill effects from his omitted decompression, he needs immediate recompression. Take him to depth in the chamber as appropriate for Recompression Treatment Table 1A or 5. If he shows no ill effects, decompress him in accordance with the Treatment Table. Consider any decompression sickness developing during or after this procedure as a recurrence.

When No Chamber is Available

When no chamber is available, use the following in-water procedure, which is based on the Standard Air Decompression Table with 1 minute between stops -

1. Repeat any stops deeper than 40 feet.
2. At 40 feet, remain for one-fourth of the 10-foot stop time.
3. At 30 feet, remain for one-third of the 10-foot stop time.
4. At 20 feet, remain for one-half of the 10-foot stop time.
5. At 10 feet, remain for $1^1/_2$ times the scheduled 10-foot stop time.

Keep the diver at rest, provide a standby diver, and maintain good communication and depth control. Following this decompression procedure, observe for symptoms of decompression sickness for 24 hours.

SPECIAL CONDITIONS

Surface Decompression

Surface decompression is a technique for fulfilling all or a portion of the diver's decompression obligation in a recompression chamber. By using this technique, the time which the diver must spend in the water is significantly reduced, and when oxygen is breathed in the recompression chamber the diver's total decompression time is reduced.

Surface decompression is commonly used in commercial and military diving operations where recompression chambers are more readily available. However, because chambers are not generally available on scientific/academic scuba diving operations, Surface Decompression Tables have not been included in this handbook. Also, since surface decompression procedures are not routinely included in scientific/academic diver training courses, this technique is not authorized for use by University divers except for emergency management of an omitted decompression situation when a chamber and qualified operator and supervisor are available. The Diving Safety Committee may grant special permission for use of surface decompression using appropriate U.S. Navy Tables and procedures.

Diving At Altitude

The Standard Air Decompression Tables are based upon diving in sea water from atmospheric pressure at sea level. When diving is in inland waters with surface elevations above 700 feet (210 meters) altitude corrections to the tables become necessary. A number of "correction procedures" and "altitude tables" are available. The following publication is currently recommended for establishing diving procedures to be used at altitude:

> Smith, C.L., Altitude Procedures for the Ocean Diver, NAUI Technical Publication No. 5 (Colton, CA.: National Association of Underwater Instructors, 1976).

Although the tables included in this publication follow the same criteria as the Standard Tables and should provide the same degree of safety, they have not been subjected to the rigorous manned validation tests required for decompression tables. A cautious and conservative approach should be taken when diving at altitude.

Excursion to Altitude Following a Sea Level Dive

It is advisable to avoid excursions to more than 1980 feet (600 meters) altitude within 24 hours of diving. The following University policy regarding flying has been established for non-saturation dives:

1. If you stay within the no-decompression limits of the Standard Air Decompression Tables, you can fly in pressurized commercial aircraft (or at maximum altitude equivalent of 8000 feet or 2400 meters) after a surface interval of 12 hours.

2. If decompression dives are performed (or should have been performed), the surface interval must be 24 hours.

In some cases, driving over high mountain passes may incur a risk of decompression sickness and the same procedures should be observed as for flying after a dive.

Some authorities are more liberal regarding excursion to altitude. The following may be considered at the discretion of the Diving Supervisor or diving medical personnel for exceptional circumstances or emergencies:

1. If all dives within the past 12 hours have been no-decompression dives, flights (cabin altitude of less than 8000 feet or 2400 meters) may be considered after a 2 hour surface interval.

2. Helicopter/low altitude aircraft flights (maximum altitude of 990 feet or 360 meters) may be considered within 1 hour of no-decompression dives or 4 hours of decompression dives.

Special Considerations

Decompression sickness can be prevented by proper planning, proper diving procedures, and some special precautions. The following special considerations or helpful hints are included to aid in the prevention of decompression sickness:

1. Whenever possible, AVOID decompression dives; plan all scuba dives within the NO-DECOMPRESSION LIMITS.

2. If in doubt regarding depth, time, or diver condition, use a CONSERVATIVE SCHEDULE.

3. DO NOT dive right up to the no-decompression limit (i.e., terminate bottom time for 60 fsw at 50-55 minutes, not 60 minutes).

4. Establish a strict team requirement that all scuba cylinders must have a minimum pressure of 200 psig when the diver reaches the surface. This will help avoid running out of air followed by rapid ascent.

5. Be aware of the physical condition of your divers. Use CONSERVATIVE SCHEDULES for cold and/or heavy exertion dives, persons with history of decompression sickness, persons with prior athletic type injuries (especially knee injuries), female divers, overweight individuals, older divers, and persons in poor physical condition.

6. AVOID decompression requirements in sea conditions which make maintaining exact decompression stop depths difficult.

7. MANDATORY DECOMPRESSION STOPS even on no-decompression dives may enhance safety IF sea conditions permit; remaining air supply is satisfactory; the idea of a safety "stop" does not cultivate haphazard diving techniques, inaccurate depth/time monitoring, and so on; and proper repetitive schedules are used. The SAFEST and BEST procedure to add SAFETY FACTORS is to use a greater depth and/or bottom time to determine the decompression schedule AND base the repetitive dive computation on the SCHEDULE USED.

8. ASCENT to the surface on NO-DECOMPRESSION dives at a rate SLOWER than 60 fpm is safe, IF the ascent time is included as part of the bottom time. Ascent rates FASTER than 60 fpm are UNSAFE!

9. Although the U.S. Navy specifies that "bottom time" terminates when the diver begins ascent, many scuba divers use a SLOW ascent rate and the TOTAL DIVE TIME for dive schedule determinations.

10. EXTRAPOLATION of tables to cover multilevel depth dives is practiced by many divers. Such calculations of exact tissue nitrogen tensions on multilevel dives can be performed, but not for the infinite number of combinations, and not during the dive itself with assured safety. The only ACCEPTABLE procedure at this time, although very CONSERVATIVE, is to consider the MAXIMUM depth for the total bottom time.

11. DECOMPRESSION METERS/DEVICES currently available for scuba diving give MARKED DEVIATIONS from Standard U.S. Navy Air Decompression Tables and DO NOT provide the diver with the same margin of safety. Some of these schedule inconsistancies may prove to be DANGEROUS. As with any mechanical device, they are also subject to MALFUNCTION. At this time, existing scuba diver decompression meters/devices are NOT APPROVED for University divers as an alternative to Standard Decompression Tables.

12. Experience suggests that some decompression schedules carry some HIGHER RISK than others. These include:

    50 fsw/100 min. no decompression limit
    140 fsw/30 and 40 min. schedules
    150 fsw/30 min. schedule
    170 fsw/30 min. schedule

    This is not an all inclusive list. A more CONSERVATIVE decompression schedule should be considered for these depths and times.

13. Exceptional exposure table dives have a significantly HIGHER INCIDENCE of decompression sickness than found when using Standard Tables. AVOID diving in the exceptional exposure range if at all possible.

14. Whenever possible, plan the DEEPEST dive of a repetitive sequence first and the repetitive dives progressively shallower.

15. When working with decompression tables, you can ALWAYS use a GREATER than actual bottom time, greater than actual depth, higher repetitive group, and greater residual nitrogen time for dive schedule calculation.

16. U.S. Navy Standard Air Decompression and Repetitive Dive Tables can be DANGEROUS IF you use them in ways they were NOT INTENDED to be used, or if you IGNORE them, MODIFY them without regard to their design, or if you EXTRAPOLATE them to cover non-standard conditions.

17. TIME AND AIR ARE CHEAPER THAN BONES AND NERVE TISSUE!

NOTES:

SECTION 6

EMERGENCY PROCEDURES

Emergency situations occasionally arise on even the best planned and supervised underwater operation. Many of these emergencies are the result of failure to observe some safety precaution; others are unforeseen and unavoidable. Very few underwater emergencies are so desperate as to require instantaneous action. Take a few seconds to think! Instinctive actions are seldom right. They may prove to be blind impulses brought on by panic. Adequate training will prepare the underwater swimmer for almost all emergencies, provided that he/she keeps his/her head. Do not panic and, above all, never abandon your breathing apparatus underwater unless ascent is impossible without doing so.

SCUBA EMERGENCIES

Exhaustion of Air Supply

A scuba diver should never have to cope with an exhausted air supply underwater. If the scuba is equipped with a submersible pressure gauge and the diver is observing common sense safety practices, he/she will surface well before the air supply is depleted. As a standard practice many instructors require that at least 200 to 300 psig of pressure remain in the cylinder when the diver surfaces. This means that the diver will start ascent at a pressure of 400 to 600 psig, depending upon conditions and depth. Never deplete the air supply while underwater.

However, in the event that a diver does deplete the air supply while underwater, ascent should be no problem to the properly trained and equipped diver. When breathing resistance becomes noticeable, simply open the air reserve mechanism and start ascent. Even if the reserve fails, increased breathing resistance prior to exhaustion of air supply gives some warning. Do not panic and ditch the scuba! The reduction in pressure and subsequent gas expansion during ascent provides additional air for breathing. The emergency ascent or "free ascent" is a last resort. All divers should experience exhaustion of air supply during training!

Loss or Flooding of Face Mask

The self-contained diver must learn to swim underwater without a face mask and how to purge water from the mask in the event of flooding. If the mask becomes dislodged and partially or completely fills with water, it should be repositioned on the face and purged of water by tilting the head backwards to place the lower edge of the mask at the lowest position. The diver then presses the upper portion of the mask firmly against the forehead and exhales through his nose. The exhaled air will displace the water and force it out under the lower edge of the mask.

If the mask is equipped with a purge valve, simply position the head so the purge valve is in the lowest position relative to the rest of the mask and exhale through the nose. Some divers prefer to press the top portion of the mask against the face while purging to limit the loss of air.

Purging Water From the Breathing System

There are various methods of purging water from flooded mouthpieces and hoses. Each method should be mastered and the trainee should learn the procedure for both double- and single-hose units.

The simplest method is to place the mouthpiece in your mouth and exhale. This will generally purge the water from the assembly and restore free breathing. Inhale cautiously following the purging procedure to be sure that all water is out. When purging the single-hose regulator, position the exhaust valve so that all water will drain through it. This may require the diver to look straight ahead or tilt his/her head slightly backward. Turning the left side down so that the water will run into the exhalation hose will facilitate clearing two-hose regulators.

If the diver does not have enough air in his lungs to expell the water, he will have to use the "free-flow" method. In two-hose units, the air will flow freely through the mouthpiece when it is raised above the level of the regulator housing. Therefore, raise the mouthpiece above the housing until it free flows, turn the mouthpiece down to trap air in it, tilt the head back, insert the mouthpiece into the mouth while free flowing, and resume breathing. The same method may be used with a single-hose regulator; however, a purge button must be depressed to initiate the free flow of air. An alternate method of purging a single-hose regulator is to place the tongue into the air inlet opening and depress the purge button. The water is forced out through the exhaust valve.

The diver should be alert for the cause of the flooding of the system. Some problems such as damaged breathing tube, diaphragm, or exhaust valve may hamper successful clearing of the sytem.

Recovery of Lost Mouthpiece

When the mouthpiece of a two-hose unit is lost, it will float to the highest point. When in the swimming position, the diver should bring his feet forward and lay on his back.

The mouthpiece will be directly above his face. Single-hose regulators generally lead over the right shoulder. If the mouthpiece is dropped, the diver should reach back, feel the first stage of the regulator, and follow the hose to the second-stage mouthpiece. The use of a neck strap to retain the regulator in front is discouraged; harness clips are permissible as long as they release readily for sharing air in emergencies. Failure of neck strap fasteners to release can be disastrous in air sharing emergencies.

ENTANGLEMENT

The diver's knife is his safeguard against entanglement in nets and lines. The entanglement situation generally requires more thought than action. Do not struggle; this only increases the degree of entanglement. This is where the "buddy system" is useful. The buddy can carefully cut the entangled diver loose. Only as a last resort should the diver remove his breathing apparatus and make a "free ascent."

THE ROLE OF THE "BUDDY" IN UNDERWATER EMERGENCIES

"Buddies" must learn to work together and should know and understand a standard set of signals. They should be in visibile range at all times and observe each other. In poor visibility a short buddy line may be required. The diver should signal his/her "buddy" at the first sign of trouble. If your "buddy" shows signs of distress, get to him/her at once whether he/she signals or not. The hardest job for a "buddy" will be in the presence of a panic. You may be able to do no more than take him/her to the surface at once. In handling a panicked person underwater every effort must be made to keep the mouthpiece in place. In ascent, the possibility of air embolism exists. It may be necessary to tilt the victim's head far back to facilitate exhalation, especially in panic situations. Some divers prefer to position themselves behind the victim and encircle the victim with their arms to depress the stomach area and induce exhalation. Never strike the victim in the stomach or chest; this procedure could cause an air embolism.

It may be necessary for scuba divers to share air (buddy breathe) in the event of air supply exhaustion or equipment malfunctions. There are several methods of sharing air and the diver must use the one best adapted to the situation. Generally, air sharing is necessary only for direct ascents. The divers simply face each other and exchange the mouthpiece of the operative scuba while making a slow, controlled ascent. When sharing air with a single-hose regulator, the diver providing the air should be slightly to the left (when facing the stricken diver). Do not fill your lungs and then hold your breath while your "buddy" is taking a breath! Remember you are ascending and that you must continue to exhale as you rise to prevent air embolism. The diver supplying the air should always retain control of the mouthpiece and may grasp the harness of the victim. He/she is generally in a better position to regulate breathing cycles and to control the ascent than the diver who has experienced air supply failure.

When working in caves or under ice, divers may find it necessary to move in a lateral direction before ascending to the surface. In this case, the diver wearing scuba containing air swims with his/her right side down. The distressed diver swims on his/her left side. The donor holding his/her "buddy's" harness with his/her left hand and exchangning the regulator with his/her right.

Divers making buddy breathing ascents must be constantly aware of buoyancy changes due to expansion of the wet suit material and air in the buoyancy compensation unit. During ascent the expanding air in the buoyancy compensator can cause the divers to "lose control" and rise rapidly to the surface. Ideally, the diver supplying the air will grasp the victim's harness for control. However, if the diver supplying air starts to ascend too rapidly due to air expansion in the buoyancy compensator, he will have to release his/her grasp and vent air from the buoyancy compensator. Some divers prefer "long" hose buoyancy compensators so they can hold the hose in their hand at all times and still grasp the victim for control during most of the ascent. The victim must also vent air from his/her buoyancy compensator during ascent. If the victim does not vent air from his/her buoyancy compensator and the divers are starting to lose control, the rescue diver must either vent the victim's air or vent all of the air from his/her own buoyancy compensator to provide a drag factor and slow the ascent.

Some instructors prefer to have each diver hold his/her own buoyancy compensator vent hose and thus control the ascent by systematic venting. Divers must be careful not to vent too much air from the buoyancy compensator and become negatively buoyant. If the divers are negatively buoyant on the bottom at the time of the emergency, then one or both must inflate his/her buoyancy compensator or release the weight belt. Some texts suggest that both divers systematically inflate their buoyancy compensators to achieve slight positive buoyancy and essentially float to the surface while buddy breathing. Naturally, the buoyancy compensators will be vented during ascent to control the rate of ascent. In other cases, the victim is near panic and incapable of handling the buoyancy compensator. The rescuer may choose to inflate his/her own buoyancy compensator in order to provide adequate buoyancy to "carry" both himself/herself and the victim to the surface. One can readily see that overweighting, excessive buoyancy compensation, buoyancy control and sharing a single mouthpiece are difficult problems to cope with in an emergency. The desirability of an auxiliary breathing system is evident.

An alternate method of lateral swimming is for the "buddy" with the air supply to swim face down. The other diver swims directly above him holding onto the neck of the air cylinder. The diver on the bottom passes the regulator up and the top diver places it back in veiw of the bottom diver. These methods may be used for both double- and single-hose regulators. Another method of lateral swimming while sharing air with a single-hose regulator is to have the divers swim side by side in a prone position.

Sharing air under emergency conditions is difficult even for the best trained and most experienced divers. Divers should practice the skill frequently. Furthermore, the use of auxiliary breathing systems is encouraged.

At the Surface

Upon reaching the surface after emergency ascent, or when in trouble at the surface following normal ascent (rough water, exhausted, etc.), jettison the weight belt, inflate the buoyancy vest, and signal for pick up. When a long distance from assistance, it may be necessary to use the signal flare to attract attention. The surface crew should be alert for divers in trouble at all times.

When not in difficulty, swim for the craft or shore base. If the breathing apparatus interferes with swimming, the diver should remove the equipment and tow it to safety while swimming on his back (vest inflated or deflated) or on his front with a snorkel. Never hesitate to inflate the buoyancy system. Most divers will inflate the vest as a matter of routine practice. Conserve energy! The diver may have to discard his scuba if he faces a long swim to safety.

Review of accident reports and discussions with diving instructors and guides reveals that most drownings and near-drownings occur at the surface, not underwater. In other words, relatively few scuba divers get into trouble underwater. Most accidents and rescues involve divers that are incapable of handling a surface swimming situation. During training,scuba divers must learn the following:

1. Buoyancy vest inflation at the surface by both oral and mechanical means;

2. Dropping weight belts at the surface in simulated emergency exercises;

3. Inflation of the "buddy's" buoyancy vest by both oral and mechanical means.

4. Removal of the scuba for towing or ditching;

5. Inflation of buoyancy vest while coping with excessive weight on the belt;

6. Long surface swims using both snorkels and regulator;

7. Students should not be allowed to escape to the surface to resolve minor problems such as equipment adjustment;

8. Students must not be allowed to hold on to the side of the pool while adjusting equipment or resting; always use the buoyancy vest.

The above procedures and skills must be mastered during training. Various exercises are used to test the trainee's ability to cope with underwater situations.

DROWNING

The U.S. Navy considers drowning to be the most frequent cause of death in self-contained diving. Drowning may result from simple mechanical malfunction of equipment, but is most frequently the result of underwater accidents and environmental factors. The most common cause is physical exhaustion resulting from swimming on the surface after the air supply has been depleted. Surface swimming in rough seas is an even greater hazard. Another primary cause of drowning is the inability of the diver to cope with emergency situations. Any of these conditions may result in panic and consequent drowning. Any underwater accident that causes unconsciousness generally results in drowning.

Self-contained divers must take every precaution to prevent drowning. The following preventive measures must be considered by all self-contained divers:

1. Adequate training with drill in emergency procedures;

2. Good physical condition;

3. <u>Use of a buoyancy vest at all times</u> -- with or without scuba;

4. Proper maintenance and use of approved equipment only;

5. Good diving practices with adequate preparation;

6. Knowledge and observance of personal limitations;

7. Provisions for aiding divers in distress (keep someone in the boat at all times);

8. Training in lifesaving and water safety;

9. Training of each person in the use of artificial respiration.

SKIN AND SCUBA DIVER RESCUE

Since divers spend more time in the water under more hazardous conditions than do most swimmers, it is essential that they know the fundamentals of lifesaving and water safety. One of the first principles of water safety is fulfilled by the "buddy system" -- never swim or dive alone. Divers have another important factor in their favor -- the buoyancy vest. Through the "buddy system" and the use of a buoyancy vest, most situations can be resolved.

The additional equipment used by divers modifies, to some degree, lifesaving techniques. The fact that the "buddy" is generally always in the water, near the victim, lessens the use of reaching or throwing assists. It is a known fact that most divers get into trouble at the surface, rather than at depth. In "trouble" situations the "buddy" is normally obligated to render all assistance possible. Frequently, "trouble" situations may develop into panic situations.

Cramp Release

At one time or another any diver will have to release a cramp. Cramps most commonly occur in the foot or calf muscles. The cramp is often preceded by a distinct twitch or unusual muscular contraction. Slowly stretch the affected muscle by grasping the sides of the fin with both hands and gently pulling the toe toward the knee. Relax and very lightly exercise the affected leg. Change to a different kick and/or stroke. Thigh cramps are more difficult to release in the water. On the surface the buoyancy vest should be inflated if the cramp is at all severe and remain inflated until the diver is ready to resume normal activity.

Trouble Situation

In the "trouble" situation, the diver is simply having difficulty in keeping afloat, but he had not lost control of himself. The victim may rescue himself by jettisoning his weight belt, inflating his buoyancy compensator, or regaining physical control of the situation. In this situation, the "buddy" or rescuer can do several things. First, encourage self-rescue by talking to the potential victim. Repeatedly call to the victim to drop his weight belt and inflate his buoyancy vest. Be calm, do not panic the victim. If there is a float to push to the victim or other means of avoiding contact, the rescuer should use it. Otherwise, the rescuer must move in, staying behind the victim; if possible. The safest and simplest means of aid is to reach around and inflate the victim's buoyancy vest and/or release his/her weight belt. If he/she is not wearing a vest or if this method is not feasible, the rescuer should support him/her at the surface from behind by gripping him/her firmly under the arm to support while talking to him/her and thus enabling him/her to get his/her breath. If the victim is wearing a weight belt, the rescuer should jettison it. The rescuer should reassure the victim and keep calm. A calm reassurance can often prevent a panic situation.

Panic Situation

Panic is a sudden unreasoning and overwhelming fear which attacks people in the face of real or fancied danger. Panic is the diver's most deadly hazard and is a contributory cause of practically all water accidents. A panic situation is dangerous to both victim and rescuer. The rescuer must know what he/she is doing and apply all of his/her skill and training to avoid personal danger. The will to aid sometimes ends tragically for both victim and rescuer. The first impulse of a panic-stricken swimmer will be to "climb" the rescuer and get himself/herself out of the water. The rescuer must retain his/her common sense, good judgment, and reasoning, and must not let the victim get hold of him/her -- stay clear. While the victim is violently thrashing in his/her panic, these movements will probably keep him/her afloat. When he/she tires, the rescuer can move in from behind and proceed with the rescue as in the "trouble" situation. The rescuer must be sure to keep the victim facing away from him/her so the victim cannot grab him/her. By holding the diver firmly under the arm the rescuer can both hold him/her up and control him/her. He/she should inflate the victim's vest and jettison the weight belt as soon as possible.

Approach

If it is necessary to approach the victim from the front, the rescuer should swim to within 6-8 feet (1.8-2.4 meters) of him/her. He/she should do a surface dive and approach the victim underwater, grasping him/her at the knee and turning the victim around. From the moment the rescuer makes contact with the victim, he/she should keep hold of him/her and control the situation. He/she should not drag the victim underwater as he/she moves up to a support or carry position. As the rescuer moves up he/she should release the victim's weight belt and inflate his/her vest. When approaching from the rear, the rescuer should be in a position to move quickly out of the victim's reach in case he/she turns. He/she should use the underarm grasp and control if necessary.

Equipment Aids

The fact that divers are equipped with mask and fins can greatly facilitate rescues. The addition of the buoyancy vest simplifies the situation considerably. The rescuer should not inflate his/her personal buoyancy vest or drop his/her weight belt until the situation is in hand and he/she knows he/she will not have to go underwater to approach or maneuver the victim. If he/she does inflate his/her vest and finds that he/she must go back underwater, he/she can remove it and leave it for a float, or deflate it. The rescuer must remember to drop his/her own weight belt if faced with anything but a very short tow.

Towing

Once the victim is under control, the rescuer should tow or push him/her to safety. The simplest method of towing the victim is for the rescuer to grasp the collar of the victim's inflated vest and swim on his/her side or back, towing the victim at arms' length. He/she should take care not to kick the victim. The important thing is to keep the victim's head above water. The rescuer should keep control of the victim at all times. If the victim is struggling, the rescuer should not let the victim turn on him/her. An alternate method of towing is the head carry. The rescuer can use his/her personal buoyancy vest (inflated) when doing this carry. The rescuer places a hand on each side of the head. The palms cover the victim's ears, the fingers are extended along the jaw and the thumbs are placed on the temples. He/she holds firmly and depresses his/her wrist to tilt the victim's head back. The rescuer holds his/her arms straight and swims on his/her back. The "fin-push" is considered a far more acceptable procedure than the conventional tired swimmer's carry. With weight belt off and vest inflated, simply have victim rest on his/her back, legs straight, and push him/her by the feet or fins. The victim's fins may be placed on the rescuer's shoulders and a firm grasp used on the legs in the vicinity of the knees. This position facilitates observation and is reassuring to the victim.

Two rescuers may more comfortably and efficiently tow a victim on the surface. After the victim has been leveled on his/her back, weight belt removed, vest inflated, and mask and mouthpiece removed, one rescuer is positioned on each side of the victim. The first rescuer (on the victim's right side) supports the victim's head with his left hand and grasps the victim's elbow or upper arm using his right hand in a palm down position. The rescuers are swimming on their backs. The second rescuer is positioned on the victim's left side. He/she grasps the victim's upper arm, his/her right hand under the arm. The second rescuer's left hand holds the victim's lower left arm firmly.

Another method of two rescuers towing is to place the victim on his/her back as above and each rescuer grasps the wrist with his/her outside hand and places the inside hand on the victim's upper arm or in the arm pit. The rescuers swim in a snorkel position.

Assist

As previously stated, the fact that the "buddy" is generally in the water, near the victim, lessens the possibility of a reaching or throwing assist. However, it should be stated that if at all possible, direct contact with the victim should be avoided. If near a pier, boat, etc. the rescuer should reach for the victim with a towel, pole, or whatever may be handy. If the victim is too far away for a reaching assist, the rescuer should throw him/her a rope, ring buoy, etc. If the rescuer reaches for the victim, he/she should keep low and firmly placed so the victim will not pull him/her in. The prone position is best.

Releases

If, for some reason, the victim gets a hold on the rescuer, the rescuer must know how to break it. Holds can sometimes be prevented by blocking the arm, grasping it, and turning the victim around; go directly to a control and carry position. At other times, it may be necessary to block the victim by ducking underwater, placing a hand on the victim's chest and pushing him/her away. Aggressive counteraction may not always be necessary. For instance, if the victim grabs the rescuer's arm, the rescuer may simply straighten the arm, reach underwater with the other hand and inflate the victim's vest and/or release the weight belt. This is beneficial in preventing further distress or panic in the victim. Even if the victim does get a "hold" on the rescuer, the rescuer can inflate his/her own buoyancy vest to prevent himself/herself from being pulled underwater. Larger capacity vests will probably float both individuals until further action can be taken.

When the victim actually gets a hold on the rescuer, the rescuer should not panic. He/she should sink, think, and act. If the victim gets a front head-hold on the rescuer, the rescuer should submerge, tuck his/her chin, grasp the victim with both hands on the mid-section (grasping his/her sides), and push outward and upward, while turning his/her own head to the side. When the victim hold releases, inflate his/her vest and/or release the weight belt and turn and control. If the victim gets a rear head-hold, the rescuer should sink, grasp the lower elbow and wrist, and push up on the elbow and down on the wrist. As the rescuer frees himself/herself, he/she should move under the victims's arm, retaining hold and control. If the victim grabs the rescuer's arm, the rescuer should release the hold with a quick twisting jerk of the arm. The rescuer should use leverage to advantage in all breaks. Conventional lifesaving release procedures apply in most situations, but may be complicated by the presence of hood, mask, and snorkel.

Inner Tube Rescue Technique

Many divers use automobile inner tubes for surface floats. The tube can be used as an effective support and towing aid. The rescue technique is as follows:

1. While holding the victim with one arm, use your other to place the victim's arm over the top of the tube.

2. Holding the victim securely, reach under the tube and grasp the victim's arm from the inside of the tube.

3. Push the tube under the victim's arm pit; flip the tube over the victim's head.

4. Lock the victim's arm onto the tube by bending the forearm downward.

5. Reach inside the tube, grasp the victim's chin, and level off. With practice mouth-to-mouth resuscitation can be given in this position.

Submerged and Unconscious Skin Diver

An unconscious, submerged skin diver must be surfaced as rapidly as possible and artificial respiration procedures started immediately. The rescuer should dive to the victim, release his/her weight belt, inflate the buoyancy vest and pull the victim toward the surface by grasping his/her arm or vest collar. In shallow water the buoyancy of the vest and wet suit (if worn) will generally lend considerable assistance to the surfacing procedure.

Assuming that the victim does not begin breathing upon surfacing, mouth-to-mouth resuscitation must be started immediately -- in the water. The most common method of administering in-water mouth-to-mouth resuscitation has been nicknamed the "do-si-do" method. This term was derived from the position similarity to the do-si-do in square dancing. The basic procedure is as follows:

1. An inflatable buoyancy vest is vital to success in this procedure. Inflate it immediately. Although most people advocate immediate release of the victim's weight belt, some feel it helps position the body better if left in place when the victim is wearing a full wet suit. Some authorities indicate that the rescuer should also release his/her weight belt once the victim has been surfaced; others find it difficult to swim with a full wet suit and no weight belt. Students should be encouraged to practice both procedures and form their own opinion. Excessive rescuer buoyancy can complicate the situation.

2. Assuming that the victim is to the right of and facing the rescuer, the rescuer will reach between the victim's arm and body (as if hooking arms with the victim). The rescuer's right hand may then grasp the victim's hair to facilitate tilting the head back, grasp the collar of the buoyancy vest, or reach under the victim's back to provide support. Students should be encouraged to practice various hand positions and determine which they like best. Pulling the head back over the collar of the vest aids in opening the victim's air passage. If the victim is wearing a backpack buoyancy unit, the rescuer may merely grasp the shoulder strap of the pack with one hand and use the other to seal the nose.

3. Using the left (free) hand, remove the victim's mask and seal his/her nose. Practice this while wearing the gloves or mittens normally used while diving.

4. The victim may be easily rotated toward the rescuer who places his/her mouth over the victim's and begins routine mouth-to-mouth rescue breathing. Be sure to get a tight seal. Blow gently at first in the event that the victim is not totally unconscious. Rotate the victim's head and body to avoid restricting the airway. Also, this way the rescuer doesn't have to lift his/her head out of the water.

5. After lung inflation, the rescuer may allow the victim to rotate back to the level position. He/she should listen and observe for exhalation. If difficulties are encountered, the rescuer may have to pull the head back further to clear matter from the mouth or airway.

6. The rescuer should attempt to maintain a normal 12 breaths per minute rhythm for adults. The critical factor is, however, to get air into the victim as soon as possible and to continue ventilating the victim even if conditions dictate an irregular pattern.

7. Between inflations, the rescuer should call for additional assistance. Another swimmer can push the victim by grasping his/her fins or legs while the rescuer continues resuscitation. If no other assistance is available, the rescuer may start toward shore (or boat) with his/her victim under tow without changing positions. With practice the rescuer may quite successfully tow the victim and give resuscitation simultaneously. On the surface, the rescuer may cover the victim's mouth as the waves break over.

Practice the rescue breathing procedure first in shallow water and then in deep water. Both the practice victim and the rescuer should wear all equipment that would normally be worn while diving. Also, practice in full equipment under various environmental conditions, especially in waves and cold water.

An alternative method of administering resuscitation in deep water is the mouth-to-snorkel method. The description of the procedure with comments on its use has been supplied by its originator, Albert L. Pierce and is included in Appendix J.

Scuba Diver Rescue

The rescue and subsequent care of a person who is using scuba (self-contained underwater breathing apparatus) is a far more complex procedure than the non-diver may realize. The fact that the victim has been breathing air under pressure leads to a host of complications. Any of the following conditions may lead directly or indirectly to near-drowning in scuba diving:

1. Contaminated air supply;
2. Overexertion;
3. Exhaustion;
4. Abnormal breathing;
5. Loss of mask or fins;
6. Unsuccessful "buddy breathing" attempt;
7. Adverse surface conditions;
8. Lung barotrauma;
9. Improperly fitted wet suit;
10. Decompression sickness;
11. Panic;
12. Cold stress; and
13. Anxiety.

The basic elements of diver rescue have been previously discussed. When rescuing a distressed scuba diver, one must consider the additional complications imposed by the presence of the scuba and special buoyancy equipment, and the special physiological problems.

Conscious, Troubled Scuba Diver on the Surface

To a rescuer, the distressed scuba diver may appear as only a very fatigued swimmer. The broad spectrum of physiological and psychological stress factors that may accompany an abnormal scuba diving situation do require special attention, even at the initiation of the rescue attempt. The psychological stress imposed by exhaustion, abnormal breathing, adverse surface or underwater conditions, and cold can cause the diver to forget even the most basic techniques of self-rescue. The verbal rescue may be all that is required. Simply approach the victim and calmly direct him/her to inflate his/her vest, release his/her weight belt, and relax. Do not lose visual contact since the victim may lose consciousness from the physiological changes induced by abnormal breathing and sink silently below the surface. Even with immediate recovery, resuscitation attempts may be unsuccessful.

If the victim does not respond, approach as previously described, inflate the vest and drop the weight belt. Constantly talk to and reassure the victim that he/she is going to be all right. Relax the victim and stabilize the situation. If there is apparently still air in the scuba, encourage the victim to replace the mouthpiece and breathe from the scuba while swimming or resting on the surface. This is especially true in rough water.

The presence of the scuba cylinder may, on the other hand, complicate the rescue procedure. Once the belt has been dropped and vest inflated, it is generally best to remove an empty cylinder if the victim must be towed. Cylinder removal may be complicated by the fact that on some units an inflation hose leads from scuba regulator to the buoyancy vest. This hose must be manually disconnected from the vest. If the vest inflation mechanism is funtioning properly, air will not leak from the vest when the inflator is disconnected; if not, air will discharge and the inflator hose connection will have to be re-inserted to stop the discharge or loss of air. Unfortunately, there is no standardization of inflation mechanisms for scuba diver buoyancy vests. Each manufacturer seems to use a different type and location of the inflation mechanism. The rescuer may have to study the victim's equipment in order to properly inflate the vest. Persons who anticipate being placed in situations which may involve the rescue of scuba divers are encouraged to seek diver training themselves and routinely visit diving equipment suppliers to update themselves on the vast variety of buoyancy vests and inflation mechanisms being used.

With the advent of vest inflation directly from the scuba air supply, many vests appeared on the market without small "emergency" self-contained CO_2 or air cylinder inflation mechanisms. Consequently, if the victim's scuba air supply is exhausted, the vest may be inflated only by oral means.

A highly distressed victim may be incapable of self-oral inflation. Therefore the rescuer will have to move in and orally inflate the vest. This is a difficult and potentially hazardous situation for the rescuer. If the victim panics at this point, the rescuer is in a very awkward position. If possible, and providing that the vest has a hose, move behind the victim to inflate his/her vest. This is a better position to take defensive action.

Some divers use a scuba system which incorporates the scuba, weights, and buoyancy device all into one unit. In this situation, the scuba must be retained in order to retain the buoyancy. Weights contained in the backpack may be dropped by pulling a pin mechanism on the backpack. The rescuer should stabilize the situation, inflate the buoyancy unit to full capacity (orally or with air from the scuba), and use it as a float or raft for the distressed diver.

This type of scuba system may produce complications in self-rescue if the diver is exhausted. Reports of divers being held in a face down position and unable to regain a position to hold their head clear of the water when the buoyancy device is fully inflated have been circulated throughout the diving community. Unfortunately, in either equipment design or rescue procedures, objective research has not kept pace with the introduction of new scuba diving equipment on the public market. Both divers and potential rescuers of divers <u>must</u> constantly upgrade their knowledge of equipment.

When necessary, and possible, the scuba should be removed. One <u>exception</u> to this statement is the diver wearing a backpack flotation system. In this case, removal of the scuba would also result in loss of supplemental flotation. Placing the victim on his/her back with a fully inflated backpack buoyancy system provides significant flotation. The victim may then move toward safety under his/her own power and the rescuer may tow the scuba. If the rescuer has to render aid to the victim, the scuba should be discarded. It is very difficult and inefficient to tow a scuba equipped victim. Unfortunately, distressed scuba divers sometimes place a higher value on their equipment than their lives. Tests have shown that in scuba diving rescue, the speed and efficiency of towing can be improved nearly three fold if the scuba of both the rescuer and victim are discarded.

Once the victim has been returned to safety, the rescuer's responsibilities are not terminated. He/she must assess the physical state of the victim and attempt to determine if the victim is suffering from conditions such as lung barotrauma, decompression sickness, carbon monoxide poisoning, etc. An unattended rescued scuba accident victim may pass into unconsciousness and even die within minutes or up to several hours after initial rescue as a result of physiological complications.

The victim must be observed and, if any abnormality at all is present, a physician consulted. Above all, the rescuer must inform the first aid and medical personnel that the victim was participating in scuba diving at the time of the accident. Accompany the victim, if possible, to the hospital or at least attach an accident description to his clothing.

Unconscious Scuba Diver on the Surface

The rescuer may encounter an unconscious scuba diver floating on the surface. In this case;the victim may have dropped his/her weight belt and even inflated his/her vest prior to losing consciousness. Unconsciousness may have been induced by factors such as cardiac arrest, decompression sickness, air embolism, contaminated breathing air, etc. Also, it is not inconceivable that the fatigued victim could have been unable to maintain his/her head above water sufficiently to breathe because of improper use of his/her equipment. In any case, the rescuer should immediately take action to position the individual and, if necessary, start mouth-to-mouth resuscitation. Discarding the scuba may be necessary, but should not delay the initial resuscitation procedures. Handling the diver's equipment has been discussed previously. Tow the victim to shore or boat as instructed in the section on skin diving and take appropriate action to cope with the near-drowning and diving induced injuries.

Submerged Diver Rescue

In the handling of submerged scuba divers we will consider both the possibility of a distressed conscious diver and the non-breathing victim lying on the bottom. In the case of a distressed conscious diver, the victim's diving "buddy" or another nearby scuba diver would probably be placed in the role of the rescuer. In the event of equipment failure or loss or exhaustion of air supply, the trained diver may choose self-rescue by making an emergency ascent.

Learning the technique of a "controlled emergency swimming ascent" or "free ascent" (without assistance from another diver or flotation vest) is an important part of scuba training.

Frequently, the diving "buddy" must rescue his distressed partner underwater. "Buddies" must learn to work together and should know and understand a standard set of signals. They should be in visible range at all times and observe each other. It may be necessary for scuba divers to share air (buddy breathe) in the event of air supply exhaustion or equipment malfunction. There are several methods of sharing air and the diver must use the best adapted to the situation.

Sharing air under emergency conditions is difficult even for the best trained and most experienced divers. Divers should practice the skill frequently. Many individuals feel that buddy breathing is a more hazardous emergency procedure for divers than the controlled emergency swimming ascent. A number of single and double drownings(and incidences of lung barotrauma) have been directly attributed to unsuccessful attempts at buddy breathing under stress situations. A buddy breathing ascent will generally take considerably longer, two to five times, than a free ascent. The use of free ascent procedures in shallow water and inclusion of diver carried auxiliary breathing units (octopus rig, pony bottle, etc.) for deeper diving is increasing in popularity. Proper training and diver discretion are key factors in handling emergency situations underwater.

The potential rescuers of unconscious submerged divers encompass a much larger group of individuals. Any swimmer, skin diver or lifeguard operating in an area of scuba diving activity may find himself or herself in a situation of recovering an unconscious scuba diver. This is especially true in recreational pools and beach areas where scuba diving is permitted. Assume that the rescuer is not equipped with scuba and that the victim is in water that is shallow enough to reach by normal surface diving techniques.

The rescuer should dive to the victim, and proceed as follows:

1. Position the victim so that his/her head may be extended back, thus opening the airway as in mouth-to-mouth resuscitation. This can generally be best accomplished by getting behind the victim and pulling his/her head back by grasping his/her hood or hair with one hand and supporting him/her under the arm with the other hand. If the regulator is in place, Busch (1976) recommends that the rescuer securely grip the victim's chin and exert pressure up and against the chin to prevent the mouthpiece from falling out of the victim's mouth. Two fingers are placed above and two below the chin.

2. With the free hand, reach around and release the victim's weight belt and, if the victim cannot be pulled from the bottom, inflate his/her buoyancy vest. If the victim can be surfaced without vest inflation or considerable delay, do so.

3. Maintain the victim in the upright head held back position throughout ascent. This is vital for the prevention of air embolism or other lung barotrauma. It may be necessary to swim the victim up if his/her vest does not inflate and he/she is not wearing a wet suit. Some advocate placing both arms around the victim's chest or abdominal area and squeezing. This practice is difficult when the victim is wearing scuba. Busch (1976) recommends exerting pressure on the victim's abdominal wall with the free hand.

4. Do not take time to remove the scuba unless it is entangled in rope, net, weeds, etc. or it is significantly inhibiting handling the victim.

The scuba diver may find himself/herself in a similar position of victim recovery, only at a much greater depth. The techniques of recovery are basically the same except for the following considerations:

1. Buoyancy vest inflation is at the discretion of the rescuer. If the victim is buoyant when the weight belt is released, the rescuer may have better control if he/she does not inflate the vest until he/she reaches the surface.

2. Scuba removal may make surfacing the victim faster, depending on the depth, type of scuba harness, etc. However, the rescuer should not spend valuable seconds attempting to release the scuba if not necessary.

3. The rescuer must not endanger himself/herself; keep in mind the need for exhalation throughout the ascent.

4. If the victim's vest is inflated and the ascent gets "out of control", the rescuer is probably better off if he/she releases the victim and takes care of himself/herself. Recent research has shown that the airway in an unconscious diver may, in fact, remain sufficiently open to allow adequate venting in such situations as rapid buoyant ascent. Studies show that the rescue of a diver from 30 feet (9 meters) can be accomplished in a bout 1/2 to 1/3 the time using this technique of inflating the vest and letting the victim float unassisted to the surface. More research will be required, however, before this can be recognized as a standard procedure.

Many divers now use "diaphragm depression" to insure that the victim expells air during ascent. The rescuer encircles the victim from the side or rear, places the hands or fingertips on the area just below the rib cage, and applies light pressure while ascending.

Other divers choose to bring the victim immediately to the surface in a head down, feet up position. The advocates of this technique suggest that in the event of lung barotrauma the air bubbles would pass into the heart or lower portion of the body, rather than the brain.

Some divers advocate positioning the victim in a face down - feet up position and placing the regulator against his/her mouth to facilitate purging water from the airway. At this time research and documented successful experience using this technique are not sufficient to endorse it as a "standard" procedure. A relatively significant amount of time is consumed in positioning, airway purging, and ascending in an "abnormal position." Time is of greatest essence in successful rescue and resuscitation.

Once the victim is on the surface, inflate the vest and immediately start mouth-to-mouth resuscitation. Do not take time to remove equipment. Once resuscitation is underway, systematically remove the diver's scuba equipment without interrupting resuscitation procedures. Have the other divers remove equipment if possible. Frequently, it may be best to remove both the victim's and your scuba. Use the resuscitation techniques previously described. Busch (1976) published an excellent, well illustrated article on scuba diver rescue.

It is clear that more objective research is required in the area of scuba diver lifesaving. Techniques must be proven or disproven and some "standardization" of technique is required.

EQUIPMENT FAILURE

Equipment failure is an uncommon cause of scuba diving accidents. All scuba divers are instructed in management of the following equipment related emergencies:

1. Exhaustion of air supply;
2. Loss or flooding of face mask;
3. Flooding of breathing system;
4. Loss of mouthpiece;
5. Entanglement;
6. Breathing apparatus failure; and
7. Buddy rescue (possible failure of flotation equipment).

These items have been discussed in detail in this section.

MEDICAL ILLNESS/INJURY

The nature and location of University diving operations in the Great Lakes is such that medical facilities are generally within a few minutes to a few hours from the operations area. An ill diver can be readily transported by the vessel to shore and from there by ambulance to the nearest hospital or clinic.

Although there will be some variation depending upon exact location, the following is recommended:

1. Terminate diving operations and secure equipment for getting underway.
2. Immediately provide aid and comfort to the ill diver.
3. Advise the master of the vessel to contact the U.S. Coast Guard or other appropriate agency and arrange for an ambulance (and physician, if deemed necessary) to meet the vessel at the nearest dock facility.
4. If the condition is serious, request U.S. Coast Guard helicopter evacuation (especially if surface travel involves a considerable time delay).
5. Beach based diving parties will acquire medical services by CB radio or nearest telephone.

Details of first aid for injuries and diving accidents are included in Section 7 of this handbook.

ADVERSE ENVIRONMENTAL CONDITIONS

1. Review weather forecast prior to committing divers to the water. Postpone scuba diving if high winds/ seas decreasing surface visibility, or storm conditions are predicted.
2. Do not start diving operations during storm or high sea/wind conditions.
3. Do not allow scuba diving under low surface visibility conditions (fog, snow, etc.); use surface-supplied divers.
4. If divers are in the water and surface visibility is decreasing, sound recall and terminate the dive.
5. If divers are lost in poor surface visibility conditions, they should inflate buoyancy systems and periodically give three blasts on their whistles (all scuba divers are to carry whistles). The support vessel will display all appropriate lights and sound fog horn at appropriate intervals. A security call should be given to alert other vessels in the area to the fact that divers are lost, possibly on the surface awaiting rescue. Commit radio equipped search boat at the discretion of the ship's officers.

FIRE ON UNIVERSITY VESSEL

In the event of a fire on one of the large research vessels the diving team must consider the following:

1. Do not interfere with the emergency activities of the trained crew.
2. Be prepared to assist in fire control as directed by the captain of the vessel or crew members.
3. Be prepared to assist in lifesaving and survival procedures if it is necessary to abandon ship.

Naturally, each vessel will have its own fire drill procedures. On larger vessels the appropriate lifeboat stations are designated for each person on the vessel including scientists and technical persons which generally includes the diving teams. If a general alarm (or fire alarm/abandon ship alarm) sounds, the divers should quickly assemble their exposure suits along with fins, mask snorkel, and inflatable vest, and a ship's lifejacket and proceed immediately to their designated lifeboat station. If time permits, don exposure suit and have other equipment ready for use. Divers have a distinct advantage over non-diving crew members. The exposure suit may ensure hours of survival in cold water. In addition, the divers are very capable of performing lifesaving tasks if a general abandon ship is necessary.

A fire on board the vessel while divers are underwater or under pressure in a deck chamber is an extremely serious situation. The following procedure should be followed:

1. Immediately terminate in-water diving operations. Recall scuba divers using underwater sound device. Surface-supplied divers are recalled, decompressed, and removed from the water. If extensive in-water decompression is required, place a communicator, air cylinder and regulator in a lifeboat or chase boat and transfer the diver's umbilical assembly to that unit. Cast off and decompress away from the distressed vessel.
2. The scuba divers will ascend to the chase boat or tending boat, remove scuba, and stand by the staging location of the distressed vessel to render assistance or perform lifesaving tasks.
3. If a chase boat is not being used, the scuba divers will ascend to the support vessel, remove and secure scuba on the diving ladder (or descent line, and stand by in the water with inflated vest to render assistance or lifesaving tasks as required (adjacent to staging location).

4. Divers will board the support vessel at the direction of the Captain or the Diving Supervisor.

5. If persons are under pressure in a deck chamber, the Supervisor should immediately inform the Captain and request permission to continue decompression as long as permitted. Secure oxgyen. If the fire is threatening and it is necessary to abandon the vessel or the chamber area, bring the divers to surface pressure, transfer to a lifeboat, and resume oxygen breathing on portable inhalation units as soon as possible at surface pressure. Be prepared to manage decompression sickness.

Retain only the personnel required to handle the divers at the dive staging area. Others should proceed directly to their designated lifeboat/assembly station. If no specific assembly station has been designated by the ship's officers, the divers will assemble at the diving station unless it is threatened by fire. If so, they will assemble as a group at a location designated by the Diving Supervisor away from fire and await further orders from the ship's officers.

REFERENCES

Busch, W., "Rescue of the Unconscious Scuba Diver", *Skin Diver*, 25(6): 60-61 (1976).

SECTION 7

MANAGEMENT OF DIVER INJURIES

Most diving injuries may be attributed to environmental factors causing stings, cuts or abrasions; the direct effects of pressure causing tissue damage during descent or ascent; the indirect effects of pressure involving gas absorption/ elimination in body tissues or breathing contaminated air. Drowning can be the result of many of these factors.

Most, if not all, diving injuries can be prevented through adequate training, proper diving procedures, and common-sense safety precautions. Through an understanding of the cause of accidents or injuries, the diver can generally prevent their occurrence. However, all members of the dive team must be able to recognize diving injuries and administer proper first aid. Proper and immediate management of a diving related injury can prevent further complications or injury to the diver and, in many cases, save the diver's life.

The following is only a summary of major diving related injuries. It is intended as a review for experienced divers, a field reference, and a supplementary condensed review of the subject for trainees. Consult appropriate diving manuals for a complete, illustrated discussion of diving physiology and management of diving injuries. A standard first aid and CPR manual should be included in every diver's personal library.

PHYSICAL INJURIES: NOT PRESSURE ASSOCIATED

Basic First-Aid Procedures

First aid is the "immediate and temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained." Proper first aid can make the difference between life and death. Every diver and person related to diving operations should have a good knowledge of first aid. An American National Red Cross first-aid course or equivalent is recommended. The following is a brief reminder of some vital aspects of first aid particularly applicable to diving-related accidents.

If the nature of the injury is uncertain, immediately check the victim for respiration, bleeding, head injury, or broken bones. In case of serious injury or sudden illness, while help is being summoned, give immediate attention to the following first aid priorities:

1. Effect a prompt rescue. (For example, remove the victim from water, fire or noxious fume environments.)
2. Ensure that the victim has an open airway and give mouth-to-mouth artificial respiration, if necessary.
3. Control severe bleeding.
4. Give first aid for poisoning, or ingestion of harmful chemicals.

Most authorities also recognize the significant incidence of cardiac arrest and support properly administered cardio-pulmonary resuscitation by specially trained first aiders. The first aider should also prevent further contamination of wounds and take measures to combat the onset of shock.

The first aider must avoid panic, inspire confidence and do no more than is necessary to sustain life and provide psychological comfort to the victim until professional help arrives. Obtain the services of paramedical personnel and/or a physician in all but minor, uncomplicated wounds or burns. Never release a victim that has been unconscious without first having the person examined by a medical person.

Control of Heavy Bleeding

If bleeding is heavy, from wounds to one or more large blood vessels, this must be stopped as soon as possible. Such heavy loss of blood can result in death in 3-5 minutes. Immediately apply pressure directly over the wound with dressing, clean cloth, hand or fingers. Secure dressing with bandage or cloth strips and elevate the bleeding part higher than the rest of the body unless bones in the part are broken. Application of pressure on specific "pressure-points" may be required if direct pressure does not stop the bleeding. Keep the victim lying down. Take shock prevention measures. Administer liquids (water, tea, coffee) if the victim is conscious and can swallow. Do not give the victim any alcoholic beverages. Do not give the victim any liquid at all if he is unconscious, nauseated or if abdominal injury is suspected.

Use a tourniquet only for an amputated, mangled, or crushed limb or profuse bleeding that cannot otherwise be controlled. Use only a wide, strong piece of cloth. Wrap tourniquet around upper part of limb above wound. Tie with an overhand knot, place a short stick on the knot, and secure with a square knot. Twist stick just tight enough to stop bleeding. Once the tourniquet has been applied, leave it in place until immediate, qualified, surgical, and support measures can be applied by medical personnel.

Keep under constant observation and place a note on the victim stating the time applied and location of the tourniquet. Also, write a large "T" on the victim's forehead using a marking pen, lipstick, etc. Do not cover tourniquet or note.

Artificial Respiration

If the victim is apparently not breathing or the lips, tongue, and fingernails become blue, start artificial respiration immediately; seconds count. When in doubt, begin artificial respiration, since little or no harm can result from its use, and delay may cost the victim's life. Mouth-to-mouth breathing is generally considered the best method since it can be performed in a number of positions, including in the water or in cramped surroundings; requires no special equipment; is not fatiguing for the first-aider; and allows the first-aider greater control of the rescue procedure.

Proceed as follows:

1. Quickly check mouth and throat for obstructions. Remove vomitus, mucus, etc. with a cloth or index finger. Tilting the head and body to the side is helpful.

2. Turn victim on his back.

3. Lift victim's neck with one hand and tilt his head by holding the top of his head with your other hand. If necessary, pull the chin up so the tongue doesn't fall back to block the airway.

4. Close the nose by pinching with thumb and index finger of the hand that is pressing on the victim's forehead.

5. Take a deep breath and place your mouth over the victim's mouth, making an air-tight seal.

6. Blow into the victim's mouth until the chest rises (forcefully into adults and gently into children).

7. Remove your mouth and let the victim exhale while you take another breath; listen for exhalation and watch the chest to see if it falls.

8. Check for and remove obstructions if air exchange is not evident.

9. Repeat inflation of the lungs 12 times per minute (adult) until the victim is pronounced dead or regains breathing. Do not give up!

Cardio-pulmonary Resuscitation

Cardiac arrest is a common condition that may be associated with diving injuries, near-drowning, electrocution, and a host of other accidents or conditions. Prompt emergency measures in cardio-pulmonary resuscitation by trained persons can and has saved many lives. The basic procedure is as follows:

1. Place the victim flat on his back on a hard surface.
2. If the victim is unconscious, open airway by lifting up neck, pushing forehead back and clearing out the mouth (if necessary).
3. If the victim is not breathing, give 4 rapid inflations of the lungs.
4. Check carotid pulse. If the pulse is absent, begin chest compression. Depress the sternum 1½ to 2 inches (3.8-5 cm) at a rate of 60 times per minutes (two rescuers) or 80 times per minute (one rescuer)
5. Inflate the victim's lungs once every five chest compressions (two rescuers) or give two quick inflations for every 15 compressions (one rescuer).

All divers and support personnel are encouraged to acquire specific training in cardio-pulmonary resuscitation. Training is available through the American National Red Cross.

Prevention of Shock

Shock is a serious complication in almost any injury, severe illness, or emotional upset. Signs of shock include: (1) cold, moist skin; (2) paleness; (3) chilling; (4) nausea or vomiting; (5) shallow breathing; and (6) weak, rapid pulse. Prevent or treat as follows:

1. Keep victim lying down with head slightly lower than the rest of the body (except if head injury is suspected or this position causes breathing difficulties).
2. Keep victim warm by covering.
3. If medical care is delayed for an hour or more and if conscious, able to swallow, not vomiting and has no apparent abdominal injury, give water (never alcoholic beverage). Give shock solution (1 qt water, 1 tsp salt, 1/2 tsp baking soda) if available.
4. Keep victim calm and reassured.

Ingested Poisoning

In situations where the victim has ingested poison, measures should be taken to dilute or neutralize the poison as quickly as possible, to induce vomiting (except where corrosive poisons or petroleum products are swallowed or if the victim is unconscious or having convulsions), to maintain respiration, to preserve vital functions and to seek medical assistance without delay. Water or milk is commonly used to dilute poison. If the person has swallowed strong acids, strong alkalis, or petroleum products, do not induce vomiting. Attempt to indentify the poison.

Minor Wound

Small cuts and abrasions are common to divers. Infection is the principal danger in small wounds, so any break in the skin must be protected. Do not touch a wound with your fingers or allow clothes to touch it. Keep it clean. Do not use an antiseptic on the wound. Immediately cleanse the wound and surrrounding area with antibacterial soap and warm water, wiping away from the wound. Hold a sterile pad firmly over the wound until bleeding stops. Apply a clean dressing and secure with a bandage. Band-aids may be used for small wounds.

Burns

Burns result from heat or chemicals. Any burn, including sunburn, may be complicated by shock and the victim must be given first aid for shock. For first or second degree burns immerse burned part in cold water (not ice water) until pain subsides. Immersion is not used for third-degree burns (deep tissue destruction and charred appearance). Place the cleanest available material over all burned body areas to exclude air. Consumption of nonalcoholic liquids by the victim is beneficial if possible. Transport victim immediately to hospital for severe burns. All burns, except where skin is reddened in only a small area, should be seen by a physician. Do not apply ointments, grease, baking soda, or other substances to extensive burns.

Head Injury

It is difficult to discover internal injury to the head. Suspect a brain injury if the person loses consciousness; has blood or fluid escaping from the ears, or nose; has a slow pulse, headache, convulsions, different size eye pupils; or is vomiting. It is necessary to keep the victim lying down, warm, and under close supervision. Do not place the head lower than the feet. If the victim is unconscious, remove false teeth or objects that might cause choking. Do not give fluids. Do not move if there is bleeding from the nose, mouth, or ears. Control bleeding from a head wound by applying a pressure dressing. Use common sense in regard to using pressure over a possible skull fracture.

Convulsions

Do not attempt to restrain or douse victim with water. Remove objects that might injure victim, or in close quarters. Surround with padding (pillows, air mats, blankets, etc.). Don't place a finger or hard object between the teeth.

Injury to Spine or Neck

If possible, do not move victim or allow victim to move without proper stretcher and professional assistance. If the victim must be removed from the water and a neck or head injury is suspected, support victim, taking care not to move the head, neck, or back. Place a stiff, wide board under the victim and secure with straps. Keep head level and under slight tension. Do not let it drop forward. Keep victim warm and quiet until professional assistance is available.

Fractures

Do not move a person with suspected fracture until it has been splinted unless the victim is in imminent danger. Place the limb in as natural a position as possible without causing discomfort. Apply splints which are long enough to extend beyond the joints above and below the fractured area. Any firm material can be used. Inflatable splints are excellent for lower leg and forearm fractures. Secure non-inflatable splint at a minimum of three sites: (1) above the joint above the fracture, (2) below the joint below the fracture, and (3) at the level of the fracture. If the fracture is open, apply a pressure dressing to control bleeding and prevent contamination, and splint without trying to straighten the limb or return it to natural position.

Heat Exhaustion

A person suffering from heat exhaustion has pale and clammy skin, rapid and weak pulse, weakness, headache, nausea, and possibly, cramps in the abdomen or limbs. The victim should be kept lying down with his head level or lower than the rest of his body. Move him to a cool place; however protect him from chilling. Give the victim salt water (1 tsp salt to 1 qt water) if he is conscious.

Heat Stroke

A heat-stroke victim will have flushed, dry, and hot skin, rapid and strong pulse, and is often unconscious.

Cool the body by sponging with cold water or by cold applications and if the victim is conscious, give him salt water (1 tsp salt to 1 qt water).

Frostbite

As frostbite develops, the skin changes from a pink color to white or greyish-yellow. Initial pain quickly subsides and the victim will feel cold and numb. Generally he is not aware of frostbite. Cover the frostbitten area with a warm hand or woolen material. If the fingers or hands are frostbitten, have the victim hold his hand next to his body, in his armpits. Get the victim to a heated area as soon as possible and place the frostbitten part in warm water (108° F, 42° C). If this is impractical, gently wrap the area in blankets. Do not rub with snow or ice; let circulation return naturally. When the part is warmed, encourage the victim to exercise fingers and toes. Do not use hot water, hot-water bottles, or heat lamps on the frostbitten area.

Snakebite

Poisonous snakebites must be dealt with immediately. Except for the coral snake, in the United States poisonous snakebites can be recognized by the presence of two distinct punctures caused by fangs. Swelling occurs rapidly and the skin becomes dark purple in color. Lay victim down immediately and apply a constricting band around the arm or leg above the bite if the bite is on a limb. Tighten the band just enough to make veins stand out prominently under the skin without causing the pulse to disappear below the band or causing a throbbing sensation. Keep the victim absolutely quiet and transport immediately to a physician. Apply ice over the bite if possible. If there is to be considerable delay between occurrence of bite and treatment, make a crosscut (approximately 1/4 in. long and 1/4 in. deep, 6 mm by 6 mm) over each fang mark to encourage free bleeding. Apply suction by mouth or suction device; continue for 30 minutes. Although some still recommend the use of incisions, many authorities now agree that this technique is undesirable. Simple immobilization of the victim and transport to medical assistance is discerned most desirable. The victim may administer first aid to himself.

The above is only a brief review of the major aspects of first aid. This is not a first aid text. Many injuries such as those to the eyes, chest, abdomen, and so on have not been addressed. All divers are again encouraged to acquire specific first aid training. At least one on-site individual associated with each diving experience should hold advanced qualification in first aid and cardio-pulmonary resuscitation. A first aid kit, blankets, oxygen inhalation equipment, stretcher (and/or back board), and appropriate first aid manual should be available at the dive site.

PHYSICAL INJURIES: PRESSURE ASSOCIATED

Descent Associated Injuries

Barotrauma (pressure injury or squeeze) occurs when the ambient pressure to which a diver is exposed becomes greater than the air pressure within closed air spaces inside the diver (primarily sinus cavities and ears) or attached to the diver's body (for example, face mask or ear plugs). As a result a painful squeeze occurs as tissue and body fluids are compressed into the air space. Barotrauma can be prevented by following simple rules. First, do not dive if passages to the sinuses and the middle ear are blocked (cold or allergy). Second, while descending prevent any pressure differential from developing by equalizing pressure in closed body cavities or attached air spaces. Third, if ear or sinus discomfort is experienced during descent and pressure cannot be equalized, stop and ascend. Fourth, do not wear ear plugs.

External Ear Injury

During descent, air trapped at the surface in the external ear canal by ear plugs or a tight-fitting rubber suit hood can not equalize with increasing ambient pressure. The tissue of the ear canal will be "squeezed" and the eardrum will bulge outward and, possibly, rupture.

The diver will feel ear pain even though he/she is able to equalize middle ear pressure. If intense pain quickly subsides, the eardrum has probably ruptured. If for some reason cold water enters the middle ear after this rupture, the effects on the inner ear "balance" organs will be evident by the onset of dizziness, nausea and possibly vomiting. Stability will return shortly as the intruding water warms. When the diver surfaces, there will generally be bleeding from the external ear and/or spitting up of blood.

If an eardrum rupture is suspected, ascend as soon as dizziness (if any) subsides. Attempting to surface while dizzy and disoriented can be hazardous; the diver may have difficulty differentiating up from down.

Do not attempt to flush or clean the external ear canal. Avoid placing medications or objects in the ear canal. Simply cover the external ear opening with a sterile dressing to prevent further contamination. Consult a physician as soon as possible. Prescribed medicaiton may be required to prevent or control infection.

Middle Ear Injury

The most common type of pressure injury experienced by divers is middle ear squeeze. During descent a blocked eustachian tube (tube connecting the middle ear space with the throat) keeps air from passing into the middle ear as ambient pressure increases. The result is compression of tissue fluids and blood into the middle ear space. If the diver continues descent, the eardrum will also rupture inward.

Eustachian tube blockage is caused by swelling or mucus associated with colds, respiratory infections, or allergies. Even most healthy divers have to perform an equalization maneuver such as jaw movement, swallowing, or blowing against closed nostrils to facilitate proper middle ear ventilation or equilization. The prevention of ear squeeze is simple. Do not dive if congested! During descent equalize pressure before pain is experienced; discontinue dive if equalization is extremely difficult or impossible. Systematic use of proven decongestants is acceptable for those who have routine equalization problems.

The diver will be immediately aware of discomfort during descent and may spit up blood after surfacing. The signs, consequences and management of a ruptured eardrum have been discussed previously. If middle ear squeeze is suspected, discontinue diving so that further injury to the tissue may be prevented. If drainage, discomfort or any abnormalities persist, consult a physician. Physician prescribed medication may be required to prevent or control infection.

On occasion, pressure build-up and pain may be experienced in the middle ear during ascent. This results from closure of the eustachian tube by mucus or swelling during the dive. In such cases the diver must stop ascent, possibly descend a few feet, and then attempt continued ascent very slowly; swallowing or jaw movements may be beneficial. Reverse squeeze and outward eardrum rupture are possible.

Sinus Injuries

During descent, a pressure imbalance can occur in the sinus cavities in the same manner as described for the middle ear. Mucus or tissue swelling closes the tubes between the oral-nasal area and the sinuses. Prevention and injury management are the same as for the middle ear.

If sinus cavity equalization does not take place during descent, the diver will usually experience increasing pain in the forehead above the eyes and occasionally in the face below or behind the eyes. Upon surfacing, a victim of sinus squeeze may experience tenderness in the sinus area and a discharge of blood and mucus from the nose. This discharge may be pooled in the scuba diver's face mask.

On occasion, as with the middle ear, the sinus cavities may not ventilate during ascent. Follow the same procedures as previously discussed for the middle ear.

Other Considerations

Any attached air space such as a face mask or sealed diving suit can cause a "squeeze." The diver must maintain a proper pressure balance within a mask and dry suit to prevent the squeeze sensation and possible tissue injury. Mask and suit squeeze are rarely, if ever, seen in modern scuba diving. Simply admit air into the mask through your nose and wear undergarments and ventilate dry suit during descent. Do not use "goggles" for diving.

If, following a dive, the diver's face appears puffy and discolored; has an evident ring around the face where the mask edge sealed; and/or has blood-shot eyes, then he/she has experienced mask squeeze. Apply cold packs to the injured area and consult a physician if the damage appears severe.

Occasionally, an improperly filled tooth cavity, an infected tooth, or a tooth cavity will have a gas pocket which responds to a pressure imbalance in the same manner as other air spaces in the body. In such cases, pressure equalization will probably not be possible and pain will intensify during descent. If symptoms appear, ascend for relief and discontinue diving until a dentist checks the affected tooth. Proper dental care is absolutely necessary for divers.

Ascent Associated Injuries

The most dramatic and serious forms of pressure injury can occur during ascent. Obstruction of normal venting of the lungs as the diver ascends from a higher to lower ambient pressure can cause rupture of lung tissue. Near the surface a pressure gradient as small as 4 fsw (1.2 msw) can cause tissue damage. Once air escapes from the lungs it may move into the pleural cavity, the area surrounding the heart, tissue just under the skin, or pulmonary circulation and, subsequently, the brain. Air bubbles in the brain are by far the most serious consequence of lung tissue rupture.

Every effort must be made to insure that the diver's lungs ventilate freely during ascent. The following measures or precautions will help minimize the possiblity of lung overpressure and injury in scuba diving:

1. Routine medical examinations;
2. Never dive with a respiratory infection or chest cold;
3. Training in proper normal and emergency ascent techniques;
4. Proper maintenance of scuba to prevent malfunctions;
5. Never exhausting air supply while submerged;
6. Proper selection of diving buddy;
7. Auxiliary breathing systems;

8. Proper buoyancy control;
9. Routine diving and/or retraining; and
10. Proper handling of panicked individuals and underwater emergencies through adequate training.

Air Embolism

Air bubbles rupturing through alveolar tissue may enter pulmonary veins, pass through the heart, and enter arterial circulation to the brain. In the brain the gas bubble may stop, causing a blockage of circulation or air embolism. Severe damage resulting from anoxia of the brain tissue (lack of or inadequate oxygenation) can cause a host of minor to serious neurological symptoms, including death.

The onset of symptoms may be sudden and dramatic. The diver may or may not experience discomfort, tightness, and/or chest pain during ascent. However, in serious cases the injured diver will collapse and lose consciousness upon surfacing or within a few minutes thereafter. Bloody froth and bleeding from nose and mouth may or may not occur. Neurological symptoms/signs may include:

1. Loss of balance and/or coordination;
2. Visual disturbances;
3. Rigidity or numbness of extremities;
4. Changes in speech;
5. Nausea;
6. Paralysis; and/or
7. Personality changes (withdrawal, unresponsiveness).

Basically, the dive circumstances are the first indication of a potential air embolism occurrence. ANYTIME a scuba diver experiences an emergency or uncontrolled ascent, suspect the occurrence of lung injury and, subsequent air embolism. If you are the diving buddy, immediately go to the aid of the distressed diver. After an emergency or uncontrolled scuba diving ascent, even if the diver says he/she is all right, use the following procedure:

1. Discontinue dive; do not let the victim submerge;
2. Inflate or have the victim inflate their buoyancy unit;
3. Observe for/inquire about signs or symptoms of abnormality;

4. Be alert for loss of consciousness/respiratory arrest;
5. Return to boat or shore base; and
6. Continue to observe for signs/symptoms of air embolism for at least one hour.

The immediate and proper management of an air embolism victim can make the difference between permanent brain damage or death and complete recovery. The following procedure is recommended:

1. If the victim is not breathing, begin CPR procedure immediately;
2. If CPR is not necessary, immediately place the victim on a 30° head down incline;
3. Administer oxygen;
4. Keep the victim warm; cut off diving suit if necessary; dry, and wrap victim in blankets;
5. Transport to medical facility or obtain on site medical services;
6. Provide physician with history of the accident or circumstances leading up to the victim's present condition; emphasize that the victim was scuba diving;
7. Provide the physician with the location and telephone numbers of the nearest recompression facilities and physicians knowledgeable in diving medicine; provide the 512/LEO-FAST information;
8. See that transport to the recompression facility is initiated if an air embolism is diagnosed; and
9. Maintain oxygen and inclined position during all transport.

There are exceptions to the use of the 30° incline position. First, if the diver has experienced an obvious head injury, the head down position could cause serious or fatal injury. Second, if the head down position induces vomiting, the victim can be returned to a normal flat position until the vomiting episode has subsided.

All cases of air embolism must be treated using therapeutic recompression in a chamber.

Pneumothorax

When air ruptures through the lung wall, it may enter the space between the chest wall and the lung (the pleural cavity) collapsing the lung and in extreme cases displacing the heart. Air embolism may or may not accompany this condition.

The diver may experience sharp chest pain made worse by deep breathing; sensation of shortness of breath, and rapid, shallow breathing. The skin, lips, and fingernails may have a bluish coloration. However, in mild cases the diver may experience no symptoms or only minor discomfort in one side of the chest.

The first aider can only suspect that there has been pulmonary injury and must assume that an air embolism has also occurred until indicated otherwise by a physician. Consequently, the same management procedures as given for an air embolism must be followed. If there is absolutely no indication of neurological damage, the sharp incline may be reduced.

Mediastinal/Subcutaneous Emphysema

Air can also enter into the area around the heart, greater blood vessel, and trachea (mediastinal emphysema) and migrate into tissues just under the skin, usually in the neck area (subcutaneous emphysema) when lung tissue ruptures. The mediastinal emphysema will be evident by pain under the breast bone (especially when exercising or deep breating and in serious cases); shortness of breath or faintness (due to interference with circulation); and blueness of skin, lips, and fingernails. Subcutaneous emphysema is indicated by swelling (accompanied by a feeling of fullness) in the neck, voice changes, a crackling sensation when the skin of the enlarged area is moved slightly, and difficulty in breathing or swallowing.

As in the management of a pneumothorax the first aider must assume that an air embolism has occurred and follow the same procedures.

Stomach/Intestinal Pains

Sometimes gas forms in the stomach and/or intestines on air swallowed during a dive will cause discomfort as it expands during ascent. This gas may be evacuated by belching or by passing gas from the intestines by flatulating. Evacuation may be aided by changing body positions.

Decompression Sickness

During a dive the inert portion of the breathing air, nitrogen, is absorbed into solution in the blood and body tissues. The amount of nitrogen absorbed depends on a number of factors including dive depth, dive duration, exercise level, water temperature, physical condition, proportion of fat to lean tissue, and sex. During and after ascent the process is reversed and dissolved nitrogen is transported from the tissues via the bloodstream to the lungs where it comes out of solution through the alveoli into the expired air. The body can retain a certain higher than normal amount of nitrogen in solution without complications. Consequently, the diver's blood and tissues safely carry an elevated nitrogen content for up to 12 hours following a "normal or non-saturation" dive exposure. However, if the diver ascends too rapidly causing an unacceptable high pressure gradient between nitrogen in solution and the ambient atmosphere, the nitrogen will come out of solution within tissues and joints in the form of bubbles. These bubbles put pressure on nerves and other structures and may interfere with proper blood circulation. This results in pain symptoms and/or central nervous system involvement including paralysis. The type and extent of symptoms will depend upon where the bubble forms. This is decompression sickness or the "bends."

Divers must observe proper decompression tables and procedures as explained in the section on Air Decompression to prevent this injury. Susceptibility to decompression sickness will vary with individuals and diving conditions. Susceptibility is enhanced by obesity, fatigue, alcohol consumption prior to diving, illness, cold, age, and so on. Some authorities suggest that women are more susceptible than men.

Symptoms of decompression sickness include:

1. Pain in joints;
2. Tingling, burning, itching, numb or blotched skin;
3. Dizziness;
4. Ringing ears;
5. Blindness;
6. Paralysis;
7. Loss of feeling;
8. Breathing difficulties;
9. Unusual fatigue;
10. Unconsciousness.

If a diver experiences any of the above symptoms following a dive, the diver, dive buddy and/or Diving Supervisor should immediately evaluate the diving schedule for the day and answer the following questions:

1. Was the dive(s) timed accurately?
2. Were depth measurements accurate?

3. Did the diver remain within the "no-decompression" limits?
4. Were repetitive dive schedules calculated accurately?
5. Were reasonable margins of safety included in the dive profiles?
6. Did the diver avoid decompression dives?
7. Did a physical injury sustained during the dive cause the diver's symptoms?
8. Was the dive properly planned and executed in accordance with the tables?
9. Were the tables read accurately?
10. Was the proper ascent rate used?
11. Was exercise level, prior susceptibility, cold, age, sex, fitness, and so on taken into account?
12. Did the diver avoid heavy exertion following a dive close to the no-decompression limit?

If a diver has apparent symptoms of decompression sickness and the answer is "no" or "unsure" to one or more of the above questions, then decompression sickness can be suspected. Symptoms generally appear within 2 to 3 hours following the dive. However, symptoms delayed up to 24 hours are possible.

If decompression sickness is suspected, immediate arrangements must be made for medical attention and therapeutic recompression. The management procedure should include the following:

1. Take measures to prevent shock;
2. Start the victim on oxygen breathing;
3. Maintain a qualified diver/first aider with the victim at all times, respiratory or cardiac arrest is possible;
4. Be alert for intensifying pain, onset of extremity weakness or paralysis, etc.;
5. Provide physical and psychological comfort for the victim;
6. Do not administer drugs or pain killers;
7. Transport to an emergency medical facility or obtain on site services of a physician;
8. Provide the examining/attending physician(s) with a complete history of the dive(s) and subsequent onset of symptoms;

9. Provide the physician with the location and telephone numbers of the nearest recompression facilities and physicians knowledgeable in diving medicine; provide 512/LEO-FAST information;

10. If necessary, assist in arranging transportation to the recompression facility; and

11. Maintain oxygen breathing during transport.

BREATHING GAS RELATED PROBLEMS

Carbon Monoxide Poisoning

Carbon monoxide more readily combines with the hemoglobin in the blood than does oxygen. Since hemoglobin is the principal component of the blood that carries oxygen, the stronger carbon monoxide-hemoglobin bond greatly reduces the oxygen transport capacity of the blood. Tissue hypoxia results even though sufficient oxygen is available in the breathing medium. Consequently, carbon monoxide is probably the most life-threatening of all possibe diver's air contaminants.

Carbon monoxide is the byproduct of petroleum compound combustion. Exhaust fumes from the exhaust of a gasoline engine contain extremely large amounts of carbon monoxide. If a gasoline engine driven compressor is operated in a closed space or with the air intake close to the exhaust, dangerous amounts of carbon monoxide will be pumped into the scuba cylinder. Any oil lubricated compressor, whether electric or gasoline powered, can produce carbon monoxide internally through burning or flashing of the lubricating oil in the compression chambers. The ambient air where a compressor is operated must also be free of carbon monoxide contamination.

The diver must be provided with an uncontaminated air supply. Periodic testing and/or air purification is necessary to insure a proper air supply.

Victims of carbon monoxide poisoning will frequently lose consciousness without warning. However, they may experience tightness across the forehead, pounding in the temple area, headache, nausea, vomiting, weakness, dizziness, confusion, mental changes, or unconsciousness. Apparently these symptoms can appear in any combination. In severe cases, breathing will cease and the skin, lips, and fingernails will sometimes exhibit an abnormal red coloration.

If carbon monoxide poisoning is suspected, the victim should be immediately exposed to fresh air and placed on oxygen breathing. Continuously monitor the victim since respiratory arrest can occur even after the removal of the contaminated air source. Even if the victim regains consciousness or condition improves (if not previously unconscious), they must be examined by a physician. Many hours, generally under medical treatment, will be required to eliminate carbon monoxide from the blood. Therapeutic oxygen recompression is highly beneficial.

Carbon Dioxide Excess

Sufficient quantities of carbon dioxide will cause symptoms ranging from an increase in respiration and heart rate to unconsciousness. For the scuba diver, unconsciousness in the water can quickly lead to death by drowning. However, the potential of carbon dioxide build-up in open-circuit scuba diving is somewhat limited when compared to the use of recirculating scuba and some surface-supplied equipment. Contamination of the air supply with sufficiently high concentrations of carbon dioxide to induce symptoms is extremely rare. The diver is more likely to retain carbon dioxide produced in the body because of inadequate ventilation of the lungs. Some divers attempt to conserve air while diving by using a short period of breathholding in each breathing cycle. This leads to inadequate ventilation of the lungs and the retention of abnormal amounts of carbon dioxide by the body. Overexertion can lead to an abnormal breathing pattern where shallow, rapid breaths also fail to adequately ventilate the lungs and elevated carbon dioxide levels are retained by the body.

The diver may or may not notice signs of carbon dioxide build-up. Generally, there is an increase in breathing rate. As the concentration increases the diver may experience shortness of breath, panting, headache, dizziness, mental confusion, slowing of responses, weakness, nausea, and/or drowsiness. As symptoms progress the skin, lips, and nails will appear blue. Unconsciousness soon follows. The diving buddy should be alert for signs of excessive fatigue and abnormal breathing patterns. Once a fatigued diver begins the shallow, rapid breathing pattern, the buddy must take immediate action to make the diver relax (stop, rest, and breathe deeply), surface, and provide flotation (inflate buoyancy system). The affected diver can quickly pass into unconsciousness and drown if left unattended. Once the diver rests and breathes fresh air, normal breathing should return. A period of oxygen breathing may be beneficial. If respiratory arrest occurs, take appropriate steps to administer artificial respiration. An unconscious, breathing victim should be immediately placed on oxygen breathing. If the victim has lost consciousness, requires resuscitaiton, or feels ill after an apparent carbon dioxide episode, he/she must be examined by a physician.

The term shallow-water blackout is sometimes applied to a carbon dioxide related episode where the diver suddenly loses consciousness without warning. Hypoxia or insufficient oxygen to maintain normal body function also results in shallow-water blackout.

In contrast to carbon dioxide excess, a diver may also lose consciousness because of abnormally low levels of carbon dioxide in the body. Hyperventilation or deep, rapid breathing may be initiated by anxiety and/or physical stress. This "overventilation" breathing pattern can lead to excessive depletion of carbon dioxide with a subsequent acid-base imbalance in the blood and body. The diver may experience a light headed sensation, dizziness, or minor muscle spasms and pass quickly into unconsciousness. The diving buddy must be alert for this abnormal breathing pattern development, especially in novice divers, stressful diving situations, and during periods of heavy underwater work. The affected diver must stop work, relax, regain normal breathing, and, in some cases be taken to the surface for a period of rest. If unconsciousness occurs, follow appropriate procedures and provide surface flotation. Any diver that loses consciousness during or following a dive must be seen by a physician.

Lipoid Pneumonia

Oil vapor, from oil-lubricated compressors, is a serious air supply contaminant. Oil gives an unpleasant taste and odor, and in sufficient concentrations will cause serious pulmonary irritation, coughing, and pneumonia. The presence of oil is detectable by odor and taste. Do not use an oil contaminated air supply. Lipoid pneumonia requires medical attention.

Hypoxia

Hypoxia occurs whenever tissue cells fail to receive or utilize sufficient oxygen to maintain normal function. Brain tissue is particularly susceptible to hypoxia. Hypoxia is not commonly associated with open-circuit scuba diving. It is more commonly considered a problem in the use of recirculating scuba.

Unconsciousness in breathhold or skin diving is generally the result of hypoxia. An experienced, conditioned skin diver may remain submerged long enough to reduce the blood oxygen to an hypoxic level. The possibility of skin diver hypoxia is greatly enhanced when the diver hyperventilates before submergence. Through hyperventilation the respiratory stimulating carbon dioxide content in the blood is reduced to an abnormally low level. Hypoxia may render the submerged diver unconscious before the blood carbon dioxide increases to a sufficient level to stimulate the need for breathing. Consequently, the skin diver must avoid extensive hyperventilation and observe self-imposed time limits on submergence.

At least one open-circuit scuba diving fatality has been attributed to hypoxia. In this case the air contained in the scuba cylinder contained only about two percent oxygen. Apparently, moisture had entered the cylinder during or prior to charging. During storage, oxidation of the steel (rusting) consumed most of the oxygen in the air. Consequently, the diver breathed a medium of 98% nitrogen/2% oxygen. The importance of periodic internal inspection of cylinders, proper storage, and adequate measures to prevent introduction of moisture into scuba cylinders cannot be over-emphasized.

Unfortunately, the usual effects of hypoxia are quite pleasant, and by the time they are noticed, the will to take action is usually gone. Symptoms of hypoxia include a general feeling of well-being or giddiness, decreased ability to concentrate, impairment of muscular control, increase in pulse and respiration rates, and fainting. A hypoxic individual will often have blue lips and/or fingernails. Trembling and muscle tremors are noted in advanced cases.

If a diver appears hypoxic, have him/her immediately breathe fresh air. Oxygen breathing will speed recovery. If breathing has ceased, start appropriate artificial respiration procedures and seek medical attention.

Near-Drowning

Nearly any situation or condition that leads to unconsciousness, inability to retain an air supply/stay afloat, or impairment of normal function in or underwater can end in near-drowning. The management of near-drowning is covered under artificial respiration and cardio-pulmonary resuscitation. Emphasis is placed on immediate action with in-water resuscitation techniques being a mandatory part of scuba diver training. Resuscitation procedures must be started as soon as possible regardless of apparent non-breathing/submersion time. Successful resuscitation has been accomplished even after 30 minutes of submersion, especially in cold water near-drownings.

Nitrogen Narcosis

Exposure to an excessive partial pressure of nitrogen, breathing air in excess of 100 fsw (30 msw), produces an anesthetic or intoxication effect on the central nervous system. The degree of nitrogen narcosis response will vary with individuals and from day to day for the same individual. Some persons exhibit noticeable effects of nitrogen narcosis at 130 fsw (39 msw). Below 130 fsw (39 msw) the intoxication effect increases rapidly with depth and nearly everyone experiences severe narcosis beyond 200 fsw (60 msw).

The U.S. Navy and the Occupational Safety and Health Administration have established 130 fsw (39 msw) as the maximum safe diving depth for use of compressed air scuba. In some incidences provisions are made for specially trained and experienced scuba divers to exceed this depth. However, diving time is limited and there is increased risk. Divers can prevent nitrogen narcosis by limiting their dives to the recommended 130 fsw (39 msw) depth.

The effects of nitrogen narcosis are similar to those of alcohol intoxication. The diver will generally experience a slowing of mental activity, fixation of ideas; difficulty in concentration and reasoning; memory impairment; a feeling of well-being; lack of concern for personal safety; and difficulty in accomplishing simple tasks. Some divers experience severe depression. As the diver proceeds deeper than 200 fsw (60 msw) and the effects intensify, he/she may lose awareness of the surrounding and the situation and enter a state near of near unconsciousness. Deep divers must be aware of symptoms of nitrogen narcosis in both themselves and their buddy. The effects subside with ascent.

Oxygen Toxicity

Breathing 100% oxygen at a depth of 33 fsw (10 msw) or greater can have a significant toxic effect on some individuals. Although oxygen is used in surface decompression and therapeutic recompression at depth equivalents up to 60 fsw (18 msw), the conditions are controlled in a dry chamber. An oxygen sensitive individual may experience adverse effects at shallow depths. Underwater, especially with scuba, an oxygen toxicity seizure can most certainly lead to drowning. Consequently, open-circuit scuba must not be charged with oxygen as a substitute for compressed air. Some advanced divers who use oxygen charged scuba for decompression stop breathing. Although this practice has physiological benefits from the standpoint of decompression, it carries a significant risk for oxygen sensitive individuals. Consequently, this procedure is not commonly practiced or accepted in the scuba diving community.

Warning symptoms of oxygen toxicity include muscular twitching (often in face/lips), nausea, dizziness, disturbed hearing or vision (tunnel vision is common), a feeling of increased breathing resistance, anxiety, mental confusion, fatigue and clumsiness. If these warning symptoms are not heeded, convulsions and loss of consciousness may quickly follow. Convulsions and/or loss of consciousness may also occur immediately with little or no warning.

As soon as oxygen toxicity symptoms appear, place the diver on air and protect from injury in the event of convulsions. Symptoms will soon subside with fresh air, rest, and hyperventilation.

APPENDIX A

DIVER MEDICAL EXAMINATION FORM

THE UNIVERSITY OF MICHIGAN
DEPARTMENT OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
OFFICE OF THE DIVING SAFETY COORDINATOR

DIVER MEDICAL EXAMINATION FORM*

Name ______________________ Date of Birth __________ Sex ___ Date _______

Address ____________________________________ Telephone ____________

Social Security or Student No. ______________________________________

☐ Initial Examination ☐ Annual Re-examination ☐ Diver Training
☐ University Employee (Faculty/Staff, Non-Student) ☐ University Employee (Student)
☐ Undergraduate Student ☐ Graduate Student ☐ University Diving Authorization
☐ Work/Research Diving ☐ Recreational Diving
☐ Shallow Water Diving (0-60 fsw) ☐ Deep Water Diving (60-130 fsw)
☐ Hyperbaric Chamber ☐ Saturation Diving ☐ Special Authorization ________

Examination Requested by: ____

MEDICAL HISTORY
(To be completed by applicant)

1. Have you had previous experience in diving? Yes ___ No ___
2. When driving through mountains or flying, do you have trouble equaliing pressure in your ears or sinuses? Yes ___ No ___
3. Have you ever been rejected for service, employement, or insurance for medical reasons? Yes ___ No ___
4. When was your last physical examination? Date __________ Results ________________
5. When was your last chest x-ray? Date ______ Results __________
6. Have you ever had an electroencephalogram (brain wave study)? Yes __ No __ Date _____ Results ________________
7. Have you ever had an electrocardiogram? Yes ___ No ___
8. Do you smoke? Yes ___ No ___ If so, how much? ___________

(Check the blank if you have, or ever have had, any of the following, Explain under "REMARKS" giving dates and other pertinent information, or discuss with the 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.___ Hardness of hearing.
14.___ Asthma or bronchitis.
15.___ Shortness of breath after moderate exercise.
16.___ History of pleurisy.
17.___ Collapsed lung (pneumothorax).
18.___ Chest pain or persistant cough.
19.___ Tiring 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.

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* Modified from Safety Regulations for Scuba Diving, Department of Labor and Industries, State of Wahington and in compliance with Part 1910 of Title 19 of the Code of Federal Regulations, Subpart T.

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.___ Fear of closed-in spaces, large open places, or high places.
36.___ Any neurological or psychological condition.
37.___ Train, sea, or air sickness or 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.___ Rheumatic fever.
43.___ Diabetes.
44.___ Any serious accident, injury, or illness not mentioned above (describe under "REMARKS", give dates).
45.___ Dental bridgework or plates.
46.___ Susceptibility to panic.
47.___ Pain from altitude or flying.
48. What sports or exercise do you regularly engage in? ____________

____

REMARKS: ____

____

____

____

DIVING HISTORY

Years of diving experience ___________ Number of dives in past 12 months _______
Nature of employment related diving: ____________________________

____

I certify that I have not withheld any information and that the above is accurate to the best of my knowledge.

Date: ______________ Signature: ______________________________

I hereby authorize the University of Michigan Health Service to release information on my health status for diving to the Department of Physical Education, Department of Occupational Safety and Environmental Health, The Diving Safety Coodinator, my department/division of employment or other authorized units.

Date: ______________ Signature: ______________________________

Name ______________________

S/No. ______________________

MEDICAL EXAMINATION

(This form and the medical history form are retained by the physician for his records.)

A. NURSING STATION DATA:

Height _____(in.)

Weight ______(pds.)

Blood Pressure _________

Pulse _________

Vision (IF INDICATED):	Right eye	Left eye
Uncorrected		
Corrected		
Color Blindness		

B. MEDICAL HISTORY: Is there a significant past history which would disqualify the applicant from scuba diving? (See medical history form.)

Yes ___ No ___

Remarks: ____

____

C. EXAMINATION: (Check following items. If abnormal, give details below.)

		Normal	Abnormal
1.	General appearance (including obesity, gross defects, postural abnormalities)		
2.	Head and neck		
3.	Eyes		
4.	Nose and sinuses		
5.	Ears (including otitis, perforation)		
6.	Mouth and throat		
7.	Spine		
8.	Lungs and chest		
9.	Heart		
10.	Abdomen		
11.	Inguinal rings (males)		
12.	Genitalis (males)		
13.	Anus and rectum (if indicated)		
14.	Extremities		
15.	Skin reactions or eruptions		
16.	Neurologic		
17.	Psychiatric (including apparent motivation for diving, emotional stability, claustrophobia		

Explanation of abnormals: ________________________________

____

____

D. TEST RESULTS: All applicants :

Chest x-ray(s) _______

As indicated:

EKG ____________

V.C. and FEV ____

Audiogram ______

Sickle Cell Index ____

Hematocrit _____

Urinalysis _____

White Blood Count ____

Other ____________

E. FINAL IMPRESSION (Check one):

___Qualified (I find no defects that I consider imcompatible with diving using underwater breathing apparatus or pressurization in a hyperbaric chamber.)

___Disqualified (The Examinee has defects that I believe constitute unacceptable risk to his/her health and safety in diving using underwater breathing apparatus or pressurization in a hyperbaric chamber.)

Date: ___________ Signature: ______________________________M.D.

(Additional physician's notes on back.)

THE UNIVERSITY OF MICHIGAN
DEPARTMENT OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
OFFICE OF THE DIVING SAFETY COORDINATOR

DIVER MEDICAL EXAMINATION REPORT

Name____________________________Date of Birth____________ Sex______

Social Security
or Student No. ______________________ Date_________________________

I have examined the applicant and reached the following conclusion concerning his/her fitness for diving:

_________Qualified (I find no defects that I consider incompatible with diving using underwater breathing apparatus or pressurization in a hyperbaric chamber.)

_______ Disqualified (Examinee has defects that I believe constitute unacceptable risk to his/her health and safety in diving using underwater breathing apparatus or pressurization in a hyperbaric chamber.)

The following information should be made known to any physician who treats this person for a diving accident (include medications, drug allergies, etc.):

____

____

____

____

Date_________________ Signature______________________________MD

Address ____

____

Copy to: Department/Division or Course Instructor
Diving Safety Coordinator
Department of Occupational Safety and Environmental Health
Employee/Student

APPENDIX B

GUIDELINES FOR TRAINING AND CLASSIFICATION OF SCIENTIFIC/ACADEMIC SCUBA DIVING PERSONNEL

General

The University Diving Safety Coordinator and/or the Diving Supervisor shall determine the qualification status of all divers engaged in University sponsored or affiliated diving operations. Each dive team member shall have the training and/or experience necessary to perform tasks assigned in a safe and proper manner. This training and/or experience shall include:

1. Scuba diving operations and emergency procedures;
2. Scuba diving techniques;
3. The use of equipment, systems, and tools relevant to the assigned task;
4. Diving related physics and physiology;
5. Knowledge of environmental factors and marine life relevant to dive planning, operations and personnel safety;
6. Field assembly, inspection, disassembly, and maintenance of scuba and associated diving equipment;
7. Use of U.S. Navy Standard Air Decompression and Repetitive Dive Tables;
8. Training in diving related lifesaving, first aid, and cardio-pulmonary resuscitation; and
9. University safe diving practices and standards.

Scuba Diver Training

All new University scuba divers shall undergo training in courses approved by the Diving Safety Coordinator/Diving Safety Committee. Persons holding certificates of training from unapproved courses and/or who are already accomplished divers prior to affiliation with the University shall be evaluated/reviewed on an individual basis by the Diving Safety Coordinator and/or the Diving Safety Committee. These individuals shall complete the following in order to obtain University Diving Authorization at the discretion of the Diving Safety Coordinator:

1. Submit the following documents:
    a) Certificate of medical examination
    b) Certificate of diver training
    c) Waiver, Release, and Indemnity Agreement
    d) Proof of age (valid driver's license, passport, or birth certificate)
2. A written or oral examination on scuba diving theory, procedures and safety.
3. A watermanship and scuba diving skills test.
4. One or more open water evaluation dives.

Upon completion of evaluation and review of the individual's diving experience and prior training, the Diving Safety Coordinator/Diving Safety Committee shall determine appropriate diving authorization status.

Scientific/academic scuba divers are frequently trained in recreational scuba diving courses. The scope of such courses is often limited in the areas of physical fitness/watermanship requirements, dive operation planning and coordination, accident management, lifesaving techniques, decompression tables, and so on. Also, the recreational diver may acquire biased attitudes towards equipment, diving procedures, etc. which are inconsistent with those of organized scientific/academic scuba diving. The Diving Safety Coordinator and, later in the field, the Diving Supervisor must continue to assess the recreational trained diver for such inconsistancies.

All scuba diver training applicants must perform the following swimming test without the use of fins or other aids or their equipment, in the presence of an examiner or instructor approved by the Diving Safety Coordinator:

1. Swim 400 yards (360 meters) in less than 10 minutes;
2. Demonstrate proficiency in at least two basic swimming strokes (backstroke, sidestroke, crawl, etc.);
3. Swim underwater for a distance of 25 yards (22.5 meters) without surfacing;
4. Swim underwater for a distance of 40 yards (36 meters), surfacing not more than four times;
5. Remain afloat for 15 minutes using floating, drown-proofing, or treading techniques; and
6. Surface dive to a depth of 10 fsw (3 msw), recover an inert swimmer, and tow the swimmer 25 yards (22.5 meters) on the surface.

The applicant must complete the above test without exhibiting signs of unusual fatigue or physical stress. Rest periods are allowed between tests; however, all six tests should be completed within a 90 minute period.

Confined Water Training

At the completion of pool (confined water) training, the trainee must demonstrate the ability to perform the following minimum skill requirements:

1. Demonstrate the ability to swim 400 yards (360 meters) using mask, fins, and snorkel and skin dive to a depth of at least 10 fsw (9 msw);
2. Rescue a submerged skin diver from a depth of 10 fsw (9 msw), administer (simulate) mouth-to-mouth resuscitation in deep water, and tow 50 yards (45 meters) while continuing resuscitation;
3. Demonstrate proper techniques for approaching, rescuing, using buoyancy equipment, and towing a distressed skin and scuba diver on the surface;
4. Demonstrate proper techniques for blocking and breaking holds in skin and scuba diving rescue situations;
5. Demonstrate independent operational assembly, donning, adjusting, checking, use, operational disassembly and maintenance of all equipment used for open water scuba diving;
6. Swim 200 yards (180 meters) at the surface in less than six minutes with scuba in position while breathing through a snorkel and without using hands and arms;
7. Demonstrate ability to alternate between snorkel and scuba while swimming in deep water;
8. Demonstrate ability to share air with a buddy diver;
9. Clear water from face mask not equipped with a purge valve;
10. Demonstrate the removal and replacement of scuba and mask at a depth of 10 to 15 fsw (3 to 4.5 msw);
11. Demonstrate safe entering and exiting of the water independently using a variety of techniques appropriate to typical diving situations, including boat diving;
12. Demonstrate understanding of diver hand signals;
13. Rescue and tow a simulated scuba diving accident victim while giving (or simulating) mouth-to-mouth resuscitation;

14. Demonstrate ability to make a controlled emergency swimming ascent; and

15. Swim underwater without a mask.

Open Water Training

The trainee must satisfy an instructor, designated or approved by the Diving Safety Coordinator, that his/her judgment is adequate for safe diving and demonstrate the ability to perform the following in the ocean or other open water:

1. Demonstrate proper entry and exit techniques appropriate to the training site platform;

2. Swim 400 yards (360 meters) on the surface using mask, fins and snorkel;

3. Surface dive to a depth of about 15 fsw (4.5 msw) without scuba;

4. Snorkel 400 yards (360 meters) with breathing apparatus in position;

5. Share air with another scuba diver at a depth greater than 15 fsw (4.5 msw);

6. Demonstrate ability to perform a simulated controlled emergency swimming ascent from a depth of 15 to 20 fsw (4.5 to 6 msw);

7. Share air with another scuba diver while ascending;

8. Navigate underwater using a compass;

9. Complete a minimum of 3 ocean or other open water scuba dives for a minimum total time of one hour at a depth not to exceed 30 fsw (9 msw) accompanied by an approved diving instructor; and

10. Compute air consumption rate for each training dive and describe to instructor how to detect low air pressure in cylinder.

Diving Theory Examination

Scuba diving trainees must pass a written examination that demonstrates knowledge of the following:

1. Diving medical qualifications;

2. Physics and physiology of diving;

3. Recognition of and first aid for common diving injuries and diseases;

4. Dive planning and procedures;
5. Marine environment operational conditions including hazardous marine organisms;
6. Underwater communication;
7. Use of U.S. Navy Air Decompression and Repetitive Dive Tables;
8. Scuba diving equipment function and maintenance;
9. Emergency procedures; and
10. University scuba diving regulations.

University Diving Certification/Authorization

Applicants for University scuba diving certification/authorization must comply with the following:

1. Eighteen (18) years of age or older;
2. Submit an "Application for Diver Certification" form;
3. Submit a statement signed by a licensed physician, based on an appropriate medical evaluation, attesting to the applicant's physical fitness for diving (Appendix A);
4. Execute a release holding the University harmless from any claims which might arise in connection with diving or hyperbaric chamber activity;
5. Submit a certificate of training from an approved scuba diving course;
6. Demonstrate familiarity with cardiopulmonary resuscitation and first aid;
7. Submit a record of 12 open water dives for a minimum total time of 4 hours at depth not exceeding 30 fsw (9 msw) supervised by an instructor or University certified diver. No more than four dives shall be made in any one day;
8. Satisfy the examiner, authorized by the Diving Safety Coordinator/Diving Safety Committee, that he/she is sufficiently skilled and proficient to receive a University diver certification/authorization;

9. All required documents shall be submitted to the Diving Coordinator and/or authorized examiner.

The Diving Safety Coordinator may issue a Diver-in-Training authorization to persons completing requirements 1 through 4. However, the trainee may not advance to open water training (requirement 7), except for specific open water training dives included in the basic scuba diving course, until requirement 5 has been satisfied.

University diver certificate/authorization shall be valid for open-circuit scuba only unless specifically endorsed for other apparatus. Certificates/authorizations issued by the University shall authorize the holder for diving under normal lake conditions. To extend the certification/authorization to include ocean surf and currents, kelp, river, ice, cave and other specific geographical environmental conditions, additional training shall be required. Any applicant who does not appear to possess the judgment necessary for personal safety or the well-being of other divers under actual diving conditions shall be denied certification/authorization.

Persons completing the above requirements are authorized to dive to a depth of 30 fsw (9 msw) under environmental conditions common to the geographic location of basic open water training. Qualification advancement is based on specific environmental training and/or supervised experience; progressive diving depth advancement; and recommendations of the instructor or supervising diver. An explanation of the depth qualification advancement system is given below:

1. A diver holding a 30 fsw (9 msw) certification may be certified to a depth of 60 fsw (18 msw) upon successful completion of 12 training dives between depths of 31 to 60 fsw (9.3 to 18 msw) with a cumulative minimum underwater time of four hours. On training dives the diver shall be accompanied by a diver certified for depths of 60 fsw (18 msw) or greater and conducted under normal working and/or diving conditions.

2. A diver holding a 60 fsw (18 msw) certification may be certified for depths to 100 fsw (30 msw) upon successful completion of 12 training dives between depth of 61 fsw and 100 fsw (18.3 to 30 msw) with a minimum cumulative time of two hours. On training dives the diver shall be accompanied by a diver certified for depths of 100 fsw (30 msw) or greater and conducted under normal working and/or diving conditions. The trainee must demonstrate proficiency in the use of U.S. Navy Standard Air Decompression and Repetitive Dive Tables.

3. A diver holding a 100 fsw (30 msw) certification may be certified for depths to 130 fsw (39 msw) upon successful completion of 12 training dives between

depths of 101 and 130 fsw (30.3 and 39 msw) with a minimum cumulative underwater time of two hours. On training dives the diver shall be accompanied by a diver certified for depths of 130 fsw (39 msw) or greater and conducted under normal working and/or diving conditions.

4. Training and certification for diving in excess of 130 fsw (39 msw) requires specific authorization from the Diving Safety Committee and is only granted to those qualified individuals who demonstrate a specific need to dive beyond this depth. A diver may be certified to depths of 160 and 190 fsw (48 and 57 msw) after the completion of four training dives near each depth. Training dives shall be planned and executed under the supervision of a diver certified to the respective depth. The trainee must demonstrate a knowledge of the special problems and safety requirements associated with deep diving.

All training dives shall be validated in the diver's logbook by the diving supervisor, a University approved instructor, or the signatures of two accompanying University certified divers.

Authorization for diving under ice, in caverns, at night, and in ocean currents, surf, or kelp and other specialty situations may be issued to qualified divers upon completion of four or more supervised training dives for each specific environmental condition. Additional training requirements may be specified at the discretion of the Diving Safety Committee and/or authorized instructor. Environmental training dives must be conducted under the supervision of an authorized diver or instructor certified for the given conditions.

University certified diving personnel may be authorized for use of closed or semi-closed circuit scuba, surface-supplied equipment, special breathing gas mixtures, underwater tools, diving bells, special protective suits, and other specialty diving apparatus by the Diving Safety Committee in accordance with requirements specified by the Committee. Special practices manuals and training programs for use of specialty diving apparatus shall be approved/authorized by the Diving Safety Committee. Endorsements for the use of specialty diving equipment shall be entered on the Diving Authorization and in the diver's file upon verification of successful completion of training.

Annual Requalification

All University diving certifications/authorizations shall expire one year from the date of the last medical examination or six months from the date of the last logged dive, unless specific extensions are granted by the Diving Safety Committee.

During any 12 month period each certified diver shall log at least 12 dives; at least one dive to the depth of certification shall be logged every 6 months. Failure to log the required dives shall result in revocation or restriction of certification. Divers certified to 160 fsw (48 msw) or more may satisfy the depth of certification requirements with dives to a depth of 130 fsw (39 msw) or greater. Chamber dives may be substituted for open water dives at the discretion of the Diving Safety Coordinator.

A diver who fails to satisfy the requirements specified for annual requalification may be reinstated to his prior certification rating upon completion, at the discretion of the Diving Safety Coordinator, of two or more supervised training dives providing that the certification has not elapsed for more than 12 months. The following criteria may be used:

1. For certification ratings of 60 fsw (18 msw) or less, one dive to 30 fsw (18 msw) and one dive to a depth of certification shall be required.
2. For certification ratings of 100 fsw (30 msw) or greater, one dive to 30 fsw (9 msw), one dive to 60 fsw (18 msw), and one dive to 100 fsw (30 msw) in sequence shall be required.
3. When diver certifications have lapsed for more than 12 months, the Diving Safety Coordinator shall evaluate each case individually and recommend appropriate action to the Diving Safety Committee.

All divers and support personnel shall participate in periodic retraining courses or workshops in accordance with requirements specified by the Diving Safety Committee/ Diving Safety Coordinator.

Temporary Scuba Diving Authorization for Non-University Personnel

A Temporary Diving Certificate/Authorization may be issued by the Diving Safety Coordinator to authorized visitors who have demonstrated the required proficiency in diving. At the discretion of the Diving Safety Coordinator, all documents required for certification may be waived with the exception of a Release, Waiver and Indemnity Agreement and/or acknowledgement of risk. The Temporary Diving Certificate/Authorization shall be valid only for the period, depth, geographic location, and diving apparatus specified. Persons holding Temporary Diving Certificates/Authorizations shall comply with University policy and standards on diving.

APPENDIX C

GUIDELINES FOR SCUBA DIVING EQUIPMENT SELECTION AND USE (SELECTED ITEMS)

EMERGENCY FLOTATION EQUIPMENT

An emergency gas inflatable flotation device or buoyancy compensator is required for all routine scuba dives. Emergency flotation units should meet the following requirements:

1. Be airtight and capable of holding a pressure of 2 psig (.9 kg) when the relief valve is blocked.
2. Provide a minimum buoyancy of 25 lbs (11.4 kg) when fully inflated at the surface.
3. Be equipped with a device for manual inflation from a compressed gas supply and an oral inflation-deflation tube.
4. Be equipped with an emergency inflation device independent of the scuba (generally a CO_2 system).
5. Buoyancy compensators, used for underwater buoyancy adjustment and/or emergency surface flotation shall be equipped with an over-pressure valve capable of relieving a fully inflated unit when released by itself from 33 fsw (9.9 msw) without sustaining structural damage to the unit.
6. Be equipped with appropriate manual valve/gas release mechanism which will enable a diver to manually deflate a fully inflated unit in the time that it would take for the vest to lift a properly weighted diver from 33 fsw to 15 fsw (10 msw to 4.5 msw).
7. Have a means by which it is securely attached to the diver and must be capable of supporting the buoyancy load of a fully inflated suit.
8. Contain no holes, cracks, deterioration, abrasions, or cuts that affect the structural integrity of the unit.
9. Be maintained in accordance with recognized and accepted procedures in accordance with manufacturer and/or University recommendations.
10. Be inspected and determined fully operational prior to each dive.
11. A record of inspection and tests should be maintained by the diver and made available upon request or review or audit by the Diving Coordinator.

12. Be inflated by manual activation of the inflation system at least once every 6 months or 30 dives, whichever comes first, and must hold full inflation for 2 hours.

13. A proper length vest type unit will not cover the scuba waist belt release or the weight belt release.

14. Be so designed that it will turn an unconscious diver into a face-up position and support the head out of the water.

DEPTH GAUGES

All depth gauges used for scuba shall be selected so that the maximum scale depth is at least 30 fsw in excess of the intended use depth. The depth indicator should comply with the following requirements:

1. Each depth gauge shall be calibrated/tested against a master test gauge of ± .25% accuracy when new, every six months thereafter, and when there is a discrepancy greater than 2% of full scale between any two equivalent gauges.

2. All new depth gauges should have a minimum accuracy of ± 1 percent (of full scale) at a depth of 20 fsw (6 msw) and + 3 percent at 150 fsw (45 msw) or maximum depth of less than 150 fsw (45 msw).

3. Gauges exceeding an error of ± 2% at 20 fsw (6 msw) and ± 5% at 150 fsw (45 msw) should be discarded.

4. A calibration tag indicating gauge variations at selected depths should be secured to the gauge or carried on the divers submersible tables in the buoyancy vest pocket or other accessible location.

5. A record of bi-annual tests should be maintained by the diver and made available upon request for review or audit by the Diving Coordinator.

SCUBA

All scuba should comply with the following requirements:

1. All demand regulator components should be of sufficient design and construction to operate at the maximum pressure of the cylinder unit on which the regulator is used.

2. All scuba regulators should be inspected and designated satisfactory annually by an approved/qualified person, or more frequently if the regulator is used for deep or unusual diving operations or exhibits signs of malfunction.

3. All scuba should be equipped with a submersible pressure readout gauge. The submersible pressure gauge should comply with the following requirements:

    a. Be within ± 5% of full scale accuracy over the entire gauge pressure range;

    b. Be equipped with a means of relieving internal case over-pressure without explosively ejecting the gauge lens or bursting the case; and

    c. The pressure hose should not show signs of cuts or abrasions extending to the hose reinforcing braid and not leak air through the braid fiber.

4. All scuba should include a low-pressure warning device or reserve breathing gas supply consisting of:

    a. A manually activated reserve;

    b. A submersible pressure gauge;

    c. An independent reserve cylinder with separate regulator or connected to the breathing apparatus; or

    d. An audible low-pressure warning mechanism; and

    e. If the scuba is equipped with an internal low-pressure warning mechanism, the mechanism should activate at a cylinder pressure of not less than 250 psig.

5. High-pressure cylinders used for scuba should comply with the following:

    a. Cylinders should be designed, constructed, maintained, and stamped in accordance with the requirements of the U.S. Department of Transportation for transportable high-pressure cylinders (applicable provisions of 29 CFR, Sections 1910.166-171).

    b. Scuba cylinders should have safety relief devices in accordance with applicable Department of Labor and/or Department of Transportation specified safety codes.

    c. Scuba cylinders should be inspected internally and externally for rust, corrosion, and damage annually in accordance with C.G.A. Pamphlet C-6, and hydrostatically tested in accordance with DOT specifications every five years or more frequently if rust or corrosion are evident.

   d. Scuba cylinders should be inspected/tested by an approved/qualified person.

   e. Scuba cylinders should be stored in a ventilated area and protected from excessive heat.

6. All scuba used for dives in excess of 60 fsw, in enclosed or physically confining spaces, or around nets should be equipped with an auxiliary breathing unit.

7. All scuba harnesses and weight belts should be equipped with a quick release device which allows the scuba or weights to be rapidly jettisoned with either hand in an emergency, unless otherwise specified.

SCUBA AIR COMPRESSOR/STORAGE BANK

Air compressors and supply systems for charging scuba cylinders should:

1. Be operated and maintained in accordance with the manufacturer's instructions and specifications unless such instructions or specifications should result in infraction of the purity standards for breathable compressed air.

2. Have an operation and maintenance record maintained for all compressors and should include operating time, repairs, type and number of filters used, oil consumption and changes, filter replacements, air analysis and other pertinent details.

3. Have all pressure fittings, hoses, plumbing, and pressure system components complying with a maximum burst pressure rating specified as 4 times the maximum intended working pressure.

4. Have the air intake to the compressor located so as to prevent contamination of the air by noxious gases or materials.

5. Have filters and separators incorporated into the diver air supply system to remove moisture, oil-mist, particulates, and noxious odors.

6. Should supply respired air to a diver, not containing:

   a. A level of carbon monoxide (CO) in excess of 20 ppm;

   b. A level of carbon dioxide (CO_2) in excess of 1000 ppm;

c. A level of oil mist in excess of 5 milligrams per cubic meter;

d. Detectable gross moisture, dust, or particulates; or

e. A noxious or pronounced odor.

7. Have the output of air compressor systems tested for carbon monoxide, odor, and oil droplets every six months or 25 hours of operation, whichever comes first, by means of samples, taken at the connection to the distribution system, except that non-oil lubricated compressors need not be tested for oil mist.

Compressed gas storage cylinders should:

1. Be designed, constructed and maintained in accordance with the appropriate provisions of 29 CFR, Sections 1910.166-171;

2. Be stored in ventilated area and protected from excessive heat;

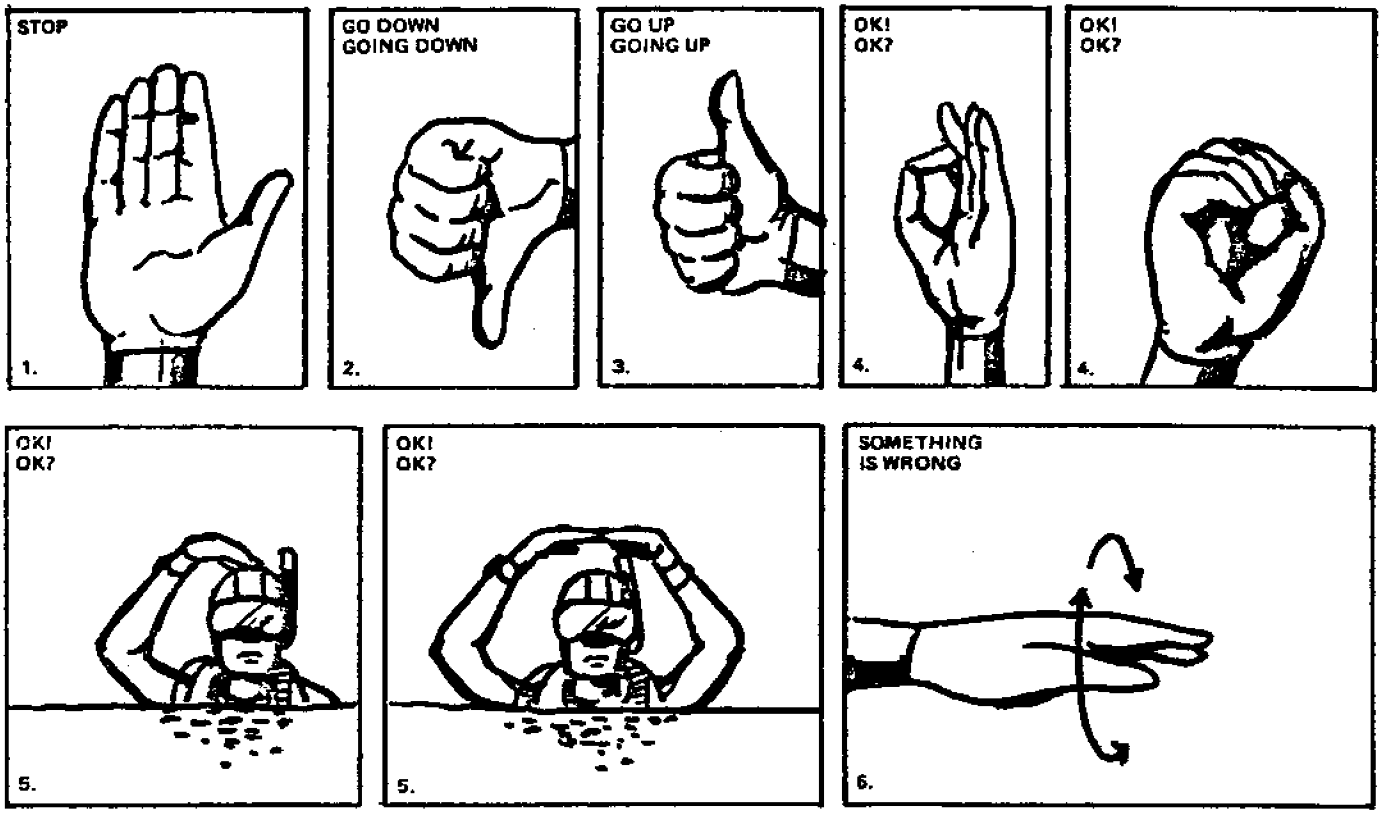
3. Be secured from falling; and

4. Have shut-off valves recessed into the cylinder or protected by a cap, except when in use or manifolded (scuba diving cylinders excluded).

NOTES:

APPENDIX D

HAND SIGNALS*



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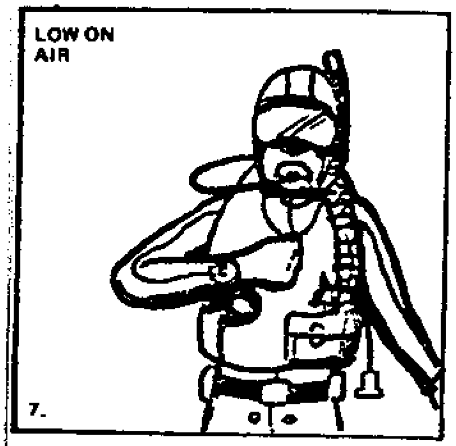
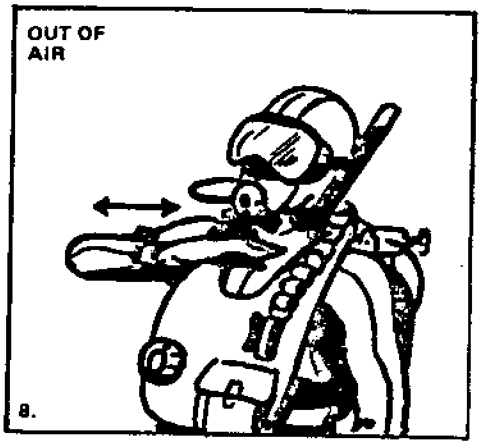
* Provided by the National Association of Underwater Instructors



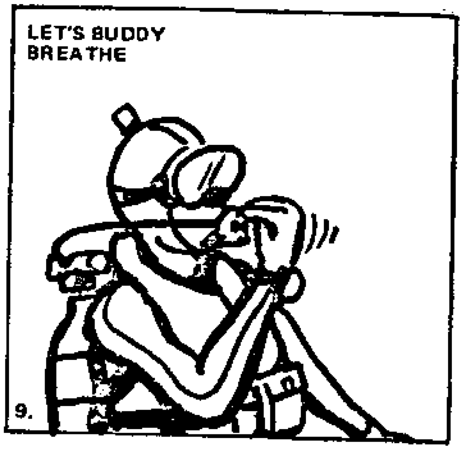
LOW ON AIR

7.



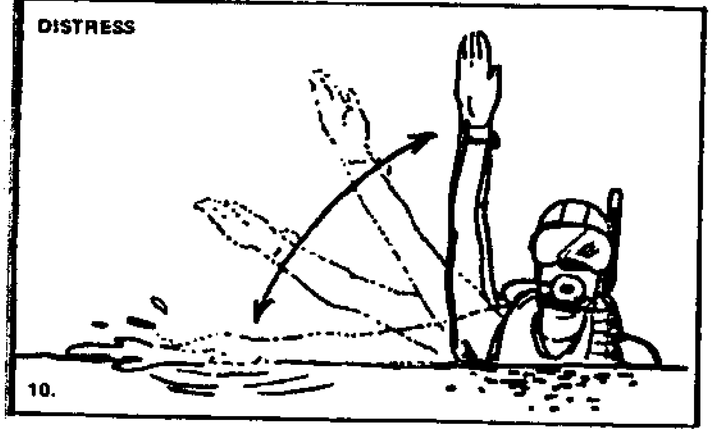
OUT OF AIR

8.



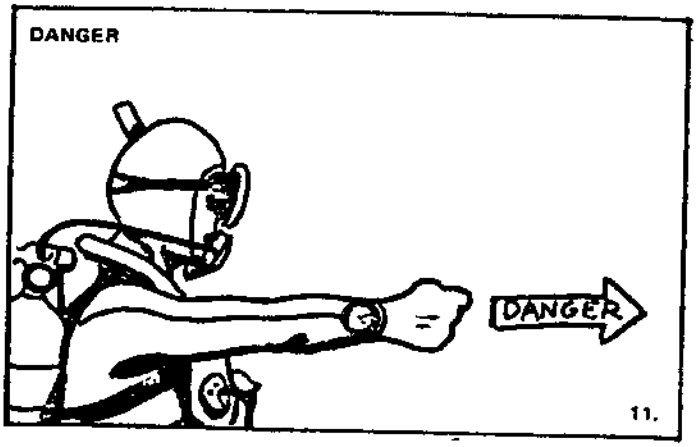
LET'S BUDDY BREATHE

9.



DISTRESS

10.



DANGER

11.

APPENDIX E

DIVING SUPERVISOR'S CHECKLIST

PLANNING

____ Have you notified all appropriate individuals or offices that diving operations are in progress?

____ Is the type of equipment that you have chosen to use adequate and safe for the task/operation?

____ Is the boat or vessel being used for the operation adequate and properly equipped?

____ Have you made provisions to obtain medical assistance in case of an emergency?

____ Have you made provisions for emergency transportation?

____ Is an operational recompression chamber ready for use at the dive site or do you have the location, contact numbers, and operational verification for the nearest chamber facility

____ Do you have a means of emergency communication (marine radio, telephone, or CB unit) at the dive site?

____ Has a timekeeper/recordkeeper been detailed and briefed on duties and responsibilities?

____ Is a copy of the decompression tables available?

____ Are an approved first aid kit, first aid manual, and oxygen inhalator available and ready for use at the dive site?

____ Has a measurement of water depth been made?

____ Have provisions been made to notify marine traffic in the area that diving operations are being conducted (security calls, visual displays, etc.)?

____ Is a copy of an appropriate/required diving regulations available at the dive site?

____ Is a copy of the "safe practices manual" available at the dive site?

____ If diving around a ship's hull, have you informed the Captain not to operate sound heads or propellers?

An alternate method of lateral swimming is for the "buddy" with the air supply to swim face down. The other diver swims directly above him holding onto the neck of the air cylinder. The diver on the bottom passes the regulator up and the top diver places it back in veiw of the bottom diver. These methods may be used for both double- and single-hose regulators. Another method of lateral swimming while sharing air with a single-hose regulator is to have the divers swim side by side in a prone position.

Sharing air under emergency conditions is difficult even for the best trained and most experienced divers. Divers should practice the skill frequently. Furthermore, the use of auxiliary breathing systems is encouraged.

At the Surface

Upon reaching the surface after emergency ascent, or when in trouble at the surface following normal ascent (rough water, exhausted, etc.), jettison the weight belt, inflate the buoyancy vest, and signal for pick up. When a long distance from assistance, it may be necessary to use the signal flare to attract attention. The surface crew should be alert for divers in trouble at all times.

When not in difficulty, swim for the craft or shore base. If the breathing apparatus interferes with swimming, the diver should remove the equipment and tow it to safety while swimming on his back (vest inflated or deflated) or on his front with a snorkel. Never hesitate to inflate the buoyancy system. Most divers will inflate the vest as a matter of routine practice. Conserve energy! The diver may have to discard his scuba if he faces a long swim to safety.

Review of accident reports and discussions with diving instructors and guides reveals that most drownings and near-drownings occur at the surface, not underwater. In other words, relatively few scuba divers get into trouble underwater. Most accidents and rescues involve divers that are incapable of handling a surface swimming situation. During training,scuba divers must learn the following:

1. Buoyancy vest inflation at the surface by both oral and mechanical means;

2. Dropping weight belts at the surface in simulated emergency exercises;

3. Inflation of the "buddy's" buoyancy vest by both oral and mechanical means.

4. Removal of the scuba for towing or ditching;

5. Inflation of buoyancy vest while coping with excessive weight on the belt;

6. Long surface swims using both snorkels and regulator;

____ Have you planned the dive to remain well within the "no-decompression" limits, if at all possible?

____ Have you filed a dive plan with a responsible person on shore indicating dive sites, estimated time of return, and procedures to follow if you do not return by the designated time?

PERSONNEL

____ Have you determined that all of the divers you intend to use have been examined and found to meet the physical standards for diving within the current calendar year?

____ Have all of your divers been trained to use the equipment you have selected?

____ Do all of your divers hold a current diving certification/ authorization?

____ Have you determined that all of your divers are trained/ qualified for the depth, environmental conditions and techniques unique to this diving operation?

____ Do you have reason to suspect the physical condition of any of your divers? Consider the following:

  ____ Do not dive a person suffering from a cold, sinusitis, or ear trouble.

  ____ Do not dive or assign important surface responsibilites to a person who is fatigued from lack of sleep or previous physical or emotional stress.

  ____ Do not dive or assign important surface responsibilities to a person who shows evidence of alcoholic/ drug intoxication or their after-effects.

  ____ If you have questions about the physical condition of any person, have him/her contact a physician and be guided by medical advice; do not dive a physically "questionable" person.

____ Do not force or urge a person to dive if they honestly desire to be excused. If reason for desiring to be excused does not appear to be sufficient or appropriate, it is best to take administrative action.

EQUIPMENT

____ Has the equipment you intend to use been tested/maintained in accordance with designated safety regulations and are the results of such tests available for your inspection?

____ Have you inspected the equipment to determine that it is in usable condition?

____ Do you have an adequate supply or source of compressed air?

____ Is each diver properly equipped with all required equipment?

____ Is the diver's personal buoyancy system operational?

____ Is the weight belt in proper position for unobstructed release and the quick release operative?

____ Is the scuba properly worn with quick release operative?

____ Is the scuba fully charged, properly assembled, turned on, and equipped with a low pressure warning device?

SAFETY DURING DIVING OPERATIONS

____ Have all efforts been made to prevent divers from becoming fouled on the surface or on the bottom?

____ Is the dive boat moored or shore staging area in the most advantageous position to minimize efforts by the divers to reach their work?

____ Are you displaying the proper "diver down" signal?

____ Has a standby/emergency assistance diver been designated and is he/she ready to enter the water in a minimum of time?

____ Has boat traffic been cleared from the immediate area?

____ Is a "chase boat" available for emergency assistance to scuba divers when working from a large, moored vessel?

____ Have you taken into account that the depth of the water and the condition of the diver (especially in regards to fatigue and cold), rather than the amount of work to be done, shall determine the amount of time the diver is to spend on the bottom?

____ Have you made provisions for decompressing the divers should this be necessary?

POSTDIVE CONSIDERATIONS

____ Have provisions been made for postdive management and warming of fatigued, cold divers?

____ Are sufficient personnel available so that divers will not have to engage in heavy work activities at the surface (such as hauling in the anchor)?

____ Have you inspected the record of the dive?

____ Have you evaluated the physical condition of each diver to insure that they are not exhibiting symptoms of decompression sickness, air embolism, physical injury or other diver related problems?

____ Have you instructed the divers to report any physical abnormality or symptom to you immediately?

____ Have you instructed the divers to remain in the vicinity of the chamber or personnel capable of managing a diving injury for at least one hour after surfacing?

____ Have you instructed the divers not to fly for at least 12 hours (24 hours following decompression dives)?

____ Have all divers and support personnel been provided with a list of emergency facilities and procedures including the nearest location of medical assistance and a chamber?

APPENDIX F

GENERAL SAFETY CHECKLIST*

STEPS IN PLANNING OF DIVING OPERATIONS

Analyze the Mission for Safety

Advanced planning is the greatest single safety precaution

____ Objective definition

____ Environmental conditions

____ Emergency assistance

____ Relevant instructions

Pin-Point Potential Hazards

Natural Hazards

Atmospheric:

____ Extreme exposure of personnel to elements

____ Adverse exposure of equipment and supplies to elements

____ Delays or disruption caused by weather

Surface:

____ Sea sickness

____ Water entry and exit

____ Handling of heavy equipment in rough seas

____ Maintaining location in tides and currents

____ Ice, flotsam, kelp petroleum disrupting operations

____ Delays or disruption caused by sea state

Underwater and Bottom:

____ Depth exceeds diving limits or limits of available equipment

____ Exposure to cold temperatures

____ Dangerous marine life

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*Modified from U.S. Navy Diving Manual (NAVSHIPS 0994-001-9010).

____ Tides and currents

____ Limited visibility

____ Bottom obstructions

____ Dangerous bottom conditions (mud, drop-offs, sewer outfalls, etc.)

"On-Site" Hazards

____ Local marine traffic

____ High powered, active sonar

____ Other conflicting scientific operations

____ Other conflicting commercial operations

____ Radiation contamination

____ Pollution

Mission Hazards

____ Decompression sickness

____ Communications problems

____ Drowning

____ Other trauma (injuries)

Object Hazards

____ Entrapment

____ Entanglement

____ Pollution, toxic

____ Explosives or other ordnance

____ Shifting or "working" of object

Minimize Hazards and Plan for Emergencies

Diving Personnel

____ Assign a complete and properly qualified Diving Team

____ Assign the right man to the right task

____ Verify that each member of the Diving Team is properly trained and qualified for the equipment and depths involved

____ Determine that each man is physically fit to dive, paying attention to:

  - ____ General condition
  - ____ Last record of medical exam
  - ____ Ears and sinuses
  - ____ Severe cold or flu
  - ____ Use of stimulants or intoxicants
  - ____ Fatigue

____ Determine each man's <u>emotional</u> fitness to dive (as fas as possible):

  - ____ Motivation (willingness)
  - ____ Stability

Diving Equipment

____ Verify that the type of diving gear chosen (and diving technique) is adequate for the particular task

____ Verify that the type of equipment and diving technique is proper for the depth involved

____ Verify that all equipment has been inspected and approved

____ Determine that all necessary support equipment and tools are readily available, and are the best for accomplishing the job efficiently and safely.

____ Determine that all related support equipment such as winches, boats, cranes, floats, etc. are operable, safe, and under the control of trained personnel

____ Check that all diving equipment has been properly maintained with appropriate records, and is in full operating condition

Provide for Emergency Equipment

____ Obtain suitable communications equipment with sufficient capability to reach "outside help". Check all communications for proper functioning

____ Verify that a recompression chamber is ready for use

____ Verify that a first aid kit is near at hand, and is completely stocked

____ If oxygen will be used as standby first aid, verify that the tank is full, and that all masks, valves and other accessories are fully operable.

____ If a resuscitator will be used, check the apparatus for function

____ Verify that emergency transportation is either standing by, or on immediate call

Establish Emergency Procedures

____ Know how to obtain medical assistance immediately

____ Assign specific tasks to the Diving Team and support personnel for different emergencies

____ Develop and post the Emergency Assistance Checklist, and ensure that all personnel are familiar with it

____ Verify that a copy of the U.S. Navy Decompression Tables is available and up-to-date

____ Be sure that all divers, boat crews, and other support personnel understand all diver hand signals

____ Pre-determine distress signals and call-signs with all members of the diving team, boat crews, and other personnel.

____ Be sure that all divers have removed anything from their mouths which might choke them during a dive (gum, dentures, tobacco)

____ Thoroughly drill and train all personnel in Emergency Procedures, with particular attention to cross-training. Drills should include:

Emergency Recompression
Fire
Rapid Dressing
Restoration of Breathing
Electric Shock
Entrapment
Rapid Undressing
First Aid
Embolism
Drowning
Blow-up

Establish Safe Diving Operational Procedures

____ Determine that all other means of accomplishing the task have been considered before deciding to use divers

____ Be sure that contingency planning has been conducted

____ Carefully state the goals of each task, and develop a flexible plan of operations

____ Completely brief the Diving Team and support personnel

____ Designate a properly qualified Diving Supervisor to be in charge of the mission

____ Designate a timekeeper and verify that he understands his duties and responsibilities

____ Determine the exact depth at the job-site through the use of a lead line or pneumofathometer

____ Verify the existence of an adequate supply of compressed air available for all planned diving operations plus an adequate reserve for emergencies

____ Be sure that no operations or action on the part of the Diving Team, support personnel, boat crews, technicians, winch operators, etc. may take place without the knowledge and by the direct command of the Diving Supervisor

____ All efforts must be made through proper planning, briefing, training, organization, and other preparations to reduce and minimize "bottom time." Remember in all cases, water depth and the condition of the diver (especially fatigue) rather than the amount of work to be done shall govern that diver's bottom time.

____ Decompression tables should be on hand, be up-to-date, and be used in all planning and scheduling of diving operations

____ Instruct all divers and support personnel not to cut any lines until that action is approved by the Diving Supervisor

____ Be sure that the ship, boat, or diving craft is securely moored and in position to permit the safest and most efficient operations (except in the case of emergency and critical ship repairs)

____ Verify that, when using surface-supplied techniques, that the ship, boat, or diving craft is in at least a two point moor

____ Ensure that, when conducting scuba operations, a boat can be quickly cast off and moved to a diver in distress

____ Ensure that each diver checks his own equipment in addition to checks made by tenders, technicians, or other support personnel

____ Designate a standby diver for all surface-supplied operations and check that the standby diver is dressed and ready to enter the water if needed.

____ Assign buddy divers for all Scuba operations

____ All efforts should be made to prevent the divers from being fouled on the bottom. If work is to be conducted inside a wreck or similar underwater structure, designate a team of divers to accomplish the task. One diver will enter the wreck, the other shall tend his lines from the point of entry

____ Brief all divers and deck personnel on the planned decompression schedules for each particular dive. Check provisions made for decompressing the diver

____ Verify that the ship, boat or diving craft is displaying the proper signals, flags, day-shapes, or lights to indicate diving operations are in progress

____ Ensure that proper protection against harmful marine life has been provided

____ Check that the quality of diver's air supply is periodically and thoroughly tested to ensure purity

____ Thoroughly brief the boat crew using the Diving Boat Operations Checklist

____ Verify that proper safety and operational equipment is aboard small diving boats or craft

Notify Proper Parties that Diving Operations Are Ready to Commence

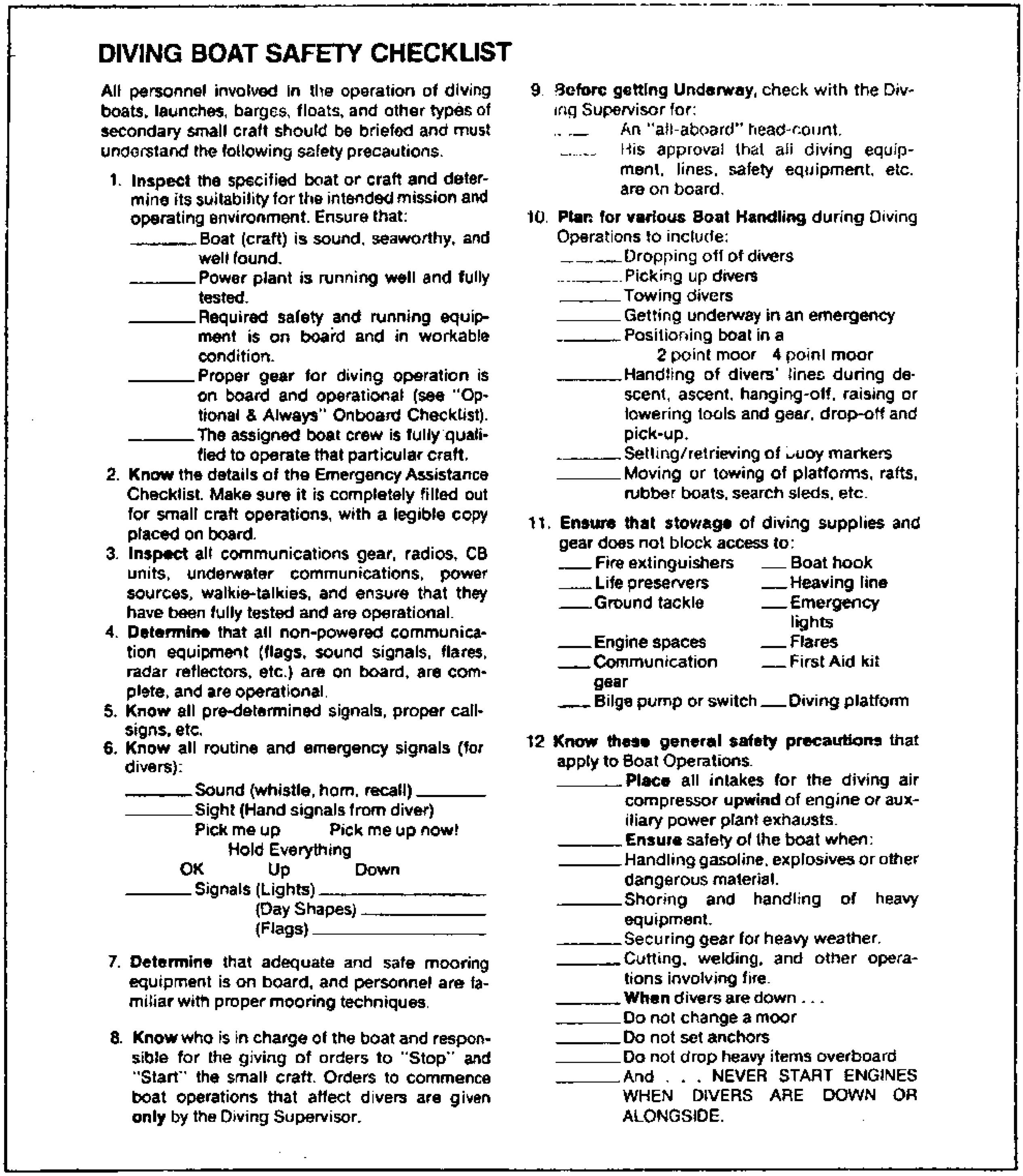
- ____ Ship's Master
- ____ Master of ships alongside
- ____ Bridge, to ensure that ship's personnel will not:
  - ____ Turn the propeller or thrusters
  - ____ Get underway
  - ____ Activate active sonar or other electronics
  - ____ Drop heavy items overboard
  - ____ Shift the moor
  - ____ Operate the rudder or steering mechanisms
- ____ Other interested parties
  - ____ Harbor Master
  - ____ U.S. Coast Guard (if broadcast warning to civilians is required)

____ Notify emergency facilities having recompression chambers as well as sources of emergency transportation that diving operations are underway and their assistance may be needed (for major operations)

NOTES:

APPENDIX G

DIVING BOAT SAFETY CHECKLIST*



DIVING BOAT SAFETY CHECKLIST

All personnel involved in the operation of diving boats, launches, barges, floats, and other types of secondary small craft should be briefed and must understand the following safety precautions.

1. **Inspect** the specified boat or craft and determine its suitability for the intended mission and operating environment. Ensure that:
   - ____ Boat (craft) is sound, seaworthy, and well found.
   - ____ Power plant is running well and fully tested.
   - ____ Required safety and running equipment is on board and in workable condition.
   - ____ Proper gear for diving operation is on board and operational (see "Optional & Always" Onboard Checklist).
   - ____ The assigned boat crew is fully qualified to operate that particular craft.
2. **Know** the details of the Emergency Assistance Checklist. Make sure it is completely filled out for small craft operations, with a legible copy placed on board.
3. **Inspect** all communications gear, radios, CB units, underwater communications, power sources, walkie-talkies, and ensure that they have been fully tested and are operational.
4. **Determine** that all non-powered communication equipment (flags, sound signals, flares, radar reflectors, etc.) are on board, are complete, and are operational.
5. **Know** all pre-determined signals, proper callsigns, etc.
6. **Know** all routine and emergency signals (for divers):
   - ____ Sound (whistle, horn, recall) ____
   - ____ Sight (Hand signals from diver)

     Pick me up Pick me up now!

     Hold Everything

     OK Up Down
   - ____ Signals (Lights) ____

     (Day Shapes) ____

     (Flags) ____
7. **Determine** that adequate and safe mooring equipment is on board, and personnel are familiar with proper mooring techniques.
8. **Know** who is in charge of the boat and responsible for the giving of orders to "Stop" and "Start" the small craft. Orders to commence boat operations that affect divers are given **only** by the Diving Supervisor.
9. **Before getting Underway**, check with the Diving Supervisor for:
   - ____ An "all-aboard" head-count.
   - ____ His approval that all diving equipment, lines, safety equipment, etc. are on board.
10. **Plan for various Boat Handling** during Diving Operations to include:
    - ____ Dropping off of divers
    - ____ Picking up divers
    - ____ Towing divers
    - ____ Getting underway in an emergency
    - ____ Positioning boat in a

      2 point moor 4 point moor
    - ____ Handling of divers' lines during descent, ascent, hanging-off, raising or lowering tools and gear, drop-off and pick-up.
    - ____ Setting/retrieving of buoy markers
    - ____ Moving or towing of platforms, rafts, rubber boats, search sleds, etc.
11. **Ensure that stowage** of diving supplies and gear does not block access to:
    - ____ Fire extinguishers
    - ____ Life preservers
    - ____ Ground tackle
    - ____ Engine spaces
    - ____ Communication gear
    - ____ Bilge pump or switch
    - ____ Boat hook
    - ____ Heaving line
    - ____ Emergency lights
    - ____ Flares
    - ____ First Aid kit
    - ____ Diving platform
12. **Know these general safety precautions** that apply to Boat Operations.
    - ____ **Place** all intakes for the diving air compressor **upwind** of engine or auxiliary power plant exhausts.
    - ____ **Ensure** safety of the boat when:
    - ____ Handling gasoline, explosives or other dangerous material.
    - ____ Shoring and handling of heavy equipment.
    - ____ Securing gear for heavy weather.
    - ____ Cutting, welding, and other operations involving fire.
    - ____ **When** divers are down . . .
    - ____ Do not change a moor
    - ____ Do not set anchors
    - ____ Do not drop heavy items overboard
    - ____ And . . . NEVER START ENGINES WHEN DIVERS ARE DOWN OR ALONGSIDE.

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*From U.S. Navy Diving Manual (NAVSHIPS 0994-001-9010).

NOTES:

APPENDIX H

U.S. NAVY STANDARD AIR DECOMPRESSION AND REPETITIVE DIVE TABLES (SELECTED SCHEDULES)

NO-DECOMPRESSION LIMITS AND REPETITIVE GROUP DESIGNATION TABLE FOR NO-DECOMPRESSION AIR DIVES

Depth (feet)	No-decompression limits (min)	Group Designation														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10		60	120	210	300											
15		35	70	110	160	225	350									
20		25	50	75	100	135	180	240	325							
25		20	35	55	75	100	125	160	195	245	315					
30		15	30	45	60	75	95	120	145	170	205	250	310			
35	310	5	15	25	40	50	60	80	100	120	140	160	190	220	270	310
40	200	5	15	25	30	40	50	70	80	100	110	130	150	170	200	
50	100		10	15	25	30	40	50	60	70	80	90	100			
60	60		10	15	20	25	30	40	50	55	60					
70	50		5	10	15	20	30	35	40	45	50					
80	40		5	10	15	20	25	30	35	40						
90	30		5	10	12	15	20	25	30							
100	25		5	7	10	15	20	22	25							
110	20			5	10	13	15	20								
120	15			5	10	12	15									
130	10			5	8	10										
140	10			5	7	10										
150	5			5												
160	5				5											
170	5				5											
180	5				5											
190	5				5											

U. S NAVY STANDARD AIR DECOMPRESSION TABLE

Depth (feet)	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet)					Total ascent (min:sec)	Repetitive group
			50	40	30	20	10		
40	200						0	0:40	*
	210	0:30					2	2:40	N
	230	0:30					7	7:40	N
	250	0:30					11	11:40	O
	270	0:30					15	15:40	O
	300	0:30					19	19:40	Z
50	100						0	0:50	*
	110	0:40					3	3:50	L
	120	0:40					5	5:50	M
	140	0:40					10	10:50	M
	160	0:40					21	21:50	N
	180	0:40					29	29:50	O
	200	0:40					35	35:50	O
	220	0:40					40	40:50	Z
	240	0:40					47	47:50	Z
60	60						0	1:00	*
	70	0:50					2	3:00	K
	80	0:50					7	8:00	L
	100	0:50					14	15:00	M
	120	0:50					26	27:00	N
	140	0:50					39	40:00	O
	160	0:50					48	49:00	Z
	180	0:50					56	57:00	Z
	200	0:40				1	69	71:00	Z
70	50						0	1:10	*
	60	1:00					8	9:10	K
	70	1:00					14	15:10	L
	80	1:00					18	19:10	M
	90	1:00					23	24:10	N
	100	1:00					33	34:10	N
	110	0:50				2	41	44:10	O
	120	0:50				4	47	52:10	O
	130	0:50				6	52	59:10	O
	140	0:50				8	56	65:10	Z
	150	0:50				9	61	71:10	Z
	160	0:50				13	72	86:10	Z
	170	0:50				19	79	99:10	Z
80	40						0	1:20	*
	50	1:10					10	11:20	K
	60	1:10					17	18:20	L
	70	1:10					23	24:20	M
	80	1:00				2	31	34:20	N
	90	1:00				7	39	47:20	N
	100	1:00				11	46	58:20	O
	110	1:00				13	53	67:20	O
	120	1:00				17	56	74:20	Z
	130	1:00				19	63	83:20	Z
	140	1:00				26	69	96:20	Z
	150	1:00				32	77	110:20	Z
90	30						0	1:30	*
	40	1:20					7	8:30	J
	50	1:20					18	19:30	L
	60	1:20					25	26:30	M
	70	1:10				7	30	38:30	N
	80	1:10				13	40	54:30	N
	90	1:10				18	48	67:30	O
	100	1:10				21	54	76:30	Z
	110	1:10				24	61	86:30	Z
	120	1:10				32	68	101:30	Z
	130	1:00			5	36	74	116:30	Z

* SEE NO-DECOMPRESSION TABLE FOR REPETITIVE GROUPS

U. S NAVY STANDARD AIR DECOMPRESSION TABLE

Depth (feet)	Bottom time (min)	Time first stop (min:sec)	50	40	30	20	10	Total ascent (min:sec)	Repetitive group
100	25						0	1:40	*
	30	1:30					3	4:40	I
	40	1:30					15	16:40	K
	50	1:20				2	24	27:40	L
	60	1:20				9	28	38:40	N
	70	1:20				17	39	57:40	O
	80	1:20				23	48	72:40	O
	90	1:10			3	23	57	84:40	Z
	100	1:10			7	23	66	97:40	Z
	110	1:10			10	34	72	117:40	Z
	120	1:10			12	41	78	132:40	Z
110	20						0	1:50	*
	25	1:40					3	4:50	H
	30	1:40					7	8:50	J
	40	1:30				2	21	24:50	L
	50	1:30				8	26	35:50	M
	60	1:30				18	36	55:50	N
	70	1:20			1	23	48	73:50	O
	80	1:20			7	23	57	88:50	Z
	90	1:20			12	30	64	107:50	Z
	100	1:20			15	37	72	125:50	Z
120	15						0	2:00	*
	20	1:50					2	4:00	H
	25	1:50					6	8:00	I
	30	1:50					14	16:00	J
	40	1:40				5	25	32:00	L
	50	1:40				15	31	48:00	N
	60	1:30			2	22	45	71:00	O
	70	1:30			9	23	55	89:00	O
	80	1:30			15	27	63	107:00	Z
	90	1:30			19	37	74	132:00	Z
	100	1:30			23	45	80	150:00	Z
130	10						0	2:10	*
	15	2:00					1	3:10	F
	20	2:00					4	6:10	H
	25	2:00					10	12:10	J
	30	1:50				3	18	23:10	M
	40	1:50				10	25	37:10	N
	50	1:40			3	21	37	63:10	O
	60	1:40			9	23	52	86:10	Z
	70	1:40			16	24	61	103:10	Z
	80	1:30		3	19	35	72	131:10	Z
	90	1:30		8	19	45	80	154:10	Z
140	10						0	2:20	*
	15	2:10					2	4:20	G
	20	2:10					6	8:20	I
	25	2:00				2	14	18:20	J
	30	2:00				5	21	28:20	K
	40	1:50			2	16	26	46:20	N
	50	1:50			6	24	44	76:20	O
	60	1:50			16	23	56	97:20	Z
	70	1:40		4	19	32	68	125:20	Z
	80	1:40		10	23	41	79	155:20	Z

* SEE NO-DECOMPRESSION TABLE FOR REPETITIVE GROUPS

RESIDUAL NITROGEN TIMETABLE FOR REPETITIVE AIR DIVES

*Dives following surface intervals of more than 12 hours are not repetitive dives. Use actual bottom times in the Standard Air Decompression Tables to compute decompression for such dives.

Repetitive group at the beginning of the surface interval

A																0:10 12:00*
B															0:10 2:10	2:11 12:00*
C														0:10 1:39	1:40 2:49	2:50 12:00*
D													0:10 1:09	1:10 2:38	2:39 5:48	5:49 12:00*
E												0:10 0:54	0:55 1:57	1:58 3:22	3:23 6:32	6:33 12:00*
F											0:10 0:45	0:46 1:29	1:30 2:28	2:29 3:57	3:58 7:05	7:06 12:00*
G										0:10 0:40	0:41 1:15	1:16 1:59	2:00 2:58	2:59 4:25	4:26 7:35	7:36 12:00*
H									0:10 0:36	0:37 1:06	1:07 1:41	1:42 2:23	2:24 3:20	3:21 4:49	4:50 7:59	8:00 12:00*
I								0:10 0:33	0:34 0:59	1:00 1:29	1:30 2:02	2:03 2:44	2:45 3:43	3:44 5:12	5:13 8:21	8:22 12:00*
J							0:10 0:31	0:32 0:54	0:55 1:19	1:20 1:47	1:48 2:20	2:21 3:04	3:05 4:02	4:03 5:40	5:41 8:40	8:41 12:00*
K						0:10 0:28	0:29 0:49	0:50 1:11	1:12 1:35	1:36 2:03	2:04 2:38	2:39 3:21	3:22 4:19	4:20 5:48	5:49 8:58	8:59 12:00*
L					0:10 0:26	0:27 0:45	0:46 1:04	1:05 1:25	1:26 1:49	1:50 2:19	2:20 2:53	2:54 3:36	3:37 4:35	4:36 6:02	6:03 9:12	9:13 12:00*
M				0:10 0:25	0:26 0:42	0:43 0:59	1:00 1:18	1:19 1:39	1:40 2:05	2:06 2:34	2:35 3:08	3:09 3:52	3:53 4:49	4:50 6:18	6:19 9:28	9:29 12:00*
N			0:10 0:24	0:25 0:39	0:40 0:54	0:55 1:11	1:12 1:30	1:31 1:53	1:54 2:18	2:19 2:47	2:48 3:22	3:23 4:04	4:05 5:03	5:04 6:32	6:33 9:43	9:44 12:00*
O		0:10 0:23	0:24 0:36	0:37 0:51	0:52 1:07	1:08 1:24	1:25 1:43	1:44 2:04	2:05 2:29	2:30 2:59	3:00 3:33	3:34 4:17	4:18 5:16	5:17 6:44	6:45 9:54	9:55 12:00*
	0:10 0:22	0:23 0:34	0:35 0:48	0:49 1:02	1:03 1:18	1:19 1:36	1:37 1:55	1:56 2:17	2:18 2:42	2:43 3:10	3:11 3:45	3:46 4:29	4:30 5:27	5:28 6:56	6:57 10:05	10:06 12:00*
NEW → GROUP DESIGNATION	Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A

REPETITIVE DIVE DEPTH																
40	257	241	213	187	161	138	116	101	87	73	61	49	37	25	17	7
50	169	160	142	124	111	99	87	76	66	56	47	38	29	21	13	6
60	122	117	107	97	88	79	70	61	52	44	36	30	24	17	11	5
70	100	96	87	80	72	64	57	50	43	37	31	26	20	15	9	4
80	84	80	73	68	61	54	48	43	38	32	28	23	18	13	8	4
90	73	70	64	58	53	47	43	38	33	29	24	20	16	11	7	3
100	64	62	57	52	48	43	38	34	30	26	22	18	14	10	7	3
110	57	55	51	47	42	38	34	31	27	24	20	16	13	10	6	3
120	52	50	46	43	39	35	32	28	25	21	18	15	12	9	6	3
130	46	44	40	38	35	31	28	25	22	19	16	13	11	8	6	3
140	42	40	38	35	32	29	26	23	20	18	15	12	10	7	5	2
150	40	38	35	32	30	27	24	22	19	17	14	12	9	7	5	2
160	37	36	33	31	28	26	23	20	18	16	13	11	9	6	4	2
170	35	34	31	29	26	24	22	19	17	15	13	10	8	6	4	2
180	32	31	29	27	25	22	20	18	16	14	12	10	8	6	4	2
190	31	30	28	26	24	21	19	17	15	13	11	10	8	6	4	2

RESIDUAL NITROGEN TIMES (MINUTES)

APPENDIX I

SAMPLE DECOMPRESSION TABLE PROBLEM

1. According to the Standard Air Decompression Tables, what is the no-decompression dive limit for a scuba dive to 60 fsw (low to moderate exertion, warm water)?

   Answer: 60 minutes

2. As a Diving Supervisor or team leader, what no-decompression dive limit would you specify for your dive team for a dive to 60 fsw (low to moderate exertion, warm water)?

   Answer: 50-55 minutes

3. In accordance with recommended procedures for a cold and/or heavy work load dive, what no-decompression dive limit would you select for an exceptionally cold dive to 60 fsw?

   Answer: 50 minutes maximum

4. Diver Jones must make three scuba dives per day in warm tropical water (low exertion level). The sequence is as follows:

Dive #	Entry Time	Dive Depth
1	9 AM	75 fsw
2	10 AM	40 fsw
3	3 PM	60 fsw

   a. What is the "conservative" no-decompression time limit and repetitive group designation for Dive # 1 (assume sufficient air supply to dive to that limit)?

   Answer: 30-35 minutes/H

   b. What is the repetitive dive group designation at the beginning of Dive #2 (assume Dive #1 bottom time of 33 minutes/total dive time of 35 minutes)?

   Answer: 9:35 to 10:00 = 25 min.
   New group H

   c. What is the residual dive time for Dive #2?

   Answer: 87 minutes

   d. What is the maximum no-decompression dive limit for Dive #2 (according to tables)?

   Answer: 200-87 or 113 minutes

e. What would the maximum no-decompression dive limit be if Dive #2 was to a depth of 25 fsw instead of 40 fsw (according to tables)?

Answer: 113 minutes

Explanation: Although many recreational diving instructors use various interpolation techniques to achieve longer times, there is still no officially approved interpolation procedure for use with the U.S. Navy tables. Consequently, since the "Residual Nitrogen Time" has a minimum depth of 40 fsw, dives less than 40 fsw must use the 40 fsw designations.

f. Assuming that the actual bottom time of Dive #2 was 65 minutes, what is the equivalent single dive time and the repetitive dive group designation at the end of the dive?

Answer:
RNT 87 min.
ABT 65 min.
ESDT 152
Group M

g. Assuming that the actual dive time of Dive #2 was 65 minutes, what is the new repetitive group designation for Dive #3?

Answer: 11:05 AM to 3 PM = 3hr 55 min.
New Group D

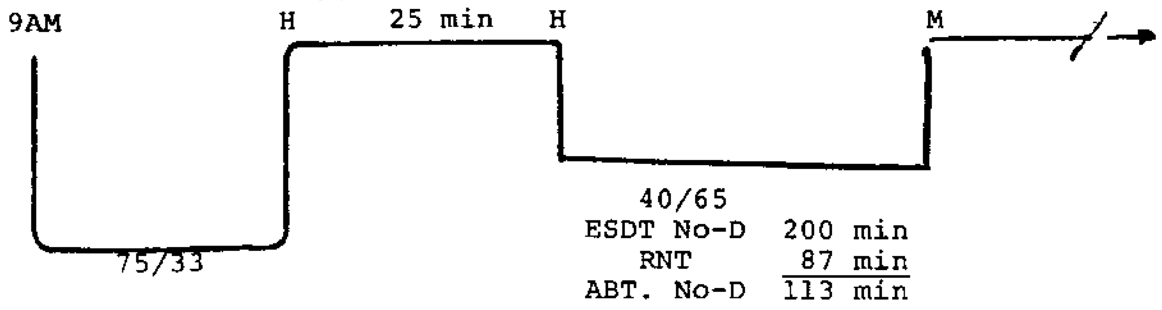
h. What is the maximum allowable actual bottom time for Dive #3 (according to the tables)?

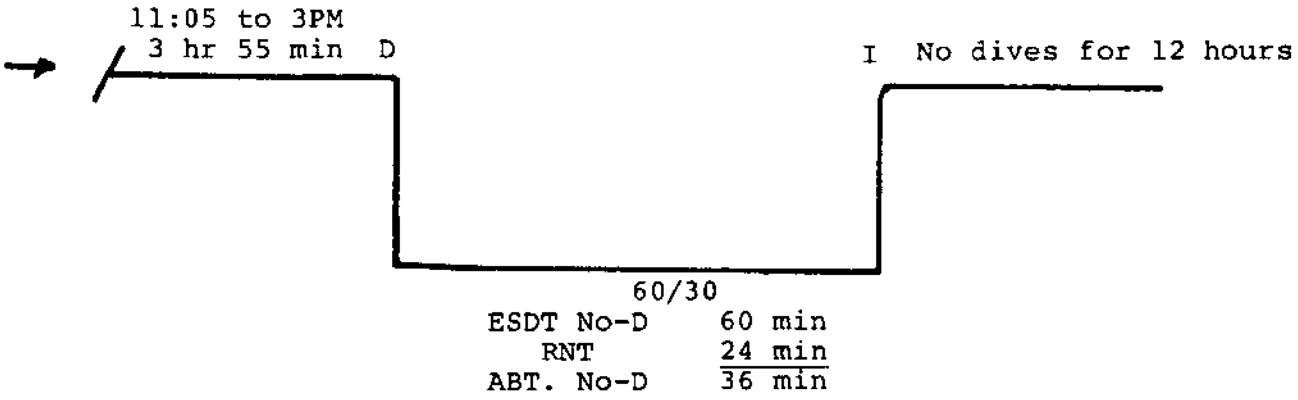
Answer:
RNT 24 min.
No-D 60 min.
ABT 36 min.

i. What would a reasonable conservative bottom time be for Dive #3?

Answer: About 30 minutes

j. Graphically present this three dive sequence





k. How could this dive sequence been better planned?

Answer: 75 fsw, 60 fsw, 40 fsw

NOTES:

APPENDIX J

MOUTH-TO-SNORKEL RESUSCITATION TECHNIQUE

The Mouth-to-Snorkel method of in-water resuscitation was developed by Albert L. Pierce and is included in this Handbook with the originator's permission. The procedure is as follows:

1. Start with the chin pull, holding your victim's head against your chest. Your free hand can control the snorkel.

2. Clear the water from your snorkel by letting it run out, or by blowing it out. Keep it clear by bending the tube end up, or by holding it in your teeth. You can bend it with one hand if you use your middle and index fingers on top and your thumb and other fingers pushing from underneath.

3. Release your fingers from the chin pull to receive the snorkel mouthpiece between your middle and ring fingers. But keep control of the victim's head by holding it tightly between your wrist and your chest. You will be keeping your hand on his chin, so you won't have to hold him in the doe-see-doe position you used for mouth to mouth.

4. Press the snorkel flange over the victim's mouth, making sure your fingers press tightly down all the way around the snorkel flange.

5. Seal his nose with the thumb and forefinger of that hand.

6. Place the tube end of the snorkel in your mouth with your other hand and blow. You'll have to blow a little longer than with mouth to mouth to overcome the dead air space of the snorkel.

7. After filling his lungs, remove the tube end and allow your victim's air to escape through the tube. You won't be able to see his chest rising and falling, but you can hear the exhaled air and feel it on your cheek.

8. Continue blowing and releasing as you tow the victim to safety. On your back you are positioned well for a carry.

If your seal with the mouthpiece is imperfect, or if his nostrils are not pinched shut, you may feel air escaping around your fingers, and may notice a lack of build-up of pressure as you blow. This is a signal that you are not filling the victim's lungs. Readjusting your fingers may make a better seal. If you feel an air blockage, tilt his head back more. Or, you may have to blow harder to overcome the effect of water in his lungs.

You should fill the victim's lungs with each breath. This will insure his getting plenty of fresh air and not just stale air being moved back and forth through the snorkel and his airways. When the victim stops exhaling you can immediately blow back into the tube and refill his lungs. A lot of air at a rapid rate is just what a drowning victim needs. However, you, as the rescuer, may get a dizzy feeling from hyperventilation. If so, you can slow down your rate. You are not as likely to get dizzy as you are when doing mouth to mouth on land because you are working, towing your victim. Of course, while the victim is exhaling you are inhaling, being careful not to breathe in the victim's exhaled air.

You may not need to pinch the victim's nostrils. You may be able to block the air from escaping by pushing up against his nose with the edge of your index finger. This will allow you to make a better seal with the snorkel flange over his mouth because your fingers are not curled.

An almost perfect seal will result if the snorkel flange is inserted between the victim's lips and teeth. But this isn't easy to do on an unconscious victim, and you may waste time trying. If the flange is pressed tightly over the outside of his lips, the seal can be made good enough and a lot faster. You can practice by pressing the flange over your own mouth. Test for leaks by blocking the end of the snorkel with your thumb and blowing through the mouthpiece. If you find it difficult to make a good seal with the flange on the outside of the victim's lips, try twisting or screwing the flange into his mouth. Your seal does not have to be perfect. He may be getting plenty of air even if some escapes. The real test of a good seal is whether or not the victim is comfortable while submerged. This will simulate waves swamping his face while you tow. If you practice with the victim's face underwater, be sure to have him signal OK with his hand out of water so you'll know he's not drowning. Curling the end of the snorkel tube downward will eliminate any possibility of water entering the tube while the victim is exhaling.

Most snorkels will work, including contoured types and those with corrugated tubes. But some work better than others. You must be able to aim the mouthpiece down over the victim's lips and still keep the tube end out of the water. Either the tube must be flexible or the mouthpiece bend or swivel to allow this. Check your snorkel and see how it works. A few are too inflexible and can't be used. Some, if bent too sharply, may cut off the air. If the snorkel is too long it will be difficult to keep a good seal while blowing. You may wish to shorten yours. A wide flange will make a better seal over the outside of the lips, but a narrow flange will be easier to get inside the mouth. There should be room for your fingers to fit around the tube behind the flange.

It will be wise to learn the technique with an easy snorkel. Later you may find you can make a good seal with almost any. For instance, you can use one with a purge valve if you prevent the air from escaping out of the valve by covering it with your finger or your hand. Air can then be released for exhalation through either the tube end or the valve. Since this will require the use of both hands, you'll have to hold the snorkel end in your teeth, and be careful not to breathe in the victim's exhaled air. This position may also work if the snorkel tube is to inflexible to bend easily.

The correct placement of the snorkel "J" will make for easier handling. With the tube end held in your left (or non-prefered) hand, the curl of the bottom of the "J" formed by the snorkel should be oriented so the mouthpiece is aimed toward the fingers of your right hand. This allows easy control of the tube end on the left of the victim's head while you are holding the snorkel flange over the victim's lips with your right hand from the right side.

If you have to use a snorkel which is tightly attached to a mask, don't bother to separate them. Just let the mask dangle. It won't be in the way. If the victim is wearing a mask, and you are sure it is clear of water, it may be left on. It will protect his face from waves and spray. You can seal his nostrils by pinching through the mask, or by pushing up on it's skirt. If waves are no problem, you may want to remove the mask so you can see his face clearly.

If the victim vomits, you will have to remove the snorkel, clear his mouth, swish the snorkel through the water to clear it, let it drain, then replace it and start over.

If two rescuers are available, one can help support the victim from the opposite side and be in a better position to watch the victim's face for return of color, or to warn of possible vomiting. If he has brought a line and float with him, he can control the victim's bouyancy and stability while all are being towed to safety. If there is a third rescuer, he can place the victim's feet on his shoulders and push.

Practice mouth to snorkel on land first. Making a good seal is tricky, because it is difficult to see what you are doing. Locate the mouth with your fingers. If you place your little finger on his chin, your hand will be about right. Practice applying the mouthpiece until you can do it easily. Since you don't have mouth to mouth contact, both you and your practice victim may feel more relaxed.

Then try your seal in shallow water. You should stoop down until the water is at chin level while you support the victim in a floating position with a chin pull. Here you can practice keeping the tube end out of the water while applying the mouthpiece. Keep the seal while you blow and tow in the shallows.

When you feel confident in shallow water, try it in deep water, the easy way first, using fins and flotation. Fins are a big asset. You can tow the victim easily with your legs while you control the victim and the snorkel with your hands. It will help to keep your head in the water and to tow the victim's head first right from the start so his momentum will help to keep his face out of the water. Later try it without buoyancy or fins.

This also should be practiced with full scuba gear. The thick neoprene of wet suit gloves will make your fingers feel clumsy; but you may find they will help to make a better seal. Because of this even three finger gloves or mittens can be made to work. Keep trying under varied conditions until you are sure of yourself. Open water, waves and cumbersome gear make a big difference.

APPENDIX K

ACCIDENT MANAGEMENT PROCEDURES FOR UNIVERSITY DIVERS

All supervisors and dive team members must be prepared to respond properly in the event of an accident. Regardless of the nature of the accident, prompt emergency procedures can reduce the residual effects on the victim and possibly save a life. Emergency drills are encouraged! Development of a standardized accident management protocol is difficult since the procedures will depend upon diving location, available personnel, available medical/chamber facilities, nature of the injury, available transportation and so on. Proper management procedures are extremely difficult to formulate for diving in remote locations. Consequently, the Diving Supervisor (and Diving Safety Coordinator) will have to assess each location on an individual basis. An "Emergency Assistance List" should be prepared for each dive location. The following checklist is intended to aid Diving Supervisors in the field in formulating specific procedural guidelines:

____ 1. The person nearest to the accident victim will initiate rescue/recovery procedures. In scuba diving this is usually the diving buddy.

____ 2. The rescuer will signal for assistance (voice, whistle, flare, etc.).

____ 3. IF THE VICTIM IS NOT BREATHING, the rescuer will immediately start resuscitation in the water.

____ 4. The Diving Supervisor will dispatch the standby diver and/or other divers to assist in rescue procedures and take charge of the scene. He/she will delegate tasks to various responsible individuals.

____ 5. Upon return to shore/boat, resuscitation will be continued (including CPR, if indicated) with a minimum of interruption time.

____ 6. IF AN AIR EMBOLISM IS SUSPECTED AND THE VICTIM IS BREATHING, immediately begin prescribed first aid procedures (30° incline, prevent shock, oxygen, constant observation).

____ 7. Be certain that all dive team members are accounted for.

____ 8. Recall all divers in the water; terminate diving operations and secure equipment (while rescue personnel are proceeding to handle the emergency).

____ 9. Advise the vessel's Master of the situation and request what assistance is needed, generally communication and rapid transportation to shore.

____10. IF SHORE BASED, call Rescue Unit and ambulance.

____11. Designate dive team members to control crowds/bystanders. Keep non-essential personnel away from the accident victim and first aid personnel. This is especially necessary in beach operation.

____12. Non-involved dive team members are to standby and not interfer with emergency efforts. Instruct dive team members to NOT mingle with bystanders and to NOT discuss the accident with anyone.

____13. If the accident occurs in a training class, have an assistant isolate all students away from the scene. Do not let anyone leave until the Diving Instructor/Supervisor authorizes dismissal. Have an accurate record of all persons involved in the class. In serious accidents/fatal accidents, authorization from local law enforcement authorities will generally be required for dismissal of witnesses.

____14. Contact local law enforcement officials if this is a fatal accident.

____15. Contact designated Diving Physician for advice on management/transportation.

____16. Transport accident victim to nearest medical facility (or approved diving accident treatment facility if the travel time is not too great). Local medical attention is necessary prior to subsequent transportation to a chamber if the transportation time will exceed 1 hour. Designated Diving Physician will advise. This applies to air embolism/decompression sickness. Non-pressure related injuries will be handled at local hospital.

____17. Arrange for communications with Diving Physician during transport.

____18. Alert chamber.

____19. Instructor/Supervisor remain with victim during transport/emergency treatment (if possible).

____20. Advise University Security.

____21. Have University Security notify appropriate University authorities and contact victim's family.

____22. IF EMERGENCY IS MANAGED AT THE SCENE AND HOSPITALIZATION/PROFESSIONAL MEDICAL ATTENTION IS NOT REQUIRED (Emergency ascent, water accident where resuscitation is not required, etc.):

a. Provide victim with emergency identification, telephone numbers for diving physician, local medical facility, etc.

b. Do not let the victim be alone for next 6 hours.

c. Do not let the victim drive.

____23. Any person resuscitated at the dive location must be transported to a medical facility for follow-up examination/treatment.

____24. Contact Diving Safety Coordinator and Department/ Division Head.

If this is a fatal accident or serious accident that occurs on training exercises, observe the following in addition to the above:

____ 1. Do not discontinue resuscitation procedures until the victim is pronounced dead by a physician.

____ 2. Transport to the nearest medical facility if there is no physician at the scene.

____ 3. Make every effort to avoid contact with newspaper reporters and general public. This includes all dive team members and students.

____ 4. Be polite but firm regarding interviews and questions. If approached, simply indicate that information will be made available to the press through the University Information Services Office. Remember that any misquotation or undesirable statement made under stress can be printed and later cause considerable problems for any or all members of the dive team, the University and the victim's survivors.

____ 5. Only one individual should serve as an official spokesperson for the group. The spokesperson will be the Diving Supervisor or a person delegated by him/her.

____ 6. Give only facts to law enforcement officials. If the authorities attempt to interview you or members of the dive team in public (in the presence of unidentified strangers, by-standers, reporters, etc.), politely request that such interviews be conducted in private. Give only facts such as name, address, University affiliation, authorities to contact at the University, the exact location of the accident, a brief factual description of the occurrence (only if required), the name of the victim, whom to notify in the victim's family, etc. If the interviewer attempts to force you beyond the basic "facts", request that University legal counsel be present during that portion of the interview. Avoid expressing opinions or conclusions. Under stress it is easy to make irrational or undesirable statements. Simply think before you speak. Law enforcement reports are public information.

____ 7. Immediately prepare a complete and detailed written report for the University legal office, insurance office, Diving Safety Coordinator, and other authorized persons who will be involved. This is a confidential report, not for public release. If the situation is "bad", do not give the report to anyone except the legal office. Use the accident report included in this handbook as a guide (Appendix M). The report should include photographs of the scene, sketch maps (accurate), weather conditions, water conditions, a detailed description of the activity being performed, your role, other persons involved, safety precautions, and anything, regardless of how minor it may seem that relates to the scene, activity, diver, and your action.

____ 8. Have each dive team member prepare detailed statements of facts. Do it the day of the accident, not a week later. These statements should be given only to the legal office.

____ 9. Record each team member/student that was in attendance including name, address, their involvement (if any). Inform them that they may be asked for facts as they recall them only. Do not attempt to "put words in their mouths!" Ask them not to discuss opinions with bystanders, etc.

____10. Prepare a complete file on the diving operation/course for the legal office including outlines, memos on procedures, records of all personnel, etc. These will be valuable for future reference in the event of legal actions.

____11. Complete the "Accident Report" form for the University.

____12. Complete the "Accident Report" form for the University of Rhode Island Project, but do not mail until approved by the University attorney.

____13. Assist Information Services in preparing a statement for public release.

The above procedures may appear quite demanding and restrictive. However, as a representative of the University, whether student or employee, you have a serious responsibility to the University and yourself. Serious accidents and fatalities often lead to legal actions. It is a disservice to all concerned, including yourself, if you act in an irresponsible manner.

NOTES:

APPENDIX L

EMERGENCY ASSISTANCE LIST

DIVE LOCATION ____________________ DATE __________

COMMUNICATION CENTER

Location

Contact

Response Time

RESCUE UNIT

Location

Contact

Response Time

HOSPITAL/MEDICAL CLINIC

Location

Contact

Response Time

DIVING PHYSICIAN

Location

Contact

Response Time

RECOMPRESSION CHAMBER

Location

Contact

Response Time

GROUND TRANSPORTATION (AMBULANCE)

Location

Contact

Response Time

AIR TRANSPORTATION

Location

Contact

Response Time

SEA TRANSPORTATION

Location

Contact

Response Time

"SEE OTHER SIDE"

LAW ENFORCEMENT AGENCY

Location

Contact

Response Time

MEDICAL CONSULTATION

Location

Contact

Response Time

MEDICAL CONSULTATION

Location

Contact

Response Time

UNIVERSITY SECURITY

Location

Contact

Response Time

UNIVERSITY DIVING COORDINATOR

Location

Contact

Response Time

DIVING SUPPLIES

Location

Contact

Response Time

OTHER: ____________

Location

Contact

Response Time

OTHER: ____________

Location

Contact

Response Time

APPENDIX M

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 ....

Sea: Calm .... Moderate .... Rough ....

Current: Slight .. Moderate .. Strong .. Direction ...

Wave Height: ... **Water Depth**: ... **Type Bottom**: ...

Water Temperature: (°F) ....

Weather: Clear .. Cloudy .. Fog .. Snow .. Rain .. Thunderstorm .. Tornado, Hurricane .. Other ..

Wind Force .... **Direction** ....

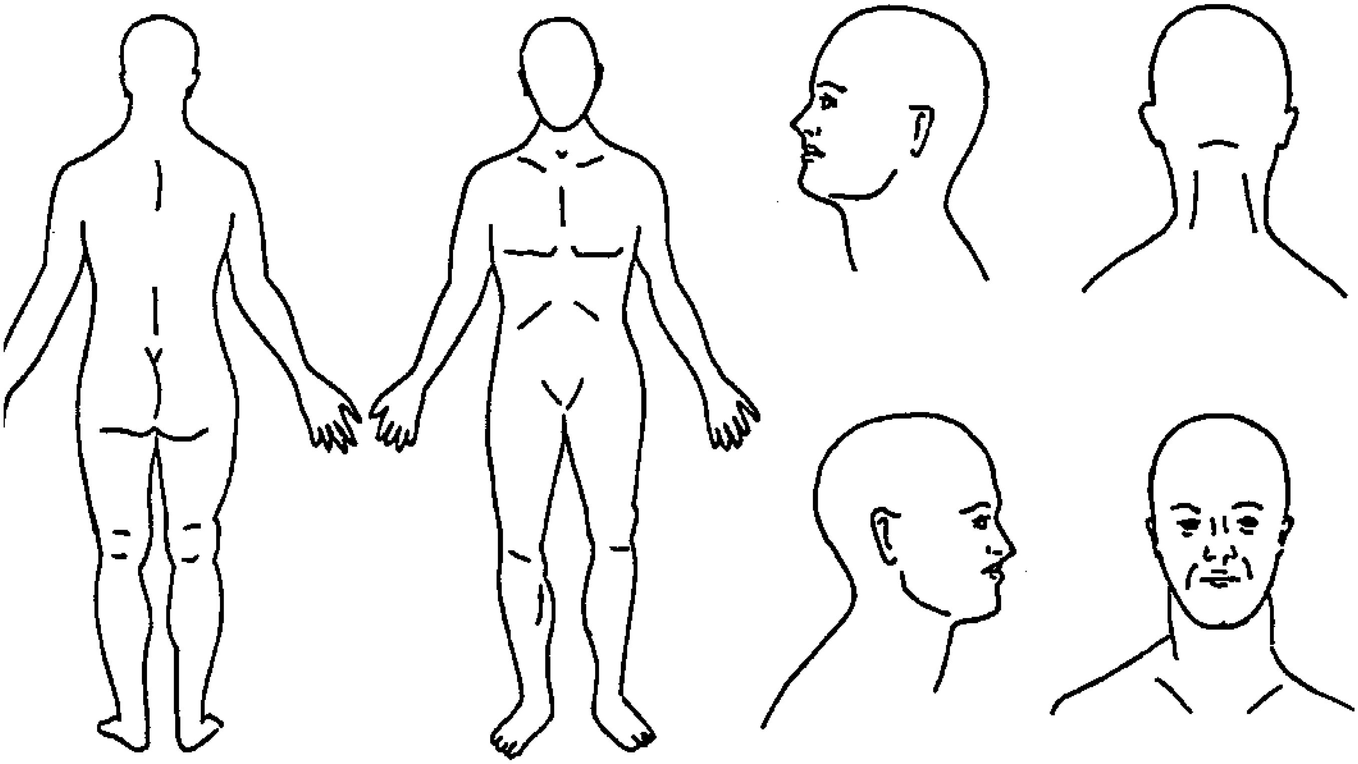
Air Temperature: (°F) ....

Illustrate all visible injuries (cuts, abrasions, fractures, etc.)

....

....

....



Courses and Agency

Swimming Experience: **Years** ......

Skindiving Experience: **Years** ......

Scuba Experience: **Years** ......

(1) .... Certification Date ....

(2) .... -DO- ....

(3) .... -DO- ....

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 N

DIVER INJURY DIAGNOSIS KEY

Symptom/Sign	Circumstances	Probable Injury	Management
Bleeding/external ear	Ear pain during descent/ascent	Ruptured eardrum	Terminate diving; nothing in ear; avoid contamination; medical attention.
Bleeding/external ear	Hit head	Fractured skull	Keep victim lying down and inactive; keep warm; <u>no</u> fluid; do not elevate feet; constant attendance; immediate medical attention.
Spitting blood	Ear pain during or following descent/ascent	(1) Ruptured eardrum	See Above (Ruptured Eardrum)
		(2) Middle ear squeeze	Terminate diving; medical attention if drainage/discomfort persist.
Spitting/coughing blood; bloody froth	Emergency ascent	Pulmonary injury; possible air embolism	Observe for illness and signs of neurological damage (visual disturbances, paralysis, personality changes,etc.); head down 30° incline position; oxygen; medical attention; transport to recompression facility.
Bloody discharge/ nose	Pain in sinuses during ascent/ descent	Sinus squeeze (or reverse sinus squeeze)	Terminate diving; medical attention if drainage/discomfort persist.
Chest pain/ breathing	Emergency/ uncontrolled ascent; chest congestion prior to dive	Pneumothorax /mediastinal emphysema/ subcutaneous emphysema	See Air Embolism

Neurological abnormalities including: Loss of balance/ coordination Visual disturbance Rigidity/numbness of extremities Voice changes Paralysis Personality changes	Emergency/ uncontrolled ascent; chest congestion prior to diving; smoker; symptoms dramatic and sudden; inadequate decompression	Air embolism or decompression sickness	30° incline position; oxygen; medical transport to recompression facility; CPR if indicated; never leave victim unattended.
Bluish coloration	Emergency/uncontrolled ascent; chest congestion prior to dive; chest pain following dive	Pneumothorax/mediastinal emphysema	See Air Embolism
Swelling in neck area	Emergency/ uncontrolled ascent; chest congestion prior to dive; chest pain following dive	Subcutaneous emphysema	See Air Embolism
Unconsciousness	Occurs while or shortly after surfacing from a dive	Air embolism or decompression sickness	See Air Embolism
Respiratory or cardio arrest	Occurs while or shortly after surfacing from a dive	Air embolism or decompression sickness	See Air Embolism
Pain in joints or extremities	Occurs shortly after surfacing from a dive near or beyond no-decompression limits	Decompression sickness	See Air Embolism (if air embolism is ruled out, 30° incline not necessary)
Unusual fatigue	Occurs shortly after surfac- from a dive near or beyond no-decompression limits	Decompression sickness	See Air Embolism (If air embolism is ruled out, 30° incline not necessary)

Bluish coloration	Lose consciousness during dive; closed circuit or mixed gas scuba used	CO_2 Excess or Hypoxia	Surface; resuscitation; oxygen; medical attention; do not exclude air embolism
Reddish coloration	Lose consciousness during or after dive	CO Poisoning	See CO_2 excess; oxygen until turned over to physician; monitor continuously
Pulmonary	Oil taste	Oil Pneumonia	Medical attention

MICHIGAN SEA GRANT PROGRAM

APPENDIX O

Reference Report

Management of Injuries Caused by Marine Organisms

by

Lee H. Somers

and

Martin J. Nemiroff

October 1979

MICHU-SG-79-604

MANAGEMENT OF INJURIES CAUSED BY MARINE ORGANISMS

by

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MICHU-SG-79-604

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MANAGEMENT OF MARINE LIFE INJURIES

Lee H. Somers, Ph.D.*
Martin J. Nemiroff, M.D.**

INTRODUCTION

According to a survey conducted by the Michigan Sea Grant Program, it is estimated that nearly 40% of the divers in Great Lakes states travel to the Bahamas, Caribbean, or the Florida Keys annually. An increasing number of recreation divers are also vacationing in the South seas. Consequently, recognition of hazardous forms of tropical marine life and proper first aid management of injuries resulting from contact with these animals must be included in all basic scuba diving courses.

Unfortunately, the procedures for managing tropical marine life injuries are unclear or incomplete in many diving texts and manuals. This is especially true for animals common to Australia and the South Sea islands. Some instructors and guides emphasize "local" or "personal" remedies that have little or no medical validity. Others recommend use of seemingly unorthodox first aid "substances" without explaining the basis for their use; i.e., meat tenderizers. The instructors presentation of "acceptable" first aid procedures is further complicated by "lack of agreement" among tropical marine life authorities and authors. For this paper we have selected the following six books or pamphlets as our principle resources:

(1) Anonymous, Danger: Stingers, (Queensland State Centre: Queensland Surf Life Saving Association, 1975).

(2) Anonymous, The NOAA Diving Manual (Washington: U.S. Government Printing Office, 1975).

(3) Edmonds, C., Lowry, C., and Pennefather, J., Diving and Subaquatic Medicine (Mosman, N.S.W., Australia: Diving Medical Centre, 1976).

(4) Halstead, B., "Hazardous Marine Life," pp. 227-256 in Strauss, R., Diving Medicine (New York: Grune and Stratton, 1976).

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**Department of Internal Medicine, University of Michigan Medical Center, Ann Arbor, Michigan, 48109.

(5) Somers, L., Research Diver's Manual, (Ann Arbor, Michigan: University of Michigan Press, 1972).

(6) Williamson, J., Some Australian Marine Stings and Envenomations, (Queensland State Centre: The Surf Life Saving Association of Australia, 1974).

In the text of this paper reference to information sources will be indicated by the numbers given above.

I have not attempted to discuss marine life recognition and injury prevention techniques. Such information is readily available in diving manuals (5). Rather, I have limited my discussion to first aid and injury management.

STINGS

Most marine animals that inflict injury by stinging belong to the phylum Coelenterata. This phylum includes about 10,000 species in three major classes: Hydrozoa (hydroids, fire coral, and Portuguese Man-of-War), Scyphozoa (jellyfish), and Anthozoa (anemones and corals). Although all coelenterates have stinging tentacles, only about 70 species have been involved in human injuries. However, over 90 percent of the venomous wounds and stings suffered by divers are from this phylum.

Coelenterates are characterized by their unique stinging cells, or nematocysts, which are situated in the outer layer of tentacle tissue. This apparatus consists of a trigger hair, which, when touched, activates a spine, followed by a hollow thread through which a paralyzing drug is injected into the victim. When a diver brushes against or becomes entangled in the tentacles of some coelenterates, thousands of tiny nematocysts may release their stinging mechanism and inject venom.

Symptoms produced by these stings will vary according to species and specimen size, locality, extent and duration of contact, and individual reaction variations. Symptoms may range from a mild prickly or stinging sensation to a throbbing pain which may render the victim unconscious and induce respiratory arrest. The pain may be localized or radiate to the armpit, groin, or abdomen. Local redness may be followed by inflammatory swelling, blistering, or minute skin hemorrhage. There may be shock, muscular cramps, loss of sensation, nausea, vomiting, severe backache, frothing of the mouth, constriction of the throat, loss of speech, breathing difficulty, respiratory/cardiac arrest, paralysis, delirium, convulsions, and possibly, death. Please note that these severe symptoms are generally limited to encounters with only a few species such as the "Box Jellyfish" or "Sea Wasp" (Chironex fleckeri) or extensive exposure to tentacles of others such as the Portuguese man-of-war. However, an encounter with any jellyfish may cause discomfort.

Common Non-Fatal Jellyfish Stings

Jellyfish commonly encountered by swimmers and divers include:

Sea nettle (Dactyloentra quinquecirrha)
Sea blubber or hair jelly (Cyanea sp.)
Carybdeid medusea (Carybdea sp. and Carukea barnesi)
Little mauve stinger (Pelagia sp.)

These and similar species are considered as non-life threatening in healthy individuals, but are capable of producing unpleasant constitutional disturbances, especially in the elderly. Most diving instructors also include the Portuguese man-of-war (Physalia physalis) and purple sail (Velella velella) in the discussion of jellyfish. Technically, these species belong to a different class of animals (Hydrozoa instead of Scyphozoa) along with fire coral (Millepora sp.). However, management of the hydrozan stings is basically the same as that for jellyfish stings.

The basic first aid procedures for common jellyfish and hydrozan stings is as follows:

1. Inflate the victim's buoyancy unit and remove the victim from the water immediately.

2. Immediately douse the area of the sting with liberal amounts of alcohol (common rubbing alcohol or methylated spirits); avoid splashing into eyes, nostrils, mouth or other mucus membrane (genital area, anus, etc.). Do not wash a jellyfish sting with water. Freshwater has an osmotic effect on the nematocysts causing them to discharge. Do not use petroleum products (gasoline, kerosene, etc.) or beer. Beer has the same effect as water.

3. Lay the victim down and keep him as quiet and as motionless as possible. Be alert for symptoms of shock (glassy eyes; dilated pupils; wet, clammy skin; weak and rapid pulse; pale or ashen gray skin; sensations of coldness; etc.) and take appropriate measures as indicated by the victim's condition. Maintain a calm, confident manner and reassure the victim frequently.

4. Using a blunt edge (e.g., a piece of wood) lift or scrape off any adhering tentacles, but only after application of the alcohol. Do not rub the sting area with wet sand. This will bring more stinging cells into contact with the skin and stimulate blood circulation in the area ensuring more rapid absorption of the venom. Also, avoid personal contact with the tentacles.

5. Some authorities recommend the use of meat tenderizer to denature the poisonous protein. The meat tenderizer may be liberally sprinkled on the alcohol moist Meat tenderizer contains the protein dissolving enzyme "papain." Leave the meat tenderizer on the sting area for several minutes; rinse with alcohol and allow to dry.

6. If available, apply an anesthetic and/or antihistamine cream or spray gently, with minimal rubbing.

7. Use simple pain relief measures, e.g., aspirin tablets or equivalent (see dosage directions on container).

8. Pain relief may require qualified medical aid. Contact a physician if the sting is extensive or the victim is severely distressed.

Some authorities recommend the use of dilute ammonia, various non-irritant fluids having a high alcohol content (e.g., after shave lotion), weak formalin solution (5 to 10 percent), sodium bicarbonate, etc., as acceptable substitues for, or instead of, alcohol. Alcohol is the fluid of choice because of its inexpensiveness, general availability, and acknowledged effectiveness for the purpose. Alcohol is also an excellent diver's multi-purpose substance being useful as an ear rinse, general disinfectant, and rinsing agent for seawater flooded cameras or strobes.

Some manuals recommend thorough cleansing of the sting area with antibacterial soap and water (2,5). However, Australian authorities specifically state that the affected area must not be washed with soap or water for 24 hours (1,6). The liberal use of alcohol should provide sufficient cleansing of the wound area. I recommend that diving instructors follow those procedures recommended by the Australians in this respect.

Naturally, all stings will not result in severe reactions or require considerable first aid. For example, fire coral stings do not involve tentacle removal and some small jellyfish stings may give only minor, momentary irritation. After minor encounters the diver may continue the dive. However, divers and their buddies must maintain an "awareness" for more serious reactions. In rare cases, respiratory/cardiac arrest may occur and require immediate life saving action.

Potentially Fatal Jellyfish Stings

The Box Jellyfish or Sea Wasp (*Chironex flecheri*) is the most dangerous known stinging animal in Australian and South East Asian waters. Although records are far from complete, at least forty fatalities have been recorded on Australian beaches(6). Examination of records shows that one third of the fatal cases are said to have died within three minutes or less of the sting. However, this historical "death within seconds" phenomenon is now questioned by modern authorities. The fact remains that death can occur within minutes and immediate first aid is required. A specimen 7 cm in diameter is capable of killing a healthy child, while a specimen 10 cm or larger in diameter may kill an adult. The following first aid procedure is recommended (1,3,4,6):

1. Remove the victim from the water immediately. *Avoid* personal contact with any adhering tentacles. If at all possible, *do not* allow injured area and tentacles to come into contact with sand or boat surfaces. Such contact may bring more sting cells in contact with the skin and cause the release of more venom.

2. *Immediately* and *thoroughly* douse the sting area and tentacles with liberal amounts of alcohol (methylated spirits).

3. Isolate the envenomed part, if on limbs, from general circulation as soon as possible. A tourniquet should be applied in the middle of the upper arm or thigh above the injury using the most suitable form of binding applied at a pressure sufficient to stop the flow of blood (pulse). This should be kept in place for 1½ hours or until anti-venin has been given, medical attention received and/or the patient is conscious and breathing normally (1). Most United States authorities on first aid maintain that once applied, the tourniquet should be removed only by medical personnel. Tourniquet shock caused by loosening a tourniquet, can be fatal in itself. Note time of day that tourniquet is applied.

4. Give mouth-to-mouth artificial respiration if the victim has stopped breathing. Cardiopulmonary resuscitation is needed when no obvious pulse is detected. Proceed immediately with routine resuscitation procedures, as indicated. Do not interrupt or delay this aspect of the first aid for any reason if an unconscious patient requires it. requires it. Do not give up on resuscitation procedures until advised to do so by a physician or qualified medical personnel, you are physically unable to continue or the victim recovers. Apply tourniquets concurrently, if not working alone.

5. Remove any remaining tentacles by irrigating the area with more alcohol. Do not handle or rub the tentacles unless removal by irrigation technique is unsuccessful.

6. Oxygen breathing is recommended if equipment is available.

7. Send for medical aid and antivenin equipment. The Australians emphasize not moving a seriously affected victim.

8. Maintain constant observation and keep the victim quiet even if his or her condition improves significantly.

9. Transfer responsibility for patient to qualified medical or ambulance personnel upon

A Sea Wasp antivenin has been developed by the Commonwealth Serum Laboratories, Melbourne, Australia. Antivenin should be administered to any victim of suspected Sea Wasp envenomation who, following the above first aid measures, continues to have difficulty in breathing, swallowing, or speaking, or is in severe pain. The antivenin should not be used for minor stings (4). The decision to use antivenin and the injection must be made by medically qualified/specifically trained persons.

Sponge Injuries

Some sponges will produce skin irritation and, in some cases, symptoms similar to non-fatal jellyfish stings. If symptoms appear after handling sponges, follow the same procedure as for non-fatal jellyfish stings. There appear to be no specific instructions in the literature for management of sponge "stings."

VENOMOUS PUNCTURE WOUNDS

Venomous puncture wounds may be inflicted by sting rays, cat fish, weeverfish, and scorpionfish (Zebrafish, Scorpionfish proper, and Stonefish) and numerous other kinds of venomous fish. The common sting ray and Scoprionfish (Scorpaena sp.) are probably the kinds most commonly encountered by Caribbean divers.

In general, the venom apparatus of the sting ray consists of a serrated spine with an enveloping sheath of skin and the caudal (tail area) appendage to which the spine is attached. The spine is edged on either side by a series of sharp retrorse (bent downward) teeth. Along either edge, on the underside of the spine, there is a deep groove. These grooves contain venom glands which are covered by the skin sheath.

Sting ray wounds are of either the puncture or laceration type. The menace is most serious to persons wading or crawling on the bottom in shallow, protected, sand bottom waters. When contacted, the ray strikes upward with its tail and may drive the spine deeply into the foot or leg. This usually produces a ragged, dirty wound or puncture wound. The wound usually causes immediate and severe pain. Swelling of the wound area is accompanied by an ashy appearance which later turns red. Symptoms of shock along with fainting, nausea, and weakness may follow, depending upon the severity of the injury and the species of sting ray.

Anatomically, the venom organs of venomous fish differ from one group to the next. Generally, the venom organs consist of the dorsal, pelvic, and anal fins, and their associated venom glands. Venom glands are located in the outer skin or sheath of the spine.

The pain from venomous fish stings is usually described as immediate, intense, sharp, shooting, or throbbing, and radiates from the affected part. The pain may be so severe from some species that the victim will lose consciousness. A large spectrum of symptoms including headache, fever, chills, delirium, nausea, vomiting, sweating, convulsions, respiratory distress, and cardiac failure have been noted in the literature.

Every species of the genus Conus (cone shells) produces a venom and most have a fully developed venom delivery apparatus near the shell opening. The venom varies considerably with species and only about 6 of the 500 species are considered deadly to man. The sting of a Conus usually produces a numbness, tingling, or burning sensation which may spread rapidly and become particularly pronounced about the lips and mouth. In severe cases, paralysis and coma may be present. Deaths are believed to result from cardiac failure.

Tetanus bacteria are often found in marine organisms and may infect a victim's wound, particularly deep punctures. Divers should be certain to have not only tetanus, but other immunications as well up-to-date.

Basic first aid for venomous fish injuries includes the following:

1. Provide immediate surface flotation and remove the victim from the water as soon as possible.

2. Pain will be severe. Have victim lie down and apply measures to prevent/manage shock. Keep affected limb level with the body and as still as possible to minimize spread of the venom.

3. Irrigate open wound areas with sterile saline solution, if available, or cold salt water or fresh water. Remove spine and debris, if visible.

4. Puncture wounds are small in size and removal of venom is difficult. Several authors state that the use of a ligature (tourniquet) is of questionable value (3,4). The use of the ligature is generally discouraged for basic first aiders.

5. Although many diving manuals recommend that first aiders should make a small incision across the wound in order to promote bleeding and irrigate it satisfactorily, Halstead (4) indicates that the incision may be of "limited" value and Edmonds (3) doesn't even refer to it in his discussion of first aid. Other authors (2,6) recommend making a small incision at the site of the wound and use of suction (suction device like the one found in snake kits, not by mouth). In light of modern trends in first aid, and the "potentially limited value" of the incision method indicated by physicians (3,4), I am inclined to not recommend this procedure unless future evidence supports its benefit.

6. Immerse the affected area in as hot of water as the victim can tolerate (up to 50°C/122°F) for 30 minutes. This may produce rapid pain relief and neutralize the venom. Be careful not to scald the tissue; immerse adjacent unaffected skin. Use hot compresses if immersion is impractical or impossible. Immersion in hot water appears to be the most important first aid procedure universally agreed upon by authors/authorities.

7. Qualified medical assistance should be obtained as soon as possible.

Some manuals suggest that cone shell injuries be managed the same as venomous fish stings (2). Edmonds (3) suggests that use of a ligature with incision and removal of venom, as in treatment of snake bite, may be of value if performed early. This procedure is also supported by Williams (6). In light of recommendations in the literature the following procedure should be considered for managing cone shell injuries:

1. Provide immediate surface flotation and remove the victim from the water as soon as possible.

2. Lay the victim down and take appropriate measure to prevent/manage shock. Elevate the affected limb if possible.

3. Apply a tourniquet above the wound site (see instructions under Sea Wasp stings).

4. Sterilize area (and instrument) and make a small incision over the wound. Apply suction with a suction device (like snake bite kit), not by mouth, to encourage bleeding. This procedure should be started as soon as possible.

5. Paralysis and respiratory failure may occur. Make routine observations of respiration and circulation continuously. Employ mouth-to-mouth resuscitation or CPR if and when indicated.

6. Obtain medical assistance as soon as possible.

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. However, at least one species can be found in the Gulf of California. No fatalities have been associated with octopus species found in the Caribbean and Florida Keys. Since octopus bites are extremely rare, little or no reference to specific first aid is given in the literature except for the blue-ring octopus.

Sea Snake Bites

Sea snake venom is approximately 2-10 times as toxic as that of land snakes. However, they deliver less of it and only about one-quarter of those bitten by sea snakes show signs of poisoning. Only a few of the some 50 species are considered of significant danger to humans.

There may be no pain or reaction at the site of the bite. Symptoms progress from mild to severe, generally beginning with an ill feeling or anxiety, thickening of the tongue, muscular stiffness, and aching. Late symptoms include shock, general weakness, paralysis, thirst, muscle spasms, respiratory difficulties, convulsions and unconsciousness. Deaths have been reported. Sea snake venom appears to block neuromuscular transmission, inducing a generalized and painless skeletal paralysis.

Modern trends in first aid for venomous snake bites exclude the use of the tourniquet-incision-suction procedure (American Red Cross). However, most authorities still recommend the use of a constricting bandage above the bite (2,3,4,6). Halstead (4) states that a tourniquet should be applied tightly enough to occlude the superficial venous and lymphatic return. It should be released 90 seconds every 10 minutes. The constricting band must be applied early, less than 30 minutes following the bite. Do not apply tightly enough to interrupt arterial flow (2). Incision and suction are of value only if applied within the first few minutes (3) and only Williamson (6) specifically states that first aid should include the procedure. The following first aid management for a sea snake bite is suggested:

1. Immediately provide surface flotation and remove the victim from the water as soon as possible.

2. Lay the victim down and take appropriate measures to prevent/manage shock.

3. Immobolize the affected limb and avoid all exertion.

4. Apply a constricting bandage above the wound site to restrict superficial venous and lymphatic return, not arterial flow. Release 90 seconds every 10 minutes and do not use for more than 4 hours (4).

5. Maintain victim under constant observation. Mouth to mouth respiration/CPR must be started immediately if indicated.

6. Acquire medical assistance as soon as possible. Antivenin is available for some species.

7. If possible, capture the snake or make positive identification of species by recording an accurate description.

Blue-Ringed Octopus Bite

The blue-ringed octopus (*Octopus maculosa* or *Hapalochlaena maculosa*) is found only in the Australian and Central Indo-Pacific region. The venom of this octopus is a neurotoxin and a neuromuscular blocker, resulting in painless muscular paralysis. Other symptoms include dryness of the mouth; abnormal sensations around mouth, neck and head, respiratory distress; nausea and/or vomiting and so on.

The following first aid procedures are recommended:

1. Provide immediate surface flotation and remove the victim from the water as soon as possible.

2. Lay the victim down and take appropriate measures to prevent/manage shock. Place victim on side in case of vomiting.

3. Apply a constricting bandage between the wound site and the heart (2,3).
4. Make a small incision over the wound and encourage bleeding (3,6).

5. Maintain the victim under constant observation. Immediately start artificial respiration/CPR if indicated.

6. Do not leave victim unattended for any reason.

7. Reassure the patient who may hear but cannot communicate.

8. Obtain medical assistance as soon as possible.

The bite of the common octopus should be managed as a venomous puncture. Heat may be beneficial in reducing pain.

NON-VENOMOUS BITES

The moray eel, 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 the moray eel and barracuda, require first aid procedures for lacerations. Consider the following:

1. Provide immediate flotation and remove the victim from the water as soon as possible.

2. Lay victim down and take appropriate measures to prevent/manage shock.

3. Elevate the affected limb and apply direct pressure to the wound to control bleeding. Use a sterile dressing, if available.

4. Obtain medical assistance as soon as possible.

5. If there is a delay in medical care and bleeding is controlled, scrub the wound with warm water and antibacterial soap and cover with a sterile dressing.

Shark bites are frequently much more severe with massive tissue damage and profuse bleeding. In many cases immediate application of a tourniquet will be required to stop life-threatening blood loss.

ABRASION, LACERATION AND PUNCTURE WOUNDS

Abrasions and lacerations are common among divers. Such injuries may result from careless contact with beach rock, boat hardware, docks, corals, barnacles and so on. Puncture wounds resulting from contact with sea urchins are probably responsible for the largest percentage of marine life associated diver injuries.

Cuts and Abrasions

First aid management of cuts and abrasions is extremely important, especially in tropical areas. Secondary infection is a major concern in marine life injuries. Often wounds are ragged and dirty. Diving and life styles in the tropics promote continuous contamination of the wound and retard healing. The following first aid measures should be considered:

1. Immediately cleanse wound with hot water and antibacterial soap. Specific antibacterial soaps may be obtained using a prescription from your physician. Dial soap has been recommended as an "off the shelf" substitute.

2. Promote free bleeding.

3. Remove all visible debris; excessive probing can cause unnecessary tissue damage. Deeply embedded materials may require medical removal.

4. Cleanse wound area again, rinse with sterile water and gently dry with a sterile pad (or air dry).

5. Keep the wound dry, at least when not diving. Cleanse and change dressing as soon as possible upon returning from a dive. Even minor wounds can become seriously infected.

6. The use of antiseptic creams, disinfectants, etc. is a matter of personal preference.

7. Medical attention may be required to cleanse and close serious cuts and/or to arrest infection. Tetanus is a possibility in marine environment wounds.

Sea Urchin Spines

The common sea urchin of the Florida Keys and Caribbean has long, brittle spines and produces a painful puncture-type wound with redness and swelling. The fragments of the spines will produce a purple skin discoloration in the area of the wound. In minor injuries, the spines will dissolve with few complications besides minor pain. However, most spines will cause irritating discomfort of long duration if not removed. Superficial spines can be removed with fine tweezers or a small needle (sterilized), the area thoroughly scrubbed with soap and water, and a sterile dressing applied. Medical services will be required to remove numerous and/or deeply embedded spines. Also, consult a physician if symptoms of infection or other complications appear.

Bristleworm Injuries

Contact with the bristles of the bristleworm may produce inflammation, swelling, and numbness. Bristles can be removed from the skin of the victim using adhesive tape and alcohol should be applied to the area to alleviate discomfort.

CONCLUSION

Prevention of injuries is the best policy. Through proper diving techniques, buoyancy control, environment familiarity, and common sense precaution most diving injuries can be prevented. Carelessness and improper diving techniques lead to injury. Do not handle marine organisms that you are unfamiliar with and do not take chances with those which you know can inflict injury.

Most divers are unprepared to administer proper first aid. Generally, they simply lack the proper "tools." A review of the procedures given in this paper indicates that a properly equipped tropical diver should include the following items in a personal or group kit:

1. Large bottle of alcohol (at least one pint);
2. Antibacterial soap;
3. Tweezers/needles/surgical blade;
4. Constricting band;
5. Sterile dressings and bandaids (ample supply of assorted sizes);
6. Metal first aid kit container (with a water-tight cover) that can be used for heating water and large enough to allow immersion of an injured hand or foot;
7. Canned heat and waterproof matches for heating water;
8. Aspirin;
9. Adhesive tape;
10. Meat tenderizer;
11. Anaesthetic and/or antihistamine cream; and
12. Snake bite kit suction device.

All divers should complete a basic/advanced first aid course. Whenever diving in an unfamiliar area, the diver must consult with local divers, professional lifeguards, diving instructors or other knowledgeable authorities regarding potentially hazardous marine life and first aid for specific marine life injuries.

There is still much to be learned regarding first aid for marine life injuries. Changing trends in modern basic first aid practices raise questions regarding "acceptable" procedures for managing a marine life injury. For example, authorities now disagree on the use of a tourniquet as a first aid procedure for venomous land snake bites. Several marine life/diving medicine authorities specifically emphasize the use of a tourniquet. There are also discrepancies in the tourniquet management. Who is right?

Some diving instructors in the United States are quick to condemn the first aid procedures specified by Australian authorities. However, North American divers do not live daily with the potential serious consequences of injuries inflicted by such animals as the sea wasp, the blue-ringed octopus and sea snakes. We must acknowledge the opinion of those persons who deal with these animals on a routine basis. Diving instructors and divers must remain abreast of new developments in first aid. Efforts must be made to establish universally accepted procedures. In the meantine, United States divers must know what first aid practices to expect when working with divers from foreign countries.

APPENDIX P

REPETITIVE DIVE WORKSHEET

I. PREVIOUS DIVE:

_____ minutes ☐ Standard Air Table

_____ feet ☐ No-Decompression Tab.

_____ repetitive group designation

II. SURFACE INTERVAL:

_____ hours _____ minutes on surface.

Repetitive group from I _____

New repetitive group from surface

Residual Nitrogen Timetable _____

III. RESIDUAL NITROGEN TIME:

_____ feet (depth of repetitive dive)

New repetitive group from II. _____

Residual nitrogen time from

Residual Nitrogen Timetable _____

IV. EQUIVALENT SINGLE DIVE TIME:

_____ minutes, residual nitrogen time from III.

+ _____ minutes, actual bottom time of repetitive dive.

= _____ minutes, equivalent single dive time.

V. DECOMPRESSION FOR REPETITIVE DIVE:

_____ minutes, equivalent single dive time from IV.

_____ feet, depth of repetitive dive

Decompression from (check one):
☐ Standard Air Table ☐ No-Decompression Table
☐ Surface Table Using Oxygen ☐ Surface Table Using Air
☐ No decompression required

Decompression Stops: _____ feet _____ minutes
_____ feet _____ minutes
_____ feet _____ minutes
_____ feet _____ minutes
_____ feet _____ minutes

Schedule used _____

Repetitive group _____

NOTES:

APPENDIX Q

STATE OF MICHIGAN
THE
DEPARTMENTS OF PUBLIC HEALTH AND LABOR

STANDARD FOR DIVING OPERATIONS

STATE OF MICHIGAN
THE
DEPARTMENTS OF PUBLIC HEALTH AND LABOR

a standard for
DIVING OPERATIONS
promulgated by
THE OCCUPATIONAL HEALTH STANDARDS COMMISSION
THE CONSTRUCTION SAFETY STANDARDS COMMISSION
and
THE GENERAL INDUSTRY SAFETY STANDARDS COMMISSION
by authority of
Act 154 of the Public Acts of 1974, as amended

Part 3. R 325.50301 to R 325.50348 — Occupational Health Standards Commission
Part 31. R 408.43101 to R 408.43162 — Construction Safety Standards Commission
Part 79. R 408.17901 to R 408.17903 — General Industry Safety Standards Commission

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9 Pages

DEPARTMENT OF PUBLIC HEALTH
OCCUPATIONAL HEALTH STANDARDS COMMISSION
OCCUPATIONAL HEALTH STANDARDS

Filed with the Secretary of State on May 31, 1979
These rules take effect 15 days after filing with the Secretary of State

(By authority conferred upon the occupational health standards commission by section 24 of Act No. 154 the Public Acts of 1974, as amended, being § 408.1024 of the Michigan Compiled Laws)

Rules of the occupational health standards commission entitled "Occupational Health Standards" are amended by adding R 325.50301 to R 325.50348 to read as follows:

PART 3. DIVING OPERATIONS

TABLE OF CONTENTS

GENERAL PROVISIONS

R 325.50301. Applicability.

Rule 301. These rules apply to diving and related support operations. These rules do not apply to any diving operation performed solely for recreational instruction purposes using open-circuit, compressed-air SCUBA and conducted within the no-decompression limits.

R 325.50302. Deviations from rules; emergencies, duty to notify.

Rule 302. An employer may deviate from the requirements of these rules to the extent necessary to prevent or minimize a situation that is likely to cause death, serious physical harm, or major environmental damage, provided that the employer complies with the following:

(a) Notifies the department of labor within 72 hours of the onset of the emergency situation indicating the nature of the emergency and extent of the deviation from these rules.

(b) Upon request from the department of labor or the department of public health, submits such information in writing.

R 325.50303. Duties as employer.

Rule 303. An employer shall be responsible for compliance with the following:

(a) All provisions of these rules of general applicability.

(b) All requirements pertaining to specific diving modes to the extent diving operations are conducted in such modes.

R 325.50304. Definitions; A to C.

Rule 304. As used in these rules:

(a) "Acfm" means actual cubic feet per minute.

(b) "ATA" means atmosphere absolute.

(c) "Bell" means an enclosed compartment, a pressurized, closed bell, or an unpressurized, open bell, that allows the diver to be transported to and from the underwater work area and which may be used as a temporary refuge during a diving operation.

(d) "Bottom time" means the total elapsed time, measured in minutes, from the time when a diver leaves the surface in descent to the time that the diver begins ascent.

(e) "Bursting pressure" means the pressure at which a pressurized device would fail structurally.

(f) "Cylinder" means a pressure vessel for the storage of gases.

R 325.50305. Definitions; D.

Rule 305. As used in these rules:

(a) "Decompression chamber" means a pressure vessel for human occupancy such as a surface decompression chamber, pressurized bell, or deep diving system used to decompress a diver and to treat decompression sickness.

(b) "Decompression sickness" means a condition with a variety of symptoms that may result from gas or bubbles in the tissues of a diver after pressure reduction.

(c) Decompression table' means a profile or set of profiles of depth-time relationships for ascent rates and breathing mixtures to be followed after a specific depth-time exposure or exposures.

(d) "Dive location" means a surface or vessel from which a diving operation is conducted.

(e) "Dive-location reserve breathing gas" means a volume tank or an independent supply of air or mixed gas at the dive location sufficient under standard operating conditions to allow the diver to reach the surface.

(f) "Dive team" means divers and support employees involved in a diving operation, including the designated person in charge.

(g) "Diver" means an employee in the water using underwater apparatus that supplies compressed breathing gas at the ambient pressure.

(h) "Diver-carried reserve breathing gas" means a diver-carried supply of air or mixed gas sufficient under standard operating conditions to allow the diver to reach the surface, a bell, or to be rescued by a standby diver.

(i) "Diving mode" means a type of diving requiring specific equipment, procedures, and techniques, such as SCUBA, surface-supplied air, or mixed gas.

R 325.50306. Definitions; F to M.

Rule 306. As used in these rules:

(a) "Fsw" means feet of seawater or equivalent static pressure head.

(b) "Heavy gear" means diver-worn deep-sea dress, including helmet, breast-plate, dry suit, and weighted shoes.

(c) "Hyperbaric conditions" means pressure conditions in excess of surface pressure.

(d) "Inwater stage" means a suspended underwater platform that supports a diver in the water.

(e) "Liveboating" means the practice of supporting a surface-supplied air or mixed gas diver from a vessel that is underway.

(f) "Mixed gas diving" means a diving mode in which a diver is supplied in the water with a breathing gas other than air.

R 325.50307. Definitions; N to S.

Rule 307. As used in these rules:

(a) "No-decompression limits" means a combination of the depth of a dive and bottom time that permits a diver to return to the surface without decompression, as expressed in the U.S. navy diving manual. The U.S. navy diving manual, volume No. 1, air diving, 1973, as amended to December, 1975, and volume No. 2, mixed gas diving, 1973, as amended through December, 1975, are incorporated herein by reference and may be inspected at the Lansing office of the Michigan department of public health. The manual may be purchased at a cost of $3.25 for each volume by ordering from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, or from the Michigan Department of Public Health, 3500 North Logan, Box 30035, Lansing, Michigan 48909.

(b) "Psig" means pounds per square inch, gauge.

(c) "Qualified employee" means one who, by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter, the work, or the project.

(d) "SCUBA diving" means a diving mode independent of surface supply in which a diver uses open circuit, self-contained, underwater breathing apparatus.

(e) "Standby diver" means a diver at the dive location available and in a sufficient state of readiness to assist a diver in the water.

(f) "Surface-supplied air diving" means a diving mode in which the diver in the water is supplied from the dive location with compressed air for breathing.

R 325.50308. Definitions; T to W.

Rule 308. As used in these rules:

(a) "Treatment table" means a depth-time and breathing gas profile used in the treatment of decompression sickness.

(b) "Umbilical" means the composite hose bundle between a dive location and a diver or bell, or between a diver and a bell, which may supply a diver or bell with breathing gas, communications, power, and heat, and may include a safety line.

(c) "Volume tank" means a pressure vessel connected to the outlet of a compressor and used as an air reservoir.

(d) "Working pressure" means the maximum pressure to which a pressure containment device may be exposed under standard operating conditions.

R 325.50309. Dive team; training and experience.

Rule 309. (1) An employer shall assure that a dive team member has the experience and training necessary to perform assigned tasks in a safe and healthful manner. The training and experience shall include the following:

(a) The use of tools, equipment, and systems relevant to assigned tasks.

(b) Techniques of the assigned diving mode.

(c) Diving operations and emergency procedures.

(d) Familiarity with the contents of the safe practices manual required by rule 317.

(2) All dive team members shall be trained in cardiopulmonary resuscitation and first aid by American red cross or equivalent organization.

(3) A dive team member who is exposed to or controls the exposure of others to hyperbaric conditions shall be trained in diving-related physics and physiology.

R 325.50310. Dive team; supervisor designation; assignments; hyperbaric exposure.

Rule 310. (1) An employer or an employee designated by the employer shall be at the dive location in charge of all aspects of the diving operation affecting the health of a dive team member.

(2) The designated person in charge shall have experience and training in the conduct of the assigned diving operation.

(3) Each dive team member shall be assigned tasks in accordance with the employee's experience or training, except that limited additional tasks may be assigned to an employee undergoing training if these tasks are performed under the direct supervision of an experienced dive team member.

(4) An employer shall not require a dive team member to be exposed to hyperbaric conditions against the employee's will, except when necessary to complete decompression or treatment procedures.

(5) An employer shall not permit a dive team member to dive or be otherwise exposed to hyperbaric conditions for the duration of any temporary physical impairment or condition that is known to the employer and is likely to adversely affect the health of a dive team member.

R 325.50311. Medical examination; duty to determine fitness; availability of reports; performance of examination.

Rule 311. (1) An employer shall determine by medical examination whether a dive team member who is, or is likely to be, exposed to hyperbaric conditions is medically fit to perform an assigned task in a safe and healthful manner.

(2) An employer shall make available to each dive team member who is, or is likely to be, exposed to hyperbaric conditions, all medical examinations required by these rules at the employer's cost except as provided in rule 316(2).

(3) All medical examinations required by these rules shall be performed by, or under the direction of, a physician.

R 325.50312. Medical examinations; frequency; following injury or illness.

Rule 312. A medical examination shall be provided as follows:

(a) Prior to initial hyperbaric exposure with an employer, unless an equivalent medical examination has been given within the preceding 12 months, and the employer has obtained the results of the examination and, has obtained an opinion from the examining physician of an employee's medical fitness to dive or to be otherwise exposed to hyperbaric conditions.

(b) At 1-year intervals from the date of initial examination or last equivalent examination.

(c) After an injury or illness requiring hospitalization of more than 24 hours.

R 325.50313. Medical examinations; information provided to examining physician.

Rule 313. An employer shall provide the following information to the examining physician:

(a) A copy of rules 311 to 316, including table I, and the guide to the determination of hyperbaric fitness, which may be obtained from the Michigan department of public health, 3500 North Logan, Box 30035, Lansing, Michigan 48909.

(b) A summary of the nature and extent of hyperbaric conditions to which the dive team member will be exposed, including diving modes and types of work to be assigned.

R 325.50314. Medical examinations; contents; following injury or illness.

Rule 314. (1) Medical examinations conducted initially and annually shall consist of the following:

(a) Medical history.

(b) Diving-related work history.

(c) Basic physical examination.

(d) The tests required by table I.

(e) Any additional tests the physician considers necessary.

(2) Medical examinations conducted after an injury or illness requiring hospitalization of more than 24 hours shall

be appropriate to the nature and extent of the injury or illness as determined by the examining physician.

TABLE I.
TESTS FOR DIVING MEDICAL EXAMINATION

Test	*Initial examination*	*Annual reexamination*
Chest X-ray	X	X
Visual acuity	X	X
Color blindness	X	
EKG: standard 12L	X	X*
Hearing test	X	X
Hematocrit or hemoglobin	X	X
Sickle cell index	X	
White blood count	X	X
Urinalysis	X	X

* To be given to the employee annually, at age 35 and over.

R 325.50315. Medical examinations; physician's report; employee copy.

Rule 315. (1) After any medical examination required by the rules in this part, an employer shall obtain a written report prepared by the examining physician that includes the following:

(a) The results of the medical examination.

(b) The examining physician's opinion of the employee's fitness to be exposed to hyperbaric conditions, including any recommended restrictions or limitations to such exposure.

(2) The employer shall provide an employee with a copy of the physician's written report.

R 325.50316. Medical examinations; determination of employee fitness; restrictions; second opinion; third opinion, assignment pending determination.

Rule 316. (1) An employer shall determine the extent and nature of a dive team member's fitness to engage in diving or to be otherwise exposed to hyperbaric conditions consistent with the recommendations in the examining physician's report.

(2) If the examining physician has recommended a restriction or limitation on the dive team member's exposure to hyperbaric conditions, and the affected employee does not concur, a second physician may be retained to render a medical opinion on the nature and extent of the restriction or limitation, if any. The second physician shall be provided the information required by rule 313.

(3) If the recommendation of the second opinion differs from that of the first examining physician, and if the employer and employee are unable to agree on the nature and extent of the restriction of limitation, an opinion from a third physician selected by the first 2 physicians shall be obtained at the employer's cost. The employer's determination of the dive team member's fitness shall be consistent with the medical opinion of the third physician unless the employer and employee reach an agreement that is otherwise consistent with the recommendation or opinion of not less than 2 of the physicians involved.

(4) Nothing in this procedure shall be construed to prohibit either a dive team member from accepting, or an employer from offering, an assignment that is otherwise consistent with at least 1 medical opinion while a final determination on the employee's fitness is pending.

R 325.50317. Safe practices manual; availability; contents.

Rule 317. (1) An employer shall develop and maintain a safe practices manual that shall be made available to each dive team member at the dive location.

(a) Operating procedures and checklists for diving operations.

(b) Assignments and responsibilities of the dive team members.

(c) Equipment procedures and checklists.

(d) Emergency procedures for fire, equipment failure, adverse environmental conditions, and medical illness and injury.

R 325.50318. Pre-dive procedures; emergency aid.

Rule 318. A list shall be kept at the dive location including a telephone or call number for each of the following:

(a) An operational decompression chamber, if not at the dive location.

(b) Accessible hospitals.

(c) Available physicians.

(d) Available means of transportation.

(e) The nearest U.S. coast guard rescue coordination center.

R 325.50319. Pre-dive procedures; required first aid kit; first aid handbook; oxygen inhalation unit.

Rule 319. (1) A first aid kit, appropriate for the diving operation and approved by a physician, shall be available at the dive location.

(2) When used in a decompression chamber or bell, the first aid kit shall be suitable for use under hyperbaric conditions.

(3) In addition to other first aid supplies, an American red cross standard first aid handbook or equivalent, and an oxygen inhalation unit shall be available at the dive location.

R 325.50320. Pre-dive procedures; health planning and assessment.

Rule 320. (1) Planning of a diving operation shall include an assessment of the safety and health aspects of the following:

(a) Diving mode.

(b) Surface and underwater conditions and hazards.

(c) Breathing gas supply, including reserves.

(d) Thermal protection.

(e) Diving equipment and systems.

(f) Dive team assignments and physical fitness of dive team members, including any impairment known to the employer.

(g) Repetitive dive designation or residual inert gas status of dive team members.

(h) Decompression and treatment procedures, including altitude corrections.

(i) Decompression tables.

(j) Emergency procedures.

(2) Decompression tables, repetitive tables, and no-decompression tables, as appropriate, shall be at the dive location.

R 325.50321. Pre-dive procedures; coordination with other activities.

Rule 321. To minimize hazards to the dive team, a diving operation shall be coordinated with other activities in the vicinity that are likely to interfere with the diving operation.

R 325.50322. Pre-dive procedures; employee briefing; physical fitness inquiry.

Rule 322. (1) A dive team member shall be briefed on all of the following:

(a) The tasks to be undertaken.

(b) Operating procedures for the diving mode.

(c) Any unusual hazards or environmental conditions likely to affect the safety of the diving operation.

(d) Any modifications of operating procedures necessitated by the specific diving operation.

(2) Prior to making individual dive team member assignments, an employer shall inquire into a dive team member's current state of physical fitness, and indicate to the dive team member the procedure for reporting physical problems or adverse physiological effects during and after the dive.

R 325.50323. Pre-dive procedures; communication system.

Rule 323. An operational 2-way voice communication system shall be provided as follows:

(a) At the dive location to obtain emergency assistance.

(b) Between each surface-supplied air or mixed gas diver and a dive team member at the dive location and bell.

(c) Between the bell and the dive location.

R 325.50324. Pre-dive procedures; equipment inspection.

Rule 324. The breathing gas supply system, including reserve breathing gas supplies, masks, helmets, and gauges, and timekeeping devices, thermal protection, and bell handling mechanism, when appropriate, shall be inspected prior to each dive.

R 325.50325. Diving procedures; dive profiles.

Rule 325. A depth-time profile, including, when appropriate, any breathing gas changes shall be maintained at the dive location for each diver during the dive, including decompression.

R 325.50326. Termination of dive.

Rule 326. The working interval of a dive shall be terminated when any of the following occurs:

(a) A diver requests termination.

(b) A diver fails to respond correctly to communications or signals from a dive team member.

(c) Communications are lost and cannot be quickly reestablished between the diver and a dive team member at the dive location, and between the designated person in charge and the person controlling the vessel in a liveboating operation.

(d) A diver begins to use diver-carried reserve breathing gas or the dive-location reserve breathing gas.

(e) When a scheduled work interval has expired.

R 325.50327. Post-dive procedures generally.

Rule 327. An employer shall comply with the following requirements, which are applicable after each diving operation:

(a) Check the physical condition of the diver.

(b) Instruct the diver to report any physical problems or adverse physiological effects including symptoms of decompression sickness.

(c) Advise the diver of the location of a decompression chamber that is ready for use.

(d) Alert the diver to the potential hazards of flying after diving.

(e) Instruct the diver to remain awake and in the vicinity of the dive location for not less than 1 hour after a dive that requires a decompression chamber.

R 325.50328. Post-dive procedures; recording and maintaining information.

Rule 328. (1) The following information shall be recorded and maintained for each diving operation:

(a) Names of dive team members, including designated person in charge.

(b) Date, time, and location.

(c) Diving modes used.

(d) General nature of work performed.

(e) Approximate underwater and surface conditions, such as visibility, water temperature, wind velocity, and current.

(f) Maximum depth and bottom time for each diver.

(2) For each dive for which a decompression chamber is required, the following additional information shall be recorded and maintained;

(a) Depth-time and breathing gas profiles.

(b) Decompression table designation, including any modification.

(c) Elapsed time since last pressure exposure, if less than 24 hours, or repetitive dive designation for each diver.

(3) For each dive in which decompression sickness is suspected or symptoms are evident, the following additional information shall be recorded and maintained:

(a) Description of decompression sickness symptoms, including depth and time of onset.

(b) Description and results of treatment.

R 325.50329. Post-dive procedures; decompression procedure assessment; corrective action; written evaluation.

Rule 329. (1) An employer shall investigate and evaluate each incident of decompression sickness based on the recorded information, consideration of the past performance of decompression table used, and individual susceptibility.

(2) Appropriate corrective action shall be taken by an employer to reduce the probability of recurrence of decompression sickness.

(3) A written evaluation of the decompression procedure assessment, including any corrective action taken, shall be prepared by the employer within 45 days of the incident of decompression sickness.

R 325.50330. SCUBA diving; restrictions.

Rule 330. SCUBA diving shall not be conducted:

(a) At depths greater than 130 fsw.

(b) At depths greater than 100 fsw or outside the no-decompression limits unless a decompression chamber is ready for use.

(c) Against currents exceeding 1 knot unless line-tended.

(d) In enclosed or physically confining spaces unless line-tended.

R 325.50331. SCUBA diving; procedures.

Rule 331. (1) A diver shall be line-tended from the surface, or accompanied by another diver in the water in continuous visual or physical contact during the diving operation.

(2) A standby diver shall be available while a line-tended diver is in the water. The standby diver shall be dressed to enter the water except for fins, mask, and breathing apparatus, which shall be readily available.

(3) A diver shall be stationed at the underwater point of entry when line-tended diving is conducted in enclosed or physically confining spaces.

(4) Each diver shall be equipped with the following functioning equipment:

(a) A low-air supply warning device, or

(b) An independent reserve cylinder with a separate regulator or connected to the underwater breathing apparatus.

R 325.50332. Surface-supplied air diving generally.

Rule 332. (1) Surface-supplied air diving shall not be conducted at depths deeper than 190 fsw, except that dives with bottom times of 30 minutes or less may be conducted to depths of 220 fsw.

(2) A decompression chamber shall be ready for use at the dive location for any dive outside the no-decompression limits or deeper than 100 fsw.

(3) A bell shall be used for dives with an inwater decompression time greater than 120 minutes, except when heavy gear is worn or diving is conducted in physically confining spaces.

R 325.50333. Surface-supplied air diving; procedures.

Rule 333. (1) Each diver shall be continuously tended while in the water.

(2) A diver shall be stationed at the underwater point of entry when diving is conducted in enclosed or physically confining spaces.

(3) Each diving operation shall have a primary breathing gas supply sufficient to support divers for the duration of the planned dive, including decompression.

(4) For dives deeper than 100 fsw or outside the no-decompression limits, the following procedures shall apply:

(a) A separate dive team member shall tend each diver in the water.

(b) A standby diver shall be available while a diver is in the water. A standby surface-supplied diver shall be dressed to enter the water except for helmet or mask and weights, which shall be readily available. A standby SCUBA diver shall be dressed in accordance with rule 331(2).

(c) A diver-carried reserve breathing gas supply shall be provided for each diver except when heavy gear is worn.

(d) A dive-location on-line reserve breathing gas supply shall be provided.

(5) For heavy-gear diving deeper than 100 fsw or outside the no-decompression limits, the following procedures shall apply:

(a) An extra breathing gas hose capable of supplying breathing gas to the diver in the water shall be available to the standby diver.

(b) An inwater stage shall be provided to a diver in the water.

(6) Except when heavy gear is worn or where physical space does not permit, a diver-carried reserve breathing gas supply shall be provided whenever a diver is prevented by the configuration of the dive area from ascending directly to the surface.

R 325.50334. Mixed gas diving generally.

Rule 334. Mixed gas diving shall be conducted only when the following occur:

(a) A decompression chamber when required by rule 341(1)(c) is ready for use at the dive location.

(b) A bell is used at depths greater than 220 fsw or when the dive involves inwater decompression time of greater than 120 minutes, except when heavy gear is worn or when diving in physically confining spaces.

(c) A pressurized bell is used at depths greater than 300 fsw, except when diving is conducted in physically confining spaces.

R 325.50335. Mixed gas diving; procedures; required equipment.

Rule 335. (1) A separate dive team member shall tend each diver in the water.

(2) A standby diver shall be available while a diver is in the water.

(3) A diver shall be stationed at the underwater point of entry when diving is conducted in an enclosed or physically confining space.

(4) Each diving operation shall have a primary breathing gas supply sufficient to support divers for the duration of the planned dive including decompression.

(5) Each diving operation shall have a dive-location on-line reserve breathing gas supply.

(6) When heavy gear is worn the following shall be provided:

(a) An extra breathing gas hose capable of supplying breathing gas to a diver in the water shall be available to the standby diver.

(b) An inwater stage shall be provided to a diver in the water.

(7) An inwater stage shall be provided for a diver without access to a bell for a dive deeper than 100 fsw or outside the no-decompression limits.

(8) When a pressurized bell is used, 1 dive team member in the bell shall be available and tend the diver who is in the water.

(9) Except when heavy gear is worn or where physical space does not permit, a diver-carried reserve breathing gas supply shall be provided for each diver who engages in the following:

(a) Diving deeper than 100 fsw or outside the no-decompression limits.

(b) Prevented by the configuration of the dive area from directly ascending to the surface.

R 325.50336. Liveboating; prohibitions.

Rule 336. A diving operation involving liveboating shall not be conducted during any of the following conditions:

(a) With an inwater decompression time of greater than 120 minutes.

(b) Using surface-supplied air at depths deeper than 190 fsw, except that a dive with bottom time of 30 minutes or less may be conducted to depths of 220 fsw.

(c) Using mixed gas at depths greater than 220 fsw.

(d) In rough seas with a wave height of more than 3 feet.

(e) In other than daylight hours.

R 325.50337. Liveboating; procedures.

Rule 337. (1) The propeller of the vessel shall be stopped before a diver enters or exits the water.

(2) A device shall be used that minimizes the possibility of entanglement of a diver's hose in the propeller of the vessel.

(3) Two-way voice communication between the designated person in charge and the person controlling the vessel shall be used while a diver is in the water.

(4) A standby diver shall be available while a diver is in the water. The standby diver shall be dressed in accordance with rule 333(4)(b).

(5) A diver-carried reserve breathing gas supply shall be carried by each diver engaged in a liveboating operation.

R 325.50338. Equipment; record of service.

Rule 338. Equipment modification, repair, test, calibration or maintenance service shall be recorded by means of a tagging or logging system, and include the date and nature of work performed, and the name or initials of the person performing the work.

R 325.50339. Equipment; air compressor system; required equipment; location; supplied air; testing output; valves.

Rule 339. (1) A compressor used to supply air to a diver shall be equipped with a volume tank with a check valve on the inlet side, a pressure gauge, a relief valve, and a drain valve.

(2) An air compressor intake shall be located away from an area containing exhaust or other contaminants.

(3) Respirable air supplied to a diver shall not contain the following:

(a) A level of carbon monoxide (CO) greater than 20 ppm.

(b) A level of carbon dioxide (CO_2) greater than 1,000 ppm.

(c) A level of oil mist greater than 5 milligrams per cubic meter.

(d) A noxious or pronounced odor.

(4) The output of an air compressor system shall be tested for air purity every 6 months by means of samples taken at the connection to the distribution system, except that non-oil lubricated compressors need not be tested for oil mist.

(5) Slow opening on-off valves shall be used when the system operating pressure exceeds 500 psig.

R 325.50340. Equipment; buoyancy control; exhaust valve; buoyancy compensator; flotation device.

Rule 340. (1) A helmet or mask connected directly to the dry suit or other buoyancy-changing equipment shall be equipped with an exhaust valve.

(2) A dry suit or other buoyancy-changing equipment not directly connected to the helmet or mask shall be equipped with an exhaust valve.

(3) When used for SCUBA diving, a buoyancy compensator shall have an inflation source separate from the breathing gas supply.

(4) Except when the diver is wearing a variable volume suit, an inflatable flotation device capable of maintaining the diver at the surface in a face-up position, having a manually activated inflation source independent of the breathing supply, an oral inflation device, and an over-pressure relief device or exhaust valve shall be used for SCUBA diving.

R 325.50341. Decompression chambers; availability and location.

Rule 341. (1) A decompression chamber capable of recompressing a diver at the surface to a minimum of 165 fsw (6 ATA) shall be available to the dive location when any of the following occur:

(a) Surface-supplied air dives are conducted between 100 fsw and 220 fsw and require less than 30 minutes in-water decompression time, except that inspection or research dives within no decompression limits may be conducted to 130 fsw.

(b) Surface-supplied air dives between 100 fsw and 220 fsw require an in-water decompression time of 30 minutes or greater.

(c) Mixed gas dives are conducted beyond 130 fsw.

(2) A decompression chamber capable of recompressing a diver at the surface to the maximum depth of the dive shall be available to the dive location for dives greater than 220 fsw.

(3) A decompression chamber shall be located within 15 minutes surface travel time from the dive location for dives described in subrule (a) and within 5 minutes surface travel time from the dive location for all other dives.

R 325.50342. Decompression chambers; operation; qualified employee; required equipment; inspection.

Rule 342. (1) A qualified employee shall be available to operate the decompression chamber for not less than 1 hour after a dive for which a decompression chamber is required. The qualified employee may be a dive team member or another employee qualified to operate the decompression chamber.

(2) The decompression chamber operator shall have available at the chamber location necessary treatment tables, treatment gas appropriate to the diving mode, and sufficient gas to conduct treatment.

(3) A muffler on each decompression intake and exhaust line and the suction guard on the exhaust line

shall be regularly inspected and maintained.

(4) A 2-way voice communication system shall be provided between the occupants of other separately pressurized compartments and a dive team member at the chamber location.

(5) A decompression chamber shall be maintained and operated to minimize sources of ignition and combustible materials in each compartment.

R 325.50343. Decompression chambers; construction requirements.

Rule 343. (1) A decompression chamber manufactured after October 20, 1977, shall be built, stamped, and maintained in accordance with ASME code, Section VIII, 1974, and the addenda thereto through December 31, 1976, and the PVHO-1, 1977 edition, which are incorporated herein by reference and may be inspected at the Lansing office of the Michigan department of public health. Section VIII of the ASME code may be purchased at a cost of $100.00 and the PVHO-1 may be purchased at a cost of $10.00 by ordering from the American Society of Mechanical Engineers, United Engineering Center, 345 East Forty-Seventh Street, New York, New York, 10017, or from the Michigan Department of Public Health, 3500 North Logan, Box 30035, Lansing, Michigan, 48909.

(2) A decompression chamber manufactured prior to October 20, 1977, shall be maintained in conformity with the code requirements to which it was built, or their equivalent.

(3) A decompression chamber shall be of dual lock construction and shall be large enough to accommodate a diver and a person or persons to render treatment.

(4) A decompression chamber shall be equipped with all of the following:

(a) An interior and exterior pressure gauge for each compartment designed for human occupancy.

(b) A built-in breathing system with a minimum of 1 mask per occupant.

(c) A means to maintain the oxygen level in the chamber atmosphere below 25% by volume.

(d) A veiwport that allows all bunks to be seen from the exterior for their entire length.

(e) Illumination sufficient to light the interior to allow viewing of the occupants, the reading of gauges by an occupant, and operation of installed systems within each compartment.

(f) A sound-powered telephone system or other emergency backup communications systems.

(g) A means of operating all installed man-way locking devices from both sides of a closed hatch.

(h) A capability to supply breathing mixtures at the maximum rate required by all occupants sufficient to maintain the interior atmosphere below 2% surface equivalent carbon dioxide by volume.

(i) A means of over-riding and controlling from the exterior all interior breathing and pressure supply controls.

(5) Electrical equipment installed inside the chamber shall be explosion-proof.

R 325.50344. Equipment; gauges and timekeeping devices.

Rule 344. (1) Gauges indicating diver depth that can be read at the dive location shall be used for all surface-supplied dives.

(2) Each depth gauge shall be dead-weight tested or calibrated against a master reference gauge initially and every 6 months thereafter, and when there is a discrepancy greater than plus or minus 2% of full scale between any 2 equivalent gauges.

(3) A timekeeping device shall be available and monitored at each surface-supplied dive location.

(4) A cylinder pressure gauge capable of being monitored by the diver during the dive shall be worn by each SCUBA diver.

(5) A timekeeping device shall be worn by each SCUBA diver in a position to be monitored by the diver.

R 325.50345. Equipment; masks and helmets.

Rule 345. (1) Surface-supplied air and mixed gas masks and helmets shall have the following:

(a) A non-return valve at the attachment point between helmet or mask and hose that shall close readily and positively.

(b) An exhaust valve.

(2) Surface-supplied air masks and helmets shall have a minimum ventilation rate capability of 4.5 acfm at any depth at which they are operated or the capability of maintaining the diver's inspired carbon dioxide partial pressure below 0.02 ATA when the diver is producing carbon dioxide at the rate of 1.6 standard liters per minute.

R 325.50346. Equipment; oxygen service; cleaning; shut off valves.

Rule 346. (1) Equipment used with oxygen or mixtures containing over 40% by volume oxygen shall be designed for oxygen service.

(2) Components, except umbilicals, exposed to oxygen or mixtures containing 40% by volume shall be cleaned of flammable materials before use.

(3) Oxygen systems over 125 psig and compressed air systems over 500 psig shall have slow-opening shut off valves.

R 325.50347. Occupational injuries; recording and reporting.

Rule 347. (1) An employer shall record and report occupational injuries and illnesses in accordance with requirements of Part 11. Recording and Reporting of Occupational Injuries and Illnesses, being R 408.22101 et seq., of the Michigan Administrative Code, administered and enforced by the Michigan department of labor.

(2) In addition, an employer shall record the occurrence of any diving-related injury or illness that requires any dive team member to be hospitalized for 24 hours or more, specifying the circumstances of the incident and the extent of any injuries or illnesses.

R 325.50348. Recordkeeping; availability of records.

Rule 348. (1) Upon the request of the director of the department of labor or the director of the department of public health, an employer shall make available for inspection and copying any record or document required by these rules.

(2) Upon request by an employee, former employee, or authorized representative, an employer shall make available for inspection and copying any record or document required by these rules that pertains to the individual employee or former employee.

(3) Records and documents required by these rules shall be retained by the employer for the following period:

(a) Dive team member physician's report — 5 years.

(b) Safe practices manual — current document only.

(c) Depth-time profile — until completion of the recording of the dive, or until completion of decompression procedure assessment where there has been an incident of decompression sickness.

(d) Recording of dive — 1 year, except 5 years where there has been an incident of decompression sickness.

(e) Decompression procedure assessment evaluation — 5 years.

(f) Record of hospitalization — 5 years.

GUIDE TO HYPERBARIC FITNESS

The following disorders mây restrict or limit occupational exposure to hyperbaric conditions depending on severity, presence of residual effects, response to therapy, number of occurrences, diving mode, or degree and duration of isolation:

History of seizure disorder other than early febrile convulsions.

Malignancies (active) unless treated and without recurrence for 5 years.

Chronic inability to equalize sinus or middle ear pressure, or both.

Cystic or cavitary disease of the lungs.

Impaired organ function caused by alcohol or drug use.

Conditions requiring continuous medication for control (e.g., antihistamines, steroids, barbiturates, mood altering drugs, or insulin).

Meinere's disease.

Hemoglobinopathies.

Obstructive or restrictive lung disease.

Vestibular end organ destruction.

Pneumothorax.

Cardiac abnormalities (e.g., pathological heart block, valvular disease, intraventricular conduction defects other than isolated right bundle branch block, angina pectoris, arrhythmia, coronary artery disease).

Juxtra-articular osteonecrosis.

Pregnancy.

DEPARTMENT OF LABOR
CONSTRUCTION SAFETY STANDARDS COMMISSION
SAFETY STANDARDS

Filed with the Secretary of State on May 31, 1979
These rules take effect 15 days after filing with the Secretary of State

(By authority conferred on the construction safety standards commission by sections 19 and 21 of Act No. 154 of the Public Acts of 1974, as amended, being §§ 408.1019 and 408.1021 of the Michigan Compiled Laws)

PART 31. DIVING OPERATIONS

TABLE OF CONTENTS

GENERAL PROVISIONS

R 408.43101. Scope.

Rule 3101. This part pertains to the safe use and maintenance of equipment and procedures of the occupation of diving and the related support operations as used in construction operations. This part does not apply to a diving operation performed solely for recreational instruction purposes using open-circuit compressed-air SCUBA and conducted within the no-decompression limits.

R 408.43103. Definitions; A to C.

Rule 3103. (1) "Acfm" means actual cubic feet per minute.

(2) "ATA" means atmosphere absolute.

(3) "Bell" means an enclosed compartment, pressurized (closed bell) or unpressurized (open bell), which allows the diver to be transported to and from the underwater work area and which may be used as a temporary refuge during diving operations.

(4) "Bottom time" means the total elapsed time, measured in minutes, from the time when the diver leaves the surface in descent to the time that the diver begins ascent.

(5) "Bursting pressure" means the pressure at which a pressurized device would fail structurally.

(6) "Cylinder" means a pressure vessel for the storage of gases.

R 408.43104. Definitions; D.

Rule 3104. (1) "Decompression chamber" means a pressure vessel for human occupancy, such as a surface decompression chamber, pressurized bell, or deep diving system used to decompress divers and to treat decompression sickness.

(2) "Decompression sickness" means a condition with a variety of symptoms which may result from gas or bubbles in the tissues of divers after pressure reduction.

(3) "Decompression table" means a profile or set of profiles of depth-time relationships for ascent rates and breathing mixtures to be followed after a specific depth-time exposure or exposures.

(4) "Dive location" means a surface or vessel from which a diving operation is conducted.

(5) "Dive location reserve breathing gas" means a volume tank or dependent supply of air or mixed gas at the dive location sufficient, under standard operating conditions, to allow the diver to reach the surface.

(6) "Dive team" means divers and support employees involved in a diving operation, including the designated person in charge.

(7) "Diver" means an employee in the water using underwater apparatus which supplies compressed breathing gas at the ambient pressure.

(8) "Diver-carried reserve breathing gas" means a diver-carried supply of air or mixed gas sufficient, under standard operating conditions, to allow the diver to reach the surface, a bell, or to be rescued by a standby diver.

(9) "Diving mode" means a type of diving requiring specific equipment, procedures, and techniques, such as SCUBA, surface-supplied air, or mixed-gas diving.

R 408.43105. Definitions; F to M.

Rule 3105. (1) "Fsw" means feet of seawater or equivalent static pressure head.

(2) "Heavy gear" means diver-worn deep-sea dress, including helmet, breast-plate, dry suit, and weighted shoes.

(3) "Hyperbaric conditions" means pressure conditions in excess of surface pressure.

(4) "Inwater stage" means a suspended underwater platform which supports a diver in the water.

(5) "Liveboating" means the practice of supporting a surface-supplied air or mixed gas diver from a vessel which is underway.

(6) "Mixed-gas diving" means a diving mode in which the diver is supplied in the water with a breathing gas other than air.

R 408.43106. Definitions; N to S.

Rule 3106. (1) "No-decompression limits" means a combination of the depth of a dive and the bottom time which permits a diver to return to the surface without decompression, as expressed in Volume I Air Diving — 1973, as amended through December 1975, and Volume II Mixed Gas Diving — 1973, as amended through December 1975 of the U.S. navy diving manual which are incorporated herein by reference and may be inspected at the Lansing office of the department of labor. These volumes may be purchased at a cost of $3.25 each from the Superintendent of Documents, Government Printing Office, Public Document Department, Washington, D.C. 20402, or from the Michigan Department of Labor, 7150 Harris Drive, Box 30015, Lansing, Michigan 48909.

(2) "O.H. rule" means an occupational health rule adopted by reference pursuant to section 14 of Act No. 154 of the Public Acts of 1974, as amended, being § 408.1014 of the Michigan Compiled Laws. Copies of these rules are available from the Michigan Department of Public Health, 3500 N. Logan, Box 30035, Lansing, Michigan 48909.

(3) "Psig" means pounds per square inch, gauge.

(4) "Qualified employee" means one who, by extensive knowledge, training, and experience, has successfully demonstrated his ability to solve or resolve problems relating to the subject matter, the work, or the project.

(5) "SCUBA diving" means a diving mode independent of surface supply in which the diver uses open-circuit self-contained underwater breathing apparatus.

(6) "Standby diver" means a diver at the dive location available in a sufficient state of readiness to assist a diver in the water.

(7) "Surface-supplied air diving" means a diving mode in which the diver in the water is supplied from the dive location with compressed air for breathing.

R 408.43107. Definitions; T to W.

Rule 3107. (1) "Treatment table" means a depth-time and breathing gas profile used in the treatment of decompression sickness.

(2) "Umbilical" means the composite hose bundle between a dive location and a diver or bell, or between a diver and a bell, which may supply a diver or bell with breathing gas, communications, power, and heat and may include a safety line.

(3) "Volume tank" means a pressure vessel connected to the outlet of a compressor and used as an air reservoir.

(4) "Working pressure" means the maximum pressure to which a pressure containment device may be exposed under standard operating conditions.

R 408.43109. Emergencies.

Rule 3109. An employer may deviate from the requirements of these rules to the extent necessary to prevent or minimize a situation which is likely to cause death, serious physical harm, or major environmental damage, provided that the employer complies with both of the following:

(a) Notifies the department of labor within 72 hours of the onset of the emergency situation, indicating the nature of the emergency and extent of the deviation from these rules.

(b) Upon request from the department of labor or public health, submits this information in writing.

R 408.43111. Employer responsibilities.

Rule 3111. The employer shall be responsible for compliance with both of the following:

(a) All provisions of these rules of general applicability.

(b) All requirements pertaining to specific diving modes to the extent diving operations in the modes are conducted.

R 408.43112. Qualifications of dive team.

Rule 3112. (1) The employer shall ensure that each dive team member has the experience and training necessary to perform assigned tasks in a safe and healthful manner. The training and experience shall include all of the following:

(a) The use of tools, equipment, and systems relevant to assigned tasks.

(b) Techniques of the assigned diving mode.

(c) Diving operations and emergency procedures.

(d) Familiarity with the contents of the safe practices manual required by rule 3114.

(2) All dive team members shall be trained in cardiopulmonary resuscitation and first aid by the American red cross or equivalent organizations.

(3) Each dive team member who is exposed to or controls the exposure of others to hyperbaric conditions shall be trained in diving-related physics and physiology.

R 408.43113. Dive team assignments.

Rule 3113. (1) The employer or an employee designated by the employer shall be at the dive location and shall be in charge of all aspects of the diving operation affecting the safety of dive team members.

(2) The designated person in charge shall have experience and training in the conduct of the assigned diving operation.

(3) Each dive team member shall be assigned tasks in accordance with the employee's experience or training, except that limited additional tasks may be assigned to an employee undergoing training if these tasks are performed under the direct supervision of an experienced dive team member.

(4) The employer shall not require a dive team member to be exposed to hyperbaric conditions against the employee's will, except when necessary to complete decompression or treatment procedures.

(5) The employer shall not permit a dive team member to dive or be otherwise exposed to hyperbaric conditions for the duration of any temporary, physical impairment or condition which is known to the employer and is likely to adversely affect the health of a dive team member.

R 408.43114. Safe practices manual.

Rule 3114. (1) The employer shall develop and maintain a safe practices manual which shall be made available to each dive team member at the dive location.

(2) The safe practices manual shall contain a copy of these rules, the employer's policies for implementing their requirements, and all of the following:

(a) Operating procedures and checklists for diving operations.

(b) Assignments and responsibilities of the dive team members.

(c) Equipment procedures and checklists.

(d) Emergency procedures for fire, equipment failure, adverse environmental conditions and medical illness, and injury.

R 408.43121. Pre-dive procedures; emergency aid.

Rule 3121. A list of the following telephone or call numbers shall be kept at the dive location:

(a) An operational decompression chamber, if not at the dive location.

(b) Accessible hospitals.

(c) Available physicians.

(d) Available means of transportation.

(e) The nearest U.S. coast guard rescue coordination center.

R 408.43122. Pre-dive procedures; planning and assessment.

Rule 3122. (1) Planning of a diving operation shall include an assessment of the safety and health aspects of all of the following:

(a) Diving mode.

(b) Surface and underwater conditions and hazards.

(c) Breathing gas supply, including reserves.

(d) Thermal protection.

(e) Diving equipment and systems.

(f) Dive team assignments and physical fitness of dive team members, including any impairment known to the employer.

(g) Repetitive dive designation or residual inert gas status of dive team members.

(h) Decompression and treatment procedures, including altitude corrections.

(i) Decompression tables.

(j) Emergency procedures.

(2) Decompression, repetitive, and no-decompression tables, as appropriate, shall be at the dive location.

R 408.43123. Pre-dive procedures; hazardous activities.

Rule 3123. To minimize hazards to the dive team, diving operations shall be coordinated with other activities in the vicinity which are likely to interfere with the diving operation.

R 408.43124. Pre-dive procedures; employee briefing.

Rule 3124. (1) Dive team members shall be briefed on all of the following:

(a) The tasks to be undertaken.

(b) Operating procedures for the diving mode.

(c) Any unusual hazards or environmental conditions likely to affect the safety of the diving operation.

(d) Any modifications to operating procedures necessitated by the specific diving operation.

(2) Prior to making individual dive team member assignments, the employer shall inquire into the dive team member's current state of physical fitness, and indicate to the dive team member the procedure for reporting physical problems or adverse physiological effects during and after the dive.

R 408.43125. Pre-dive procedures; communications.

Rule 3125. An operational 2-way voice communication system shall be provided as follows:

(a) At the dive location to obtain emergency assistance.

(b) Between each surface-supplied air or mixed-gas diver and a dive team member at the dive location or bell.

(c) Between the bell and the dive location.

R 408.43126. Pre-dive procedures; equipment inspection.

Rule 3126. The breathing gas supply system, including reserve breathing gas supplies, masks, helmets, gauges, timekeeping devices, thermal protection, and bell handling mechanisms, when appropriate, shall be inspected prior to each dive.

R 408.43127. Pre-dive procedures; warning signal.

Rule 3127. A warning flag shall be fully displayed when diving as follows: Any person diving or submerging in any of the waters of this state with the aid of a diving suit or other mechanical diving device shall place a buoy or boat in the water at or near the point of submergence. The buoy or boat shall bear a red flag not less than 14 inches by 16 inches with a 3½ inch white stripe running from 1 upper corner to a diagonal lower corner. The flag shall be in place only while actual diving operations are in progress. A vessel shall not be operated within 100 feet of a buoyed diver's flag unless it is involved in tending the diving operation. A person diving shall stay within a surface area of 100 feet of the diver's flag.

R 408.43131. Procedures during dive; water entry and exit.

Rule 3131. (1) A means capable of supporting the diver shall be provided for entering and exiting the water.

(2) The means provided for exiting the water shall extend below the water surface.

(3) A means shall be provided to assist an injured diver from the water or into a bell.

R 408.43132. Procedures during dive; hand-held power tools and equipment.

Rule 3132. (1) Tools and equipment shall be qualified for underwater use.

(2) Hand-held electrical tools and equipment shall be de-energized before being placed into or retrieved from the water.

(3) A hand-held power tool shall not be supplied with power from the dive location until requested by the diver.

(4) A current supply switch to interrupt the current flow to the welding or cutting electrode shall be:

(a) Tended by a dive team member in voice communication with the diver performing the welding or cutting.

(b) Kept in the open position except when the diver is welding or cutting.

(5) The welding machine frame shall be grounded and a ground wire shall be connected directly to the work.

(6) Welding and cutting cables, electrode holders, and connections shall be capable of carrying the maximum current required by the work, and shall be properly insulated.

(7) Insulated gloves shall be provided to divers performing welding and cutting operations.

(8) Prior to welding or cutting on a closed compartment, a structure, or a pipe, which contains a flammable vapor or in which a flammable vapor may be generated by the work, the compartment, structure, or pipe shall be vented, flooded, or purged with a mixture of gases which will not support combustion.

R 408.43133. Procedures during dive; explosives.

Rule 3133. (1) Explosives shall be transported, stored, and used as prescribed in this rule and the applicable provisions of the construction safety standards commission standard, Part 27. Blasting and Use of Explosives, being R 408.42701 of the Michigan Administrative Code, or the general industry safety standards commission standard, 1910.109, Explosives and Blasting Agents, adopted by section 14 of Act No. 154 of the Public Acts of 1974, as amended, being § 408.1014 of the Michigan Compiled Laws.

(2) Electrical continuity of explosive circuits shall not be tested until the diver is out of the water.

(3) Explosives shall not be detonated while the diver is in the water.

R 408.43134. Procedure during dive; termination.

Rule 3134. The working interval of a dive shall be terminated when any of the following occurs:

(a) A diver requests termination.

(b) A diver fails to respond correctly to communications or signals from a dive team member.

(c) Communications are lost and cannot be quickly reestablished between the diver and a dive team member at the dive location, and between the designated person in charge and the person controlling the vessel in liveboating operations.

(d) A diver begins to use diver-carried reserve breathing gas or the dive-location reserve breathing gas.

(e) When the scheduled work interval has expired.

R 408.43141. Post-dive procedures, generally.

Rule 3141. The employer shall comply with all of the following requirements which are applicable after each diving operation:

(a) Check the physical condition of the diver.

(b) Instruct the diver to report any physical problems or adverse physiological effects, including symptoms of decompression sickness.

(c) Advise the diver of the location of a decompression chamber which is ready for use.

(d) Alert the diver to the potential hazards of flying after diving.

(e) Instruct the diver to remain awake and in the vicinity of the dive location for not less than 1 hour after a dive which requires a decompression chamber.

R 408.43142. Post-dive procedures; record of dive.

Rule 3142. (1) All of the following information shall be recorded and maintained for each diving operation:

(a) Names of dive team members, including the designated person in charge.

(b) Date, time, and location.

(c) Diving modes used.

(d) General nature of the work performed.

(e) Approximate underwater and surface conditions.

such as visibility, water temperature, wind velocity, and current.

(f) Maximum depth and bottom time for each diver.

(2) For each dive for which a decompression chamber is required, all of the following additional information shall be recorded and maintained:

(a) Depth-time and breathing gas profiles.

(b) Decompression table designation, including any modification.

(c) Elapsed time since last pressure exposure, if less than 24 hours, or repetitive dive designation for each diver.

(3) For each dive in which decompression sickness is suspected or symptoms are evident, all of the following additional information shall be recorded and maintained:

(a) Description of decompression sickness symptoms, including depth and time of onset.

(b) Description and results of treatment.

R 408.43145. Liveboating, generally.

Rule 3145. Diving operations involving liveboating shall not be conducted during any of the following conditions:

(a) With an inwater decompression time of greater than 120 minutes.

(b) Using surface-supplied air at depths deeper than 190 fsw, except that dives with bottom times of 30 minutes or less may be conducted to depths of 220 fsw.

(c) Using mixed gas at depths greater than 220 fsw.

(d) In rough seas with a wave height of more than 3 feet.

(e) In other than daylight hours.

R 408.43146. Liveboating; procedures.

Rule 3146. (1) The propeller of the vessel shall be stopped before the diver enters or exits the water.

(2) A device shall be used which minimizes the possibility of entanglement of the diver's hose in the propeller of the vessel.

(3) Two-way voice communication between the designated person in charge and the person controlling the vessel shall be used while the diver is in the water.

(4) A standby diver shall be available while a diver is in the water.

(5) A diver-carried reserve breathing gas supply shall be carried by each diver engaged in liveboating operations.

R 408.43151. Equipment, generally.

Rule 3151. Equipment modification, repair, test, calibration, or maintenance service shall be recorded by means of a tagging or logging system, and shall include the date and nature of the work performed, and the name or initials of the person performing the work.

R 408.43152. Equipment; breathing gas supply hoses.

Rule 3152. (1) Breathing gas supply hoses shall meet all of the following criteria:

(a) Have a working pressure of not less than the working pressure of the breathing gas system.

(b) Have a rated bursting pressure of not less than 4 times the working pressure.

(c) Be tested initially and not less than annually thereafter to 1.5 times their working pressure.

(d) Be tensile tested before being placed into initial service and after any repair, modification, or alteration, by subjecting each hose-to-fitting connection to a 200-pound axial load and by passing a visual examination for evidence of separation, slippage, or other damage to the assembly.

(e) Be inspected prior to each diving operation for cuts, kinks, soft spots, or bubbles.

(f) Have their open ends taped, capped, or plugged when not in use.

(2) Breathing gas supply hose connectors shall meet all of the following criteria:

(a) Be made of corrosion-resistant materials.

(b) Have a working pressure at least equal to the working pressure of the hose to which they are attached.

(c) Be resistant to accidental disengagement.

R 408.43153. Equipment; umbilicals.

Rule 3153. Umbilicals shall meet all of the following criteria:

(a) Be marked and labeled in 10 feet increments to 100 feet beginning at the diver's end, and in 50 feet increments thereafter.

(b) Be made of kink-resistant materials.

(c) Have a working pressure greater than the pressure equivalent to the maximum depth of the dive relative to the supply source plus 100 psi.

R 408.43154. Equipment; buoyancy control.

Rule 3154. (1) Helmets or masks connected directly to the dry suit or other buoyancy changing equipment shall be equipped with an exhaust valve.

(2) A dry suit or other buoyancy changing equipment not directly connected to the helmet or mask shall be equipped with an exhaust valve.

(3) When used for SCUBA diving, a buoyancy compensator shall have an inflation source separate from the breathing gas supply.

(4) Except when the diver is wearing a variable volume suit, an inflatable flotation device capable of maintaining the diver at the surface in a face-up position, having a manually activated inflation source independent of the breathing supply, an oral inflation device, and an over pressure relief device or exhaust valve shall be used for SCUBA diving.

R 408.43155. Equipment; compressed-gas cylinders.

Rule 3155. (1) A compressed-gas cylinder shall be designed, constructed, and maintained pursuant to the applicable provisions of 29 C.F.R. §§ 1910.166 and 1910.167 which were adopted by section 14, of Act No. 154 of the Public Acts of 1976, as amended, being 408.1014 of the Michigan Compiled Laws.

(2) Be stored in a ventilated area and protected from excessive heat.

(3) Be secured from falling.

(4) Have shutoff valves recessed into the cylinder or protected by a cap, except when in use or manifolded, or when used for SCUBA diving.

(5) Be subjected to internal inspection for rust and corrosion not less than annually.

R 408.43156. Decompression chambers; operation.

Rule 3156. (1) A qualified employee shall be available to operate the decompression chamber for not less than 1 hour after a dive for which a decompression chamber is required. The qualified employee may be a dive team member or another employee qualified to operate the decompression chamber.

(2) The decompression chamber operator shall have available at the chamber location necessary treatment tables, treatment gas appropriate to the diving mode, and sufficient gas to conduct treatment.

(3) A muffler on each decompression intake and exhaust line and the suction guard on the exhaust line shall be regularly inspected and maintained.

(4) A 2-way voice communication system shall be provided between the occupants of other separately pressurized compartments and a dive team member at the chamber location.

(5) A decompression chamber shall be maintained and operated to minimize sources of ignition and combustible materials in each compartment.

R 408.43157. Equipment; gauges and timekeeping devices.

Rule 3157. (1) Gauges indicating diver depth which can be read at the dive location shall be used for all surface-supplied dives.

(2) Each depth gauge shall be dead-weight tested or calibrated against a master reference gauge initially and every 6 months thereafter, and shall also be tested when there is a discrepancy of more than plus or minus 2% of full scale between any 2 equivalent gauges.

(3) A timekeeping device shall be available and monitored at each surface-supplied dive location.

(4) A cylinder pressure gauge capable of being monitored by the diver during the dive shall be worn by each SCUBA diver.

(5) A timekeeping device shall be worn by each SCUBA diver in a position to be monitored by the diver.

R 408.43158. Equipment; weights and harnesses.

Rule 3158. (1) Divers shall be equipped with a weight belt or assembly, capable of quick release, except when heavy gear is worn.

(2) Except when heavy gear is worn or except in SCUBA diving, each diver shall wear a safety harness with all of the following:

(a) A positive buckling device.

(b) An attachment point for the umbilical to prevent strain on the mask or helmet.

(c) A lifting point to distribute the pull force of the line over the diver's body.

R 408.43161. Recordkeeping; recording and reporting.

Rule 3161. (1) The employer shall record and report occupational injuries and illnesses pursuant to department of labor requirements of Part 11. Recording & Reporting of Occupational Injuries and Illnesses, being R 408.22101 et seq. of the Michigan Administrative Code.

(2) In addition, the employer shall record the occurrence of any diving related injury or illness which requires any dive team member to be hospitalized for 24 hours or more, specifying the circumstances of the incident and the extent of any injuries or illnesses.

R 408.43162. Recordkeeping; availability of records.

Rule 3162. (1) Upon the request of the director of the department of labor or the director of the department of public health, the employer shall make available for inspection and copying any record or document required by these rules.

(2) Upon request of any employee, former employee, or authorized representative, the employer shall make available for inspection and copying any record or document required by these rules which pertains to the individual employee or former employee.

(3) Records and documents required by these rules shall be retained by the employer for the following periods:

(a) Dive team member physician reports — 5 years.

(b) Safe practices manual — current document only.

(c) Depth-time profile — until completion of the recording of the dive, or until completion of decompression procedure assessment where there has been an incident of decompression sickness.

(d) Recording of dive — 1 year, except 5 years where there has been an incident of decompression sickness.

(e) Decompression procedure assessment evaluations — 5 years.

(f) Records of hospitalizations — 5 years.

DEPARTMENT OF LABOR
GENERAL INDUSTRY SAFETY STANDARDS COMMISSION
SAFETY STANDARDS

Filed with the Secretary of State on May 31, 1979
These rules take effect 15 days after filing with the Secretary of State

(By authority conferred on the general industry safety standards commission by section 16 and 21 of Act No. 154 of the Public Acts of 1974, as amended, being §§ 408.1016 and 408.1021 of the Michigan Compiled Laws)

The rules of the general industry safety standards commission entitled "Safety Standards," being R 408.10001 et seq. of the Michigan Administrative Code, are amended by adding R 408.17901 and R 408.17903 to read as follows:

PART 79. DIVING OPERATIONS

TABLE OF CONTENTS

GENERAL PROVISIONS

R 408.17901. Scope.

Rule 7901. This part pertains to the safe use and maintenance of equipment and procedures of the occupation of diving and the related support operations as used in general industry. This part does not apply to a diving operation performed solely for recreational instruction purposes using open-circuit compressed-air SCUBA and conducted within the no-decompression limits.

R 408.17903. Adoption by reference.

Rule 7903. Diving operations shall be conducted as prescribed in Part 31. Diving Operations, being R 408.43101 et seq. of the Michigan Administrative Code, a construction safety standards commission standard, which is incorporated herein by reference and may be inspected at the Lansing office of the department of labor. This standard may be obtained, at no cost, from the Standards Division, Michigan Department of Labor, 7150 Harris Drive, Box 30015, Lansing, Michigan 48909.