



University of Washington  
Scientific Diving Safety Manual

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# UW Diving Emergency Telephone Numbers - 911

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Environmental Health and Safety

## University of Washington

UW Police 9-911 or (206)685-8973  
Diving Safety Officer – Will Love (206) 616-3776 (Cell) (208) 371-8977  
Diving Medical Consultant - Dr. Edmond Kay (Cell - 24hrs) (206)954-3750

## Friday Harbor Laboratories

Emergency 911 (360) 378-4151  
FHL Office (360) 378-2165  
Caretakers - Mike and Michelle Herko (360) 378-3482 (Cell) (360) 298-0220  
Billie J. Swalla - FHL Director (206) 616-0764 (Cell) (206) 769-6939  
Pema Kitaeff - FHL Dive Officer (206) 543-0876 (Cell) (206) 349-9977  
Kristy Kull - FHL Boating Officer (206) 543-0876 (Cell) (562) 972-6229  
Fred Ellis – FHL Chief of Maintenance (360)378-3491 UW (206) 616-0756  
Meegan Corcoran - Marine Operations Manager (Cell) (360) 929-9034  
Megan Dethier - FHL Associate Director (206) 543-8096 (360) 298-2018

## Virginia Mason Hospital

Emergency Room (206) 583-6433  
Hyperbaric Unit 24-Hour Consultation (206) 583-6543

## Coast Guard

Rescue Coordination. Center Washington, Oregon (206) 220-7001  
Rescue Coordination. Center Juneau, Alaska (907) 463-2000

## British Columbia

Rescue Coordination. Center (Victoria) (800) 567-5111 250-363-2333

## Divers Alert Network (DAN)

(919) 684-9111

## EMERGENCY RADIO FREQUENCIES

Coast Guard VHF Channel 16  
Canadian Coast Guard VHF Channel 16  
Citizen Band (CB) Channel 9

## RECOMPRESSION CHAMBERS

### Alaska

Anchorage Regional Hospital (907) 264-1583  
Bartlett Memorial Hospital, Juneau (907) 586-2611  
Ketchikan General Hospital, Ketchikan (907) 225-5171  
American Hyperbaric Center (907) 562-5420

### British Columbia

Fleet Diving Unit Pacific, Victoria (250) 363-2379  
Vancouver General Hospital, Vancouver (604) 875-4111

### Oregon

Providence Hospital, Portland (503) 215-1111

### Washington

Virginia Mason Hospital, Seattle (206) 583-6543  
Diver's Institute of Technology, Seattle (206) 783-5543  
Fairchild AFB, Spokane (E.R.) (509) 247-5661  
(Chamber) (509) 247-5406  
U.S. Naval Station, Keyport (360) 396-2552 (24 hrs) (360) 296-2111  
St. Joseph's Medical Center, Tacoma (253) 426-6630

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# SCIENTIFIC DIVING SAFETY MANUAL

April 2016

Published	January 1972
First Revision	July 1972
Second Revision	May 1974
Third Revision	October 1980
Fourth Revision	September 1983
Fifth Revision	January 1988
Sixth Revision	January 1993
Seventh Revision	March 1997
Eighth Revision	May 2002
Ninth Revision	May 2005
Tenth Revision	April 2007
Eleventh Revision	August 2010
Twelfth Revision	February 2012
Thirteenth Revision	January 2014
Fourteenth Revision	April 2016

## **PREFACE**

Scientific divers face some of the most challenging occupational hazards encountered in a University setting. Recognizing the need to assure the safety of University divers, in 1972 the University of Washington's Board of Regents adopted a diving safety policy. Since that time, the University's Environmental Health and Safety Department has implemented a Diving Safety Program to oversee the safety of scientific diving and a Diving Control Board has been established to oversee the diving safety program and develop the Diving Safety Manual.

I want to recognize the extensive efforts of the members of the Diving Control Board, the University's Diving Safety Officer and Diving Officer's in the development of 2010 edition of the Diving Safety Manual. With their careful work detailed research, this Manual provides important updates and the latest scientifically based, feasible and effective requirements, practices and procedures necessary for safely conducting scientific diving.

This Diving Safety Manual applies specifically to scientific diving conducted under the auspices of the University of Washington. Additionally, it incorporates the standards of the American Academy of Underwater Sciences, which form the regulatory basis for occupational safety applied to scientific diving in lieu of the State of Washington Administrative Code. In so doing, it fosters reciprocity of diver training and certification between research institutions and government agencies. All other types of diving must adhere to the State of Washington standards for commercial diving operations, Chapter 296-37, Washington Administrative Code.

To those of you using this manual, I thank you for doing your part to protect yourself and your colleagues as you conduct safe diving operations in pursuit of new knowledge.

Jude Van Buren, Director  
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# CONTENTS

Section	Page
SECTION 1.00 GENERAL POLICY.....	9
1.10 SCIENTIFIC DIVING STANDARDS .....	9
1.20 OPERATIONAL CONTROL.....	11
1.30 CONSEQUENCES OF VIOLATION OF REGULATIONS BY ORGANIZATIONAL MEMBERS.....	16
1.40 RECORD MAINTENANCE .....	16
SECTION 2.00 DIVING REGULATIONS FOR SCUBA (OPEN CIRCUIT, COMPRESSED AIR) .....	17
2.10 INTRODUCTION .....	17
2.20 PRE-DIVE PROCEDURES.....	17
2.30 DIVING PROCEDURES .....	19
2.40 POST-DIVE PROCEDURES .....	19
2.50 EMERGENCY PROCEDURES .....	20
2.60 FLYING AFTER DIVING OR ASCENDING TO ALTITUDE (OVER 1000 FEET).....	20
2.70 RECORDKEEPING REQUIREMENTS .....	20
SECTION 3.00 DIVING EQUIPMENT .....	22
3.10 GENERAL POLICY.....	22
3.20 EQUIPMENT.....	22
3.30 AUXILIARY EQUIPMENT.....	24
3.40 SUPPORT EQUIPMENT .....	25
3.50 EQUIPMENT MAINTENANCE .....	27
3.60 AIR QUALITY STANDARDS .....	28
SECTION 4.00 ENTRY-LEVEL TRAINING REQUIREMENTS .....	29
4.10 GENERAL POLICY.....	29
4.20 REFERENCES .....	29
AAUS SCIENTIFIC DIVER FLOW CHART .....	30
SECTION 5.00 SCIENTIFIC DIVER CERTIFICATION .....	31
5.10 PREREQUISITES.....	31
5.20 TRAINING.....	31
5.30 EXAMINATIONS.....	33
5.40 DIVER PERMITS/CERTIFICATIONS .....	34
5.50 DEPTH CERTIFICATIONS.....	35
5.60 CONTINUATION OF CERTIFICATION .....	35
5.70 REVOCATION OF CERTIFICATION.....	36
5.80 RECERTIFICATION .....	36
5.90 WAIVER OF REQUIREMENTS/TEMPORARY DIVER .....	36
SECTION 6.00 MEDICAL STANDARDS.....	38
6.10 MEDICAL REQUIREMENTS .....	38
6.20 FREQUENCY OF MEDICAL EVALUATIONS.....	39
6.30 INFORMATION PROVIDED BY EXAMINING PHYSICIAN.....	39
6.40 CONTENT OF MEDICAL EVALUATIONS.....	39
6.50 CONDITIONS WHICH MAY DISQUALIFY CANDIDATES FROM DIVING.....	39
6.60 LAB REQUIREMENTS FOR DIVING MEDICAL EVALUATIONS/INTERVALS.....	40
6.70 PHYSICIANS WRITTEN REPORT.....	40
SECTION 7.00 NITROX DIVING GUIDELINES .....	42
7.10 PREREQUISITES.....	42
7.20 REQUIREMENTS FOR AUTHORIZATION TO USE NITROX .....	42
7.30 NITROX TRAINING GUIDELINES .....	43
7.40 SCIENTIFIC NITROX DIVING REGULATIONS .....	44
7.50 NITROX DIVING EQUIPMENT.....	47
SECTION 8.00 HUMAN POWERED SUBMARINE DIVING OPERATIONS.....	50
8.1 GENERAL POLICY.....	50
8.20 PARTICIPANT LEVEL AND BASIC REQUIREMENTS.....	50
8.30 ADDITIONAL TRAINING REQUIREMENTS.....	51
8.40 SUBMARINE LIFE-SUPPORT SYSTEMS.....	52

8.50 SUBMARINE SAFETY REQUIREMENTS.....	52
8.60 SUBMARINE SAFETY INSPECTION.....	54
8.70 SUPPORT PERSONNEL.....	54
SECTION 9.00 STAGED DECOMPRESSION DIVING.....	55
9.10 MINIMUM EXPERIENCE AND TRAINING REQUIREMENTS.....	55
9.20 MINIMUM EQUIPMENT REQUIREMENTS:.....	56
9.30 MINIMUM OPERATIONAL REQUIREMENTS.....	56
SECTION 10.00 MIXED GAS DIVING.....	58
10.10 MINIMUM EXPERIENCE AND TRAINING REQUIREMENTS.....	58
10.20 EQUIPMENT AND GAS QUALITY REQUIREMENTS.....	59
10.30 MINIMUM OPERATIONAL REQUIREMENTS.....	59
SECTION 11.00 OTHER DIVING TECHNOLOGY.....	60
11.10 BLUE WATER DIVING.....	60
11.20 DIVER PROPULSION VEHICLE.....	60
11.30 OVERHEAD ENVIRONMENTS.....	60
11.40 SATURATION DIVING.....	60
11.50 HOOKAH.....	60
11.60 SURFACE SUPPLIED DIVING.....	60
11.70 FULL FACEMASK AND HELMET.....	60
SECTION 12.00 REBREATHERS.....	61
12.10 DEFINITIONS AND GENERAL INFORMATION.....	61
12.20 PREREQUISITES.....	62
12.30 EQUIPMENT REQUIREMENTS.....	66
12.40 OPERATIONAL REQUIREMENTS.....	67
12.50 OXYGEN REBREATHERS.....	70
12.60 SEMI CLOSED CIRCUIT REBREATHAERS(SCR).....	70
12.70 CLOSED CIRCUIT REBREATHERS(CCR).....	70
SECTION 13.00 SCIENTIFIC CAVE AND CAVERN DIVING STANDARD.....	72
13.10 DEFINITIONS.....	72
13.20 CAVE AND CAVERN ENVIRONMENT HAZARDS.....	74
13.30 MINIMUM EXPERIENCE AND TRAINING REQUIREMENTS.....	74
13.40 EQUIPMENT REQUIREMENTS.....	75
13.50 OPERATIONAL REQUIREMENTS AND SAFETY PROTOCOLS.....	76
SECTION 14.00 UNDER ICE DIVING.....	77
14.10 PURPOSE AND GENERAL COMMENTS:.....	77
14.20 DIVE ENVIRONMENT.....	78
14.30 MEDICAL/PHYSICAL CONSIDERATIONS.....	78
14.40 SAFETY.....	78
14.50 DIVE OPERATION PLANNING.....	80
14.60 DIVE EQUIPMENT.....	82
14.70 TRAINING.....	83
14.80 EQUIPMENT PREPARATIONS.....	84
14.90 DIVING OPERATIONS.....	85
14.100 FIELD OPERATIONS.....	86
14.110 SUPPLEMENTARY INFORMATION.....	87
APPENDIX 1 DIVING FORMS.....	90
APPENDIX 2 RECOMMENDED PHYSICIANS WITH EXPERTISE IN DIVING MEDICINE.....	91
APPENDIX 3 DEFINITION OF TERMS.....	92
APPENDIX 4 DIVING EMERGENCY MANAGEMENT PROCEDURES.....	99
APPENDIX 5 UNIVERSITY OF WASHINGTON DIVING INJURY/INCIDENT REPORT.....	118
APPENDIX 6 VISITOR DIVING REGULATIONS.....	119
APPENDIX 7 AIR CONSUMPTION CALCULATIONS.....	122
APPENDIX 8 DIVE TABLES AND DIVE COMPUTER WORKSHOP GUIDELINES.....	126

## **SECTION 1.00**

### **GENERAL POLICY**

On January 21, 1972, the University's Board of Regents adopted the following policy:

The University of Washington shall maintain a diving safety program that will ensure that all diving under its auspices is conducted in a manner designed to minimize accidental injury or occupational illness, and to conform to applicable rules and regulations of the Washington State Department of Labor and Industries. The President is directed to prepare, with the assistance of the Environmental Health and Safety (EH&S) Department, a guide, which shall set forth policies, responsibilities, organization, regulation, and procedures for safety in diving operations. No person shall dive under the auspices of the University of Washington without being certified to do so by the University Diving Safety Officer (DSO).

#### **1.10 SCIENTIFIC DIVING STANDARDS**

##### **Purpose**

The University of Washington maintains a Diving Safety Manual that sets policy and provides general and specific regulations for all research diving and training. This manual also covers equipment and locations (whether University owned or not) that are diving or support related and have a direct effect on the safety of any diving operation conducted under University auspices. Examples may include, but are not limited to, the supply of breathing air, materials, equipment, or supplies required by these regulations and the maintenance of diving equipment. Copies of this manual must be available to all personnel covered by its scope including each dive team member.

The purpose of these Scientific Diving Standards is to ensure that all scientific diving is conducted in a manner that will maximize protection of scientific divers from accidental injury and/or illness, and to set standards for training and certification, which will allow a working reciprocity between organizational members. Fulfillment of the purposes shall be consistent with the furtherance of research and safety. A copy of this manual must be present at all dive locations.

The American Academy of Underwater Sciences (AAUS) is an organization comprised of representatives from university, private, and governmental scientific diving programs. This organization determines minimum standards for the establishment of AAUS-recognized scientific diving programs, organizational and individual membership, procedures for safety in scientific diving operations, and a framework for reciprocity between member organizations.

In 1982, Occupational Health and Safety Administration (OSHA) exempted scientific diving from commercial diving regulations (29 CFR Part 1910, Subpart T) under certain conditions which are outlined below. The final guidelines for the exemption became effective in 1985 (Federal Register, Vol. 50, No.6, p.1046). The AAUS is recognized by (OSHA) as the scientific diving standard setting organization.

The University shall maintain organizational membership in and active communications with the AAUS. It is the University of Washington's responsibility to adhere to the AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs. The administration of the local diving program will reside with the University of Washington's Diving Control Board (DCB).

An annual report and summary of diving activities shall be prepared and submitted to the AAUS.



A scientific diver currently certified under the auspices of one member organization in good standing shall also be so recognized by any other member organization, and will operate under the standard operating procedures of the host organization.

In the event the University ceases to be as an organizational member, a summary of organizational diving activity of the past five (5) years shall be forwarded to the AAUS.

### **Scientific Diving Definition**

Scientific diving is defined (29 CFR 1910.402) as diving performed solely as a necessary part of a scientific, research, or educational activity by employees whose sole purpose for diving is to perform scientific research tasks.

### **Scientific Diving Exemption**

OSHA has granted an exemption for scientific diving from commercial diving regulations under the following guidelines (Appendix B to Subpart T):

1. The DCB consists of a majority of active scientific divers and has autonomous and absolute authority over the scientific diving program's operation.
2. The purpose of the project using scientific diving is the advancement of science; therefore, information and data resulting from the project are non-proprietary.
3. The tasks of a scientific diver are those of an observer and data gatherer. Construction and trouble-shooting tasks traditionally associated with commercial diving are not included within scientific diving.
4. Scientific divers, based on the nature of their activities, must use scientific expertise in studying the underwater environment and therefore, are scientists or scientists-in-training.
5. In addition, the scientific diving program shall contain at least the following elements:
  - a) Diving Safety Manual which includes at a minimum: Procedures covering all diving operations specific to the program; including procedures for emergency care, recompression and evacuation; and the criteria for diver training and certification.
  - b) Diving Control (Safety) Board (DCB), with the majority of its members being active scientific divers, which shall at a minimum have the authority to: approve and monitor diving projects, review and revise the diving safety manual, ensure compliance with the manual, certify the depths to which a diver has been trained, take disciplinary action for unsafe practices, and ensure adherence to the buddy system (a diver is accompanied by and is in continuous contact with another diver in the water) for scuba diving.

### **Exceptions to this Manual**

The manual does not cover any diving operation:

Performed solely for recreational purposes. Recreational dives may not in any way support the diver's occupation, academic instruction/training, or research.

Performed solely for search and rescue, or related public safety purposes by or under the control of a governmental agency.

Performed as a commercial diving operation under contract to the University. Such contracts shall provide for the requirements of the appropriate state or federal regulatory authority.

Governed by 45 CFR Part 46, (Protection of Human Subjects, U.S. Department of Health and Human Services) or equivalent rules or regulations established by another federal agency, which regulate research, development, or related purposes involving human subjects.

## **1.20 OPERATIONAL CONTROL**

Deans, Directors, and administrative persons are responsible for ensuring that their faculty, staff, and students who are involved in diving operations are aware of the contents of this Manual and conform to these regulations. (University of Washington Handbook, Vol.IV-59)

### **University of Washington Auspices Defined**

For the purposes of these standards the auspices of the University of Washington includes any scientific diving operation in which the University of Washington is connected because of ownership of any equipment used, locations selected, or relationship with the individual(s) concerned. This includes all cases involving the operations of employees of the University of Washington or employees of auxiliary organizations, where such employees are acting within the scope of their employment, and the operations of other persons who are engaged in scientific diving of the University of Washington or are diving as members of an organization recognized by the University of Washington.

It is the University of Washington's responsibility to adhere to the AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs. The administration of the local diving program will reside with the University of Washington's Diving Control Board (DCB).

The regulations herein shall be observed at all locations where scientific diving is conducted.

### **University of Washington Scientific Diving Standards and Safety Manual**

The DCB and the EH&S department shall publish and maintain a scientific diving safety manual that establishes requirements for scientific diving in compliance with the AAUS scientific diving standards, which are used as a set of minimum guidelines for the development of this manual. These scientific diving standards shall include, but not be limited to:

1. Emergency evacuation and medical treatment procedures.
2. The criteria for diver training and certification.
3. Standards written or adopted by reference for each diving mode utilized which include the following:
  - a) Safety procedures for the diving operation.
  - b) Responsibilities of the dive team members.

- c) Equipment use and maintenance procedures.
- d) Emergency procedures.

### **The Diving Safety Officer (DSO)**

The DSO serves as a member of the DCB. This person should have broad technical and scientific expertise in research related diving.

1. Shall be appointed by the responsible administrative officer or his/her designee, with the advice and counsel of the DCB.
2. Shall be trained as a Scientific Diver.
3. Shall be a full member as defined by the AAUS.
4. Shall be an active underwater instructor from a nationally recognized agency.
5. Shall be responsible, through the DCB, to the responsible administrative officer or his/her designee, for the conduct of the scientific diving program of the membership organization. The routine operational authority for this program, including the conduct of training and certification, approval of dive plans, maintenance of diving records, and ensuring compliance with this manual and all relevant regulations of the membership organization, rests with the DSO.
6. May permit portions of this program to be carried out by a qualified delegate, although the DSO may not delegate responsibility for the safe conduct of the local diving program.
7. Shall be guided in the performance of the required duties by the advice of the DCB, but operational responsibility for the local diving program will be retained by the DSO.
8. Shall suspend diving operations, which he/she considers to be unsafe or unwise.
9. Evaluate and survey equipment and equipment maintenance programs.
10. Establish/approve and survey training programs through which the applicants for certification can satisfy the requirements of the Diving Safety Manual.
11. Investigate and coordinate for the DCB reviews of injuries or dangerous incidents arising from University diving. In particular, he/she will ensure the prompt, detailed investigation and reporting of diving fatalities involving University personnel.
12. Prepare recommendations for consideration by the DCB, such as changes in policy, procedures, regulations, training programs, equipment acceptance, etc.
13. Issue or revoke diving certificates.
14. Insure that any university compressors used for filling diving cylinders meet air quality standards as described in this manual.

## The Diving Control Board (DCB)

Because of the potential hazards to health that accompany scientific, research, or educational diving, and in support of State and Federal regulations, the Executive Director for Health Sciences Administration (HSA) has appointed a University of Washington DCB with the following responsibilities:

1. The DCB shall consist of a majority of active scientific divers. At least one member shall be a physician or person qualified in diving medicine. Voting members shall include the DSO, the responsible administrative officer, or his/her designee, and should include other representatives of the diving program such as qualified divers and members selected by procedures established by the DCB. A Chair and a Secretary may be chosen from the membership of the board according to local procedure.
2. Meetings of the DCB shall be held at least four times each year with the interval between any two consecutive meetings not to exceed six months. The time for these meetings will be scheduled at least two weeks in advance. Additional meetings of the DCB may be called by the Chair. Any member with the endorsement of two additional members may require the Chair to call a meeting by submitting the request and endorsement in writing.
3. An annual meeting or group of meetings of the DCB will be held during the first half of each calendar year to receive status reports on the program and approve the board's annual report.
4. An annual report of the DCB will be submitted by the Chair as approved by the board to the HSA Executive Director. The report may include any specific additional recommendations requested by motion and recommendations from the Chair. The annual report shall be signed by the Chair.
5. An annual report of diving activities shall be prepared and submitted to the AAUS. At this time any recommendations for modifications of the AAUS standards shall be submitted for consideration.
6. A motion shall pass when approved by more than one-half of the members. Any business conducted by mail shall require a majority vote of the membership.
7. Request to refer action to board meeting may be made for any action that is conducted by mail or normally delegated to the DSO. Such a request should be submitted to the Chair. At the discretion of the person, the previous action may be stayed pending a meeting.
8. Minutes of meetings will be prepared and distributed to all members. The minutes shall be accepted by approval of a majority.
9. Has autonomous and absolute authority over the scientific diving program's operation.
10. Shall approve and monitor diving projects.
11. Shall review and revise the diving safety manual.
12. Shall assure compliance with the manual.

13. Shall certify the depths to which a diver has been trained.
14. Shall take disciplinary action for unsafe practices.
15. Shall assure adherence to the buddy system for scuba diving.
16. Shall act as the official representative of the membership organization in matters concerning the scientific diving program.
17. Shall act as a board of appeal to consider diver-related problems.
18. Shall recommend the issue or the revocation of diving certifications.
19. Shall recommend changes in policy and amendments to the AAUS and the membership organization's scientific diving manual as the need arises.
20. To advise the Executive Director, HSA and the Director, EH&S with respect to such programs and facilities as are necessary to maintain an appropriate program of diving safety at the University of Washington.
21. To be responsible to the Director, EH&S, or his/her designee, for the administration of the program.
22. Shall establish and/or approve training programs through which the applicants for certification can satisfy the requirements of the University of Washington's Diving Safety Manual.
23. Shall suspend diving programs, which it considers to be unsafe or unwise.
24. Shall establish criteria for equipment selection and use.
25. Shall recommend new equipment or techniques.
26. Shall establish and/or approve facilities for the inspection and maintenance of diving and associated equipment.
27. Shall ensure that the University of Washington's air station(s) meet air quality standards as described in Sec. 3.60 of this manual.
28. Shall periodically review the DSO's performance and program.
29. Shall sit as a board of investigation to inquire into the nature and cause of diving accidents or violations of the University of Washington Diving Safety Manual.

### **Instructional Personnel**

1. Qualifications - All personnel involved in diving instruction under the auspices of the University shall be qualified for the type of instruction being given.

2. Selection - Instructional personnel will be selected by the DSO, or his/her designee, who will solicit the advice of the DCB in conducting preliminary screening of applicants for instructional positions.

### **Lead Diver**

For each dive, one individual shall be designated as the Lead Diver who shall be at the dive location during the diving operation. In a situation where there are multiple dives occurring simultaneously, the Lead Diver may delegate their responsibilities to another qualified Lead Diver for individual dives. The Lead Diver shall be responsible for:

1. Coordination with other known activities in the vicinity, which are likely to interfere with diving operations.
2. Ensuring all dive team members possess current certification and are qualified for the type of diving operation.
3. Planning dives in accordance with Section 2.20.
4. Ensuring safety and emergency equipment is in working order and at the dive site.
5. Briefing the dive team members on:
  - a) Dive objectives.
  - b) Unusual hazards or environmental conditions likely to affect the safety of the diving operation.
  - c) Modifications to diving or emergency procedures necessitated by the specific diving operation.
6. Suspending diving operations if in his/her opinion conditions are not safe.
7. Reporting to the DSO and DCB any physical problems or adverse physiological effects including symptoms of pressure-related injuries.

### **Reciprocity and Visiting Scientific Divers**

1. Two or more AAUS Organizational Members engaged jointly in diving activities, or engaged jointly in the use of diving resources, shall designate one of the participating DCB's to govern the joint dive project.
2. A Scientific Diver from one Organizational Member shall apply for permission to dive under the auspices of another Organizational Member by submitting to the DSO of the host Organizational Member a document containing all the information described in Appendix 1 (letter of reciprocity) signed by the DSO or person of the home DCB.
3. A Visiting Scientific Diver may be asked to demonstrate his/her knowledge and skills for the planned diving.

4. A diver permanently entering the UW Dive Program through a Verification of Training is required to submit a copy of their current dive physical and exam results in accordance with Section 6 of this standard.
5. If a host Organizational Member denies a visiting scientific diver permission to dive, the host DCB shall notify the visiting scientific diver and his/her DCB with an explanation of all reasons for the denial.

### **Waiver of Requirements**

The University's DCB may grant a waiver for specific requirements of training, examinations, depth certification, and minimum activity to maintain certification. This procedure will be applied on a case by case basis and may not include medical requirements. Proof of previous or alternative training must be shown for requirements to be waived.

### **Consequence of Violation of Regulations by Scientific Divers**

Failure to comply with the regulations of the University of Washington Diving Safety Manual may be cause for the revocation or restriction of the diver's scientific diving certificate by action of the DCB.

### **1.30 CONSEQUENCES OF VIOLATION OF REGULATIONS BY ORGANIZATIONAL MEMBERS**

Failure to comply with the regulations of this standard may be cause for the revocation or restriction of the University of Washington's recognition by the AAUS.

### **1.40 RECORD MAINTENANCE**

The DSO or his/her designee shall maintain permanent records for each individual Scientific Diver certified. The file shall include evidence of certification level, log sheets, results of current physical examination, reports of disciplinary actions by the University's DCB, and other pertinent information deemed necessary. All personal records shall be maintained in confidence and released only with written permission from the diver or former diver.

#### **Availability of Records:**

1. Medical records shall be available to the attending physician of a diver or former diver when released in writing by the diver.
2. Records and documents required by this standard shall be retained by the University of Washington for the following period:
  - a) Physician's written reports of medical examinations for dive team members - five (5) years.
  - b) Manual for diving safety - current document only.
  - c) Records of dive – one (1) year, except five (5) years where there has been an incident of pressure-related injury or diving accident.

- d) Pressure-related injury assessment – five (5) years.
- e) Equipment inspection and testing records - current entry or tag, or until equipment is withdrawn from service. In the event of an accident all records for the equipment shall be kept for five (5) years.
- f) Records of hospitalization – five (5) years.
- g) Whenever a diver ceases to dive under University auspices, but continues to dive under auspices of another institution, a copy of all applicable records shall be transferred to the successor institution upon request in writing.
- h) If a diver ceases to dive under University auspices and plans no further research or scientific diving activities, the EH&S department will keep the diver's records for 5 years.



## SECTION 2.00

### DIVING REGULATIONS FOR SCUBA (OPEN CIRCUIT, COMPRESSED AIR)

#### 2.10 INTRODUCTION

No person shall engage in scientific diving operations under the auspices of the University of Washington scientific diving program unless he/she holds a current certification issued pursuant to the provisions of this manual.

Failure to comply with the regulations in this manual may be cause for the revocation or restriction of the diver's certification unless it was necessary to prevent or minimize a situation, which is likely to cause death, serious physical harm, or major environmental damage. A written report of such actions must be submitted to the DCB explaining the circumstances and justifications for such action.

#### 2.20 PRE-DIVE PROCEDURES

##### Dive Plans

Complete dive plans should be submitted to the DSO for review and approval. Dives should be planned around the competency of the least experienced diver. Before conducting any diving operations under the auspices of the University of Washington, the Lead Diver for a proposed operation must formulate a dive plan to be reviewed with all divers, and should include the following:

1. Divers qualifications, and the type of certificate or certification held by each diver.
2. Emergency plan (see Appendix 1) with the following information:
  - a) Name, telephone number, and relationship of person to be contacted for each diver in the event of an emergency.
  - b) Nearest operational recompression chamber.
  - c) Nearest accessible hospital.
  - d) Available means of transport.
  - e) Means of communication that will be used in requesting emergency services. See Section 3.40, Emergency Communications.
3. Approximate number of proposed dives.
4. Location(s) of proposed dives.
5. Estimated depth(s) and bottom time(s) anticipated.
6. Decompression status and repetitive dive plans, if required.
7. Proposed work, equipment, and boats to be employed.

8. Any hazardous conditions anticipated.
9. A first-aid kit, emergency oxygen administration kit, appropriate emergency information (Appendix 5), and emergency radio or telephone communication shall be at the dive location.
10. A set of appropriate diving tables must be available at the dive location unless dive computers are used. These tables must be at least as conservative as the U.S. Navy Diving Tables. Tables shall not be used as a backup in the event of a dive computer failure.

## **Pre-dive Safety Checks**

1. Diver's Responsibility:
  - a) Each Scientific Diver shall conduct a functional check of his/her diving equipment in the presence of the diving buddy or tender, and review emergency hand signals and techniques.
  - b) It is the diver's responsibility and duty to refuse to dive if, in his/her judgment, conditions are unfavorable, or if he/she would be violating the precepts of his/her training, of this manual.
  - c) No dive team member shall be required to be exposed to hyperbaric conditions against their will, except when necessary to prevent or treat a pressure-related injury.
  - d) No dive team member shall be permitted to dive for the duration of any known condition which is likely to adversely affect the safety and health of the diver or other dive members.
2. Equipment Evaluations
  - a) Each diver shall ensure that his/her equipment is in proper working order and that the equipment is suitable for the type of diving operation.
  - b) Each diver shall have the capability of achieving and maintaining positive buoyancy.
  - c) Each diver shall be trained, qualified, and authorized for the diving mode and specialized equipment being used, the diving activity to be performed, and the depths at which the diving is to be conducted
3. Site Evaluation - The environmental conditions at the site will be evaluated.
  - a) Boat Tenders are required for divers in current areas where there is a chance for the divers or the dive boat to be swept away from the dive site, blue water diving, and for dives after sunset. Boat Tenders are also required for diving at FHL's.

## **2.30 DIVING PROCEDURES**

### **Solo Diving Prohibition**

1. All diving conducted under the auspices of the University (See Section 1.20) shall be planned and executed to ensure that every diver involved maintains constant, effective communication with at least one other comparably equipped and certified scientific diver in the water. This buddy system is based upon mutual assistance, especially in the case of an emergency. Dives should be planned around the competency of the least experienced diver. If separation occurs, Divers will conduct an underwater search for one (1) minute, surface, and look for the missing diver's bubbles. When found, if the bubbles are stationary, follow them down and reunite, or assist the diver. If the bubbles are moving, follow them on the surface.

### **Refusal to Dive**

1. The decision to dive is that of the diver. A diver may refuse to dive, without fear of penalty, whenever he/she feels it is unsafe for them to make the dive (see Section 2.20 Pre-Dive Safety Checks).
2. Safety - The ultimate responsibility for safety rests with the individual diver. It is the diver's responsibility and duty to refuse to dive if, in his/her judgment, conditions are unsafe or unfavorable, or if he/she would be violating the precepts of his/her training or the regulations in this manual.

### **Termination of the Dive**

1. It is the responsibility of the diver to terminate the dive, without fear of penalty, whenever he/she feels it is unsafe to continue the dive, unless it compromises the safety of another diver already in the water dive (see Section 2.20 Pre-Dive Safety Checks).
2. A dive shall be terminated while there is still sufficient cylinder pressure to permit the diver to reach the surface safely with 500 PSI remaining.
3. If engaging in a special decompression dive, this 500 PSI limit must include decompression time, or to reach safely, an additional air source at the first decompression stop with 500 PSI remaining in the diver's tank.

### **Emergencies and Deviations from Regulations**

1. Any diver may deviate from the requirements of this manual to the extent necessary to prevent or minimize a situation which is likely to cause death, serious physical harm, or major environmental damage. A written report of such actions must be submitted to the DCB explaining the circumstances and justifications within 24 hours.

## **2.40 POST-DIVE PROCEDURES**

### **Post-Dive Safety Checks**

1. After the completion of a dive, each diver shall report any physical problems, symptoms of decompression sickness, or equipment malfunctions to the dive team leader and seek appropriate medical attention. Any incidents should be reported using the UW Diving Injury/Incident Report Form (Appendix 5).
2. When diving outside the no-decompression limits, the divers should remain awake for at least one hour after diving, and in the company of a dive team member who is prepared to transport him/her to a hyperbaric chamber if necessary.

## **2.50 EMERGENCY PROCEDURES**

1. The DCB will develop emergency procedures, which follow the standards of care of the community and must include procedures for emergency care, recompression and evacuation for each dive location (Appendix 4). This information must be current and included in the Dive and Emergency Plans (Appendix 1).

## **2.60 FLYING AFTER DIVING OR ASCENDING TO ALTITUDE (OVER 1000 FEET)**

1. Following a Single No-Decompression Dive: Divers should have a minimum preflight surface interval of 12 hours.
2. Following Multiple Dives per Day or Multiple Days of Diving: Divers should have a minimum preflight surface interval of 18 hours.
3. Following Dives Requiring Decompression Stops: Divers should have a minimum preflight surface interval of 24 hours.
4. Before ascending to Altitude above (1000 feet) by Land Transport: Divers should follow the appropriate guideline for preflight surface intervals unless the decompression procedure used has accounted for the increase in elevation.

## **2.70 RECORDKEEPING REQUIREMENTS**

### **Personal Diving Log**

1. Each certified scientific diver shall log every dive made under the auspices of the University of Washington program, and is encouraged to log all other dives. Dive logs shall be entered into the AAUS database.
2. Dive logs must be entered on line at (you must be an Active Scientific Diver to access this site) the AAUS /UW Diving Database. Reciprocity Divers must record their dives with their parent institution and send a copy to the UW. The diving log shall be submitted on a monthly basis to maintain active status and include the following:
  - a) Name of diver, partner, and Lead Diver.
  - b) Date, time, and location.
  - c) Diving modes used.
  - d) General nature of diving activities.

- e) Approximate surface and underwater conditions.
- f) Maximum depths, bottom time and surface interval time.
- g) Diving tables or computers used.
- h) Detailed report of any near or actual incidents.

### **Required Incident Reporting**

All diving-related incidents or accidents must be reported as soon as possible, but no later than 24 hours to the DSO (See Inside front cover and Appendix 4 for Emergency Telephone Numbers for how to contact the DSO). (If the DSO cannot be reached during normal working hours, contact the most senior University of Washington EH&S staff member available. After normal working hours, notify the EH&S Staff On Call (SOC) by calling the UW Police Department (UWPD) Dispatch at (206) 685-8973 (UWPD).

Use the standard UW Diving Incident/Injury Report Form (Appendix 5) to record the incident. Be sure to include the circumstances of the incident and the extent of any injuries or illness. Additionally, you will be required to report the accident or incident to EH&S utilizing the Online Accident Reporting System (OARS) through their website at <http://www.ehs.washington.edu/ohsoars/index.shtm>.

All information must meet the following reporting requirements:

1. The University shall record and report occupational injuries and illnesses in accordance with requirements of the appropriate Labor Code section.
2. The following information shall be recorded and retained by the DSO, with the record of the dive, for a period of five (5) years:
  - a) Complete AAUS Incident Report Form found at [www.aaus.org](http://www.aaus.org) .
  - b) Written descriptive report to include:
    - c) Name, address, phone numbers of the principal parties involved.
    - d) Summary of experience of divers involved.
    - e) Location, description of dive site and description of conditions that led up to incident, including dive data and dive plan.
    - f) Description of symptoms, including depth and time of onset.
    - g) Description and results of treatment.
    - h) Disposition of case.
    - i) Recommendations to avoid repetition of incident.

3. The University of Washington shall investigate and document any incident of diving-related injury and prepare a report, which is to be forwarded to the AAUS during the annual reporting cycle. This report must first be reviewed and released by the University's DCB.

## SECTION 3.00

### DIVING EQUIPMENT

#### 3.10 GENERAL POLICY

1. All equipment for SCUBA training shall meet ANSI Instructional Standards Minimum Course Content for Entry-Level SCUBA Certification and additional requirements determined by the DSO/DCB.
2. All divers are expected to perform a basic inspection of their own and their teammates' equipment prior to each dive.
3. The use of diving equipment other than open circuit SCUBA shall require prior written permission from the DSO or DCB.
4. Diving equipment shall be tested and repaired according to the manufacturer's recommended procedures and specifications and as required in this manual. If equipment is subjected to extreme usage under adverse conditions, it requires more frequent testing and repair.

#### 3.20 EQUIPMENT

All equipment shall be tested and inspected on the schedule listed below. Equipment will be serviced on a schedule in accordance with manufacturer's specifications. Records of testing, repair, and maintenance shall be in accordance with Section 3.50 with copies being sent to the DSO as required.

Regulator	Initially and every 12 months
Gauges	Initially and every 12 months
SCUBA Cylinders	Annual VIP and Hydro every 5 years
Cylinder Valves	Initially and every 12 months
Masks and Helmets	Initially and every 12 months
Compressors	See Section 3.40
Air Storage Vessels	See Section 3.40
Air Filtration Systems	See Section 3.40
Buoyancy Control Devices	Initially and every 12 months
Dry Suits	Initially and every 12 months

#### Regulators

1. Only those makes and models specifically approved by the DSO and the DCB shall be used.
2. Scuba regulators shall be inspected and tested prior to first use and every 12 months thereafter.
3. Regulators will consist of a primary second stage and an alternate air source (such as an octopus second stage or redundant air supply).

## **Breathing Masks and Helmets**

1. Shall be inspected and tested prior to first use and every 12 months thereafter. Breathing masks and helmets shall have:
2. A non-return valve at the attachment point between helmet or mask and hose, which shall close readily and positively.
3. An exhaust valve.
4. A minimum ventilation rate capable of maintaining the diver at the depth to which he/she is diving.

## **Scuba Cylinders**

1. Scuba cylinders shall be designed, constructed, and maintained in accordance with the current Department of Transportation (DOT) Regulations as outlined in CFR 49.
2. Scuba cylinders must be hydrostatically tested in accordance with DOT standards.
3. Scuba cylinders must have an internal inspection at intervals not to exceed 12 months.
4. Scuba cylinder valves shall be functionally tested at intervals not to exceed 12 months.

## **Backpacks**

1. Backpacks without integrated flotation devices and weight systems shall have a quick release device designed to permit jettisoning with a single motion from either hand.

## **Gauges**

1. Gauges shall be inspected and tested before first use and every 12 months thereafter.
2. All divers must have an underwater timing device, an approved depth indicator, and a submersible pressure gauge.

## **Flotation Devices**

1. Each diver must, by virtue of a buoyancy-compensating device, have the ability to float with all his or her gear on. Ideally, the ability to produce floatation (positive buoyancy) should exceed negative buoyancy by approximately 20 pounds (of lift) for an acceptable margin of safety.
2. Personal flotation systems, buoyancy compensators, dry suits, or other variable volume buoyancy compensation devices shall be equipped with an exhaust valve.
3. These devices shall be functionally inspected and tested at intervals not to exceed twelve months.
4. Buoyancy Compensator is recommended for:



- a) All dry suits, as long as it does not interfere with the operation of the dry suit's control valves. It is particularly recommended for all non-neoprene dry suits, where a severe suit failure may result in the diver being negatively buoyant even after the weight belt is ditched.
- b) For any dive that is planned for or may result in a long surface swim.
- c) For any "blue water" or mid-water column diving.
- d) For any high current dives where the diver may be swept off-station and have to float on the surface until pickup.

### **Determination of Decompression Status: Dive Tables, Dive Computers**

1. A set of diving tables, approved by the Diving Control Board, must be available at the dive location.
2. Dive computers may be utilized in place of diving tables, but must be approved by the DCB. When a diver with no dive computer is diving with diver/s who have computers, dives must be conducted based off of the dive table limits.
3. AAUS recommendations on dive computers are located in Appendix 8

### **Additional Equipment**

1. Quick release mechanisms on all weights, backpacks, and buoyancy control devices designed to permit jettisoning the entire gear. Weights should be capable of one hand release.
2. Exposure suit or protective clothing appropriate for the environment and the work.
3. Night dives shall require two dive lights in good working order capable of lasting longer than the planned dive.
4. A diver's knife or other cutting device (shears, trilobite, etc.) kept sharp and in proper condition for use.
5. When diving in hazardous environments such as under ice diving, dives with danger of entanglement, human powered submarine pilot diving, or other dangerous circumstances, divers should have a "bail out bottle" of appropriate size to provide sufficient air for an emergency air source, bail out bottles require DSO or DCB approval.

### **3.30 AUXILIARY EQUIPMENT**

#### **Hand held underwater power tools.**

1. The use of surface supplied electrical, pneumatic, and hydraulic hand held tools must be approved in writing by the DSO and/or DCB. Requests should be submitted with the dive plan. Hand-held electrical tools and equipment used underwater shall be specifically designed for this purpose. Electrical tools and equipment supplied with power from the

surface shall be de-energized before being placed into or retrieved from the water. Hand-held power tools shall not be supplied with power from the dive location until requested by the diver and tool on/off operation must be under the diver's control.

Note: Some tools may not be appropriate for scientists to use under the OSHA exemption for scientific diving.

1. Lift Bag operation should be sustained with an air supply that is separate from the diver's air supply. This mode of operation will prevent excessive depletion of the divers air supply should an emergency occur late in the dive during lift bag use.

### **3.40 SUPPORT EQUIPMENT**

#### **First-Aid Supplies and Communications**

1. A first-aid kit adequate for the diving operation shall be available at the dive location (See Appendix 4, Divers' First-Aid Kit Check List). When used in a hyperbaric chamber or bell, the first-aid kit shall be suitable for use under hyperbaric conditions.
2. An emergency oxygen kit, approved by the DSO and the DCB shall be available at the dive site. All divers must be trained in the general administration of 100% oxygen by demand mask for diving injuries and familiar with the proper assembly and use of the specific kit at the dive site.
3. Portable emergency VHF radio or telephone (standard pay phone or cellular phone) shall be available on site. Equipment must be checked for proper functioning at the dive site.
4. This manual is required at all dive sites. First Aid and Communications protocol and contacts are defined for the Northwest region in Appendix 4. Dives out of this area must have dive and emergency plans submitted as outlined in Section 2.20.

#### **Diver's Flag**

1. A diver's flag shall be displayed prominently whenever diving is conducted under circumstances where required or where water traffic is probable.

#### **Compressor Systems - University of Washington Controlled**

Low-pressure compressors used to supply air to the diver if equipped with a volume tank shall have a check valve on the inlet side, a relief valve, and a drain valve.

Diving air compressors used under University auspices, whether or not University-owned, shall

1. Meet American Society of Mechanical Engineers standards and Washington State Boiler and Unfired Pressure Vessel regulations.
2. Meet the following installation requirements:
  - a) Air intakes shall be provided with a filter, and be located to ensure a supply of clean air, free from contamination by fumes, smoke, etc.

- b) Compressed air systems over 500 psig shall have slow-opening drain valves.
  - c) Discharged compressed air shall be passed to the compressed air holder through frequently cleaned and recharged filters designed to remove dusts, oil droplets, and water, and to minimize other contaminants.
  - d) Oil lubricated compressor cylinders and coolers shall be well ventilated or otherwise cooled, or the operation cycled to ensure against the high temperatures at which carbon monoxide is formed from the oil.
3. Meet the following maintenance requirements:
- a) A log shall be kept by the compressor operator showing operational hours, repair, overhaul, and filter maintenance.
  - b) All diving air compressors shall be inspected and maintained in accordance with the manufacturer's service policy. Records of service shall be maintained according to Section 3.50.
  - c) The output of air compressor systems shall be tested for air purity at intervals not to exceed six (6) months or 100 hours of operation by means of samples taken at the connection to the distribution system. Records of tests shall be kept and copies sent to the DSO.

## **OXYGEN SAFETY**

- 1. Equipment used with oxygen or mixtures containing over 40 percent (%) by volume oxygen shall be designed and maintained for oxygen service.
- 2. Oxygen systems over 125 psig shall have slow-opening shut-off valves.

## **AIR STORAGE VESSELS**

- 1. All air storage vessels/cylinders shall be designed in accordance with the provisions of the applicable Unfired Pressure Vessel Safety Orders. Internal and external inspections shall be conducted in the manner and frequency specified by the Department of Transportation. Vessels exposed to unusual environmental conditions may require more frequent internal and external inspections. Records of tests shall be maintained according to Section 3.50 and copies sent to the DSO.

## **RECORD KEEPING**

- 2. All records of compressor systems maintenance and testing must be kept by the operator for as long as the equipment is retained for use. Records made on the proper form must be sent to the DSO.

## **3.50 EQUIPMENT MAINTENANCE**

### **Record Keeping**

Each equipment modification, repair, test, calibration, or maintenance service shall be recorded and the proper Annual Equipment Testing and Maintenance Summary sent to the DSO annually. The report shall include the date and nature of work performed, serial number of the item, and the name of the person performing the work for the following equipment:

1. Regulators
2. Submersible pressure gauges
3. Depth gauges
4. Scuba cylinders
5. Cylinder valves
6. Diving helmets
7. Submersible breathing masks
8. Compressors
9. Gas control panels
10. Air storage cylinders
11. Air filtration systems
12. Analytical instruments
13. Buoyancy control devices
14. Dry suits

### **Compressor Operation and Air Test Records**

Gas analyses and air tests shall be performed on each controlled breathing air compressor at regular intervals of no more than 100 hours of operation or six months, whichever occurs first. The results of these tests shall be entered in a formal log and be maintained by the operator with a copy of the air analysis sent to the DSO.

A log shall be maintained showing operation, repair, overhaul, filter maintenance, and temperature adjustment for each compressor.

### 3.60 AIR QUALITY STANDARDS

Breathing air for scuba shall meet the following specifications as set forth by the Compressed Gas Association (CGA Pamphlet G-7.1) and as referenced in OSHA 29 CFR 1910.134.

#### CGA Grade E

<b>Component</b>	<b>Maximum</b>
Oxygen	20 - 22%/v
Carbon Monoxide	10 PPM/v
Carbon Dioxide	1000 PPM/v
Condensed Hydrocarbons	5 mg/m <sup>3</sup>
Total Hydrocarbons as Methane	25 PPM/v
Water Vapor	NS
Objectionable Odors	None

## **SECTION 4.00**

### **ENTRY-LEVEL TRAINING REQUIREMENTS**

#### **4.10 General Policy**

Training and certification as an entry-level diver is a prerequisite to AAUS and UW Scientific Diver Training. In lieu of writing/promulgating AAUS specific standards for entry-level divers, AAUS references here the standards for entry-level diver training as defined by the WRSTC and/or ISO. AAUS programs who wish to train entry-level divers may do so using one of the following options:

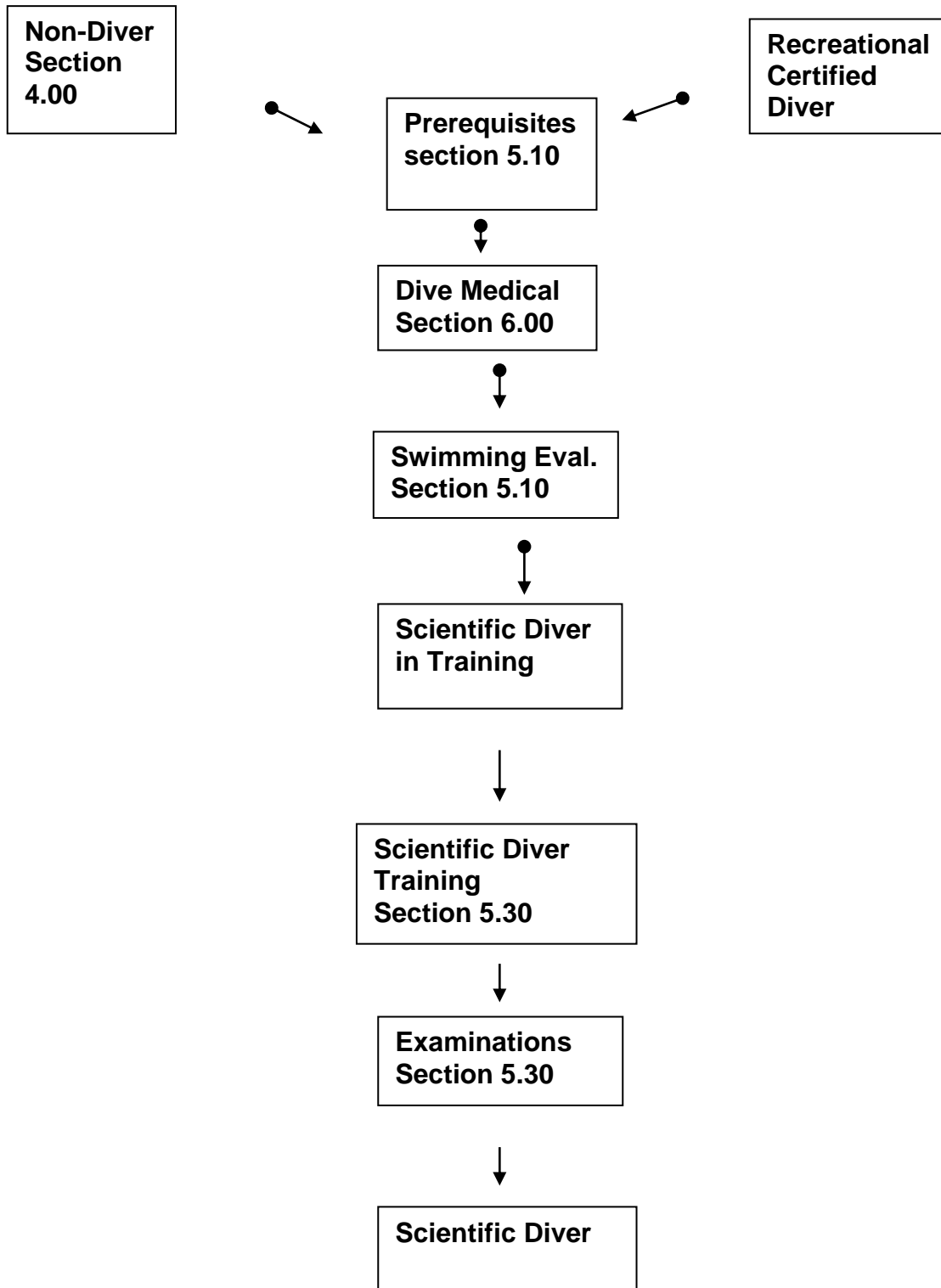
1. Under the auspices and standards of an internationally recognized diver training agency.
2. Under the auspices of AAUS using the minimum guidelines presented by the most current version of the RSTC/WRSTC and/or ISO entry-level diver standards.

#### **4.20 References**

“Minimum Course Content for Open Water Diver Certification”- World Recreational Scuba Training Council (WRSTC), [www.wrstc.com](http://www.wrstc.com).

“Safety related minimum requirements for the training of recreational scuba divers -- Part 2: Level 2 -- Autonomous diver”. ISO 24801-2:2007- International Organization for Standardization (ISO) - [www.iso.org](http://www.iso.org).

## AAUS SCIENTIFIC DIVER FLOW CHART



## SECTION 5.00

### SCIENTIFIC DIVER CERTIFICATION

This section describes the training and performance standards for UW Scientific Divers. These standards represent the minimum required level of knowledge and skills presented in a generalized format.

#### 5.10 Prerequisites

##### Administrative

The applicant/candidate must complete all administrative and legal documentation required by the University of Washington.

##### Diver Certification

The applicant/candidate must, at minimum, show documented proof of entry-level diver certification from an internationally recognized training agency. As an alternative, AAUS OMs who wish to train and certify entry-level divers under AAUS auspices may do so under the guidelines presented in Section 4.0.

##### Medical Examination

The applicant/candidate must be medically qualified for diving as described in Section 6.0.

##### Swimming/Watermanship Evaluation

The applicant/candidate must demonstrate the following in the presence of the Diving Safety Officer, instructor, or other DSO approved examiner. All tests are to be performed without swim aids, however, where exposure protection is needed, the applicant must be appropriately weighted to provide for neutral buoyancy.

1. Swim underwater for a distance of 25 yards/meters without surfacing.
2. Swim 400 yards/meters in less than 12 minutes.
3. Tread water for 10 minutes, or 2 minutes without the use of hands.
4. Transport a passive person of equal size a distance of 25 yards/meters in the water.

#### 5.20 Training

The diver must complete theoretical aspects and practical training for a minimum cumulative time of 100 hours. Theoretical aspects shall include principles and activities appropriate to the intended area of scientific study.

##### *Theoretical Training/ Knowledge Development*

##### Required Topics:

1. Diving Emergency Care Training
  - a) Cardiopulmonary Resuscitation (CPR)
  - b) Standard or Basic First Aid
  - c) Recognition of DCS and AGE
  - d) Accident Management
  - e) Field Neurological Exam
  - f) Oxygen Administration
2. Dive Rescue
3. Dive Physics
4. Dive Physiology
5. Dive Environments
6. Decompression Theory and its Application
7. AAUS Scientific Diving Regulations and History



- a) Scientific Dive Planning
  - b) Coordination with other Agencies
  - c) Appropriate Governmental Regulations
8. Scientific Method
  9. Data Gathering Techniques (Only Items specific to area of study required)
    - a) Transect Sampling (Quadrating)
    - b) Transecting
    - c) Mapping
    - d) Coring
    - e) Photography
    - f) Tagging
    - g) Collecting
    - h) Animal Handling
    - i) Archaeology
    - j) Common Biota
    - k) Organism Identification
    - l) Behavior
    - m) Ecology
    - n) Site Selection, Location, and Re-location
    - o) Specialized Equipment for data gathering
    - p) HazMat Training
    - q) HP Cylinders
    - r) Chemical Hygiene, Laboratory Safety (Use of Chemicals)
  10. Suggested Topics:
  11. Specific Dive Modes (methods of gas delivery)
    - a) Open Circuit
    - b) Hookah
    - c) Surface Supplied diving
  12. Small Boat Operation
  13. Rebreathers
    - a) Closed
    - b) Semi-closed
  14. Specialized Breathing Gas
    - a) Nitrox
    - b) Mixed Gas
  15. Specialized Environments and Conditions
    - a) Blue Water Diving,
    - b) Ice and Polar Diving (Cold Water Diving)
    - c) Zero Visibility Diving
    - d) Polluted Water Diving
    - e) Saturation Diving
    - f) Decompression Diving
    - g) Overhead Environments
    - h) Aquarium Diving
    - i) Night Diving
    - j) Kelp Diving
    - k) Strong Current Diving (Live-boating)
    - l) Potential Entanglement
  16. Specialized Diving Equipment
  17. Full face mask

- 18. Dry Suit
- 19. Communications

## Practical Training/ Skill Development

### Confined Water Evaluation

At the completion of training, the trainee must satisfy the Diving Safety Officer or the instructor of their ability to perform the following, as a minimum, in a pool or in sheltered water:

- a) Enter water with full equipment.
- b) Clear face mask.
- c) Demonstrate air sharing, including both buddy breathing and the use of alternate air source, as both donor and recipient, with and without a face mask.
- d) Demonstrate ability to alternate between snorkel and scuba while kicking.
- e) Demonstrate understanding of underwater signs and signals.
- f) Demonstrate simulated in-water mouth-to-mouth resuscitation.
- g) Rescue and transport, as a diver, a passive simulated victim of an accident.
- h) Demonstrate ability to remove and replace equipment while submerged.
- i) Demonstrate watermanship ability, which is acceptable to the instructor.

### Open Water Evaluation

The trainee must satisfy an instructor, approved by the Diving Safety Officer, of their ability to perform at least the following in open water:

- a) Surface dive to a depth of 10 feet in open water without scuba.
- b) Demonstrate proficiency in air sharing as both donor and receiver.
- c) Enter and leave open water or surf, or leave and board a diving vessel, while wearing scuba gear.
- d) Kick on the surface 400 yards while wearing scuba gear, but not breathing from the scuba unit.
- e) Demonstrate judgment adequate for safe diving.
- f) Demonstrate, where appropriate, the ability to maneuver efficiently in the environment, at and below the surface.
- g) Complete a simulated emergency swimming ascent.
- h) Demonstrate clearing of mask and regulator while submerged.
- i) Demonstrate ability to achieve and maintain neutral buoyancy while submerged.
- j) Demonstrate techniques of self-rescue and buddy rescue.
- k) Navigate underwater.
- l) Plan and execute a dive.

### Checkout Dive/ Additional Experience

Practical training must include an Open Water checkout dive(s), with evaluation of the skills listed in Open Water Evaluation, with the DSO or qualified delegate followed by at least 11 ocean or open water dives in a variety of dive sites and diving conditions, for a cumulative bottom time of 6 hours. Dives following the checkout dive must be supervised by a certified Scientific Diver with experience in the type of diving planned, with the knowledge and permission of the DSO.

## **5.30 Examinations**

### Written Exams

Before completing training, the trainee must pass a written examination that demonstrates knowledge of at least the following:

1. Function, care, use, and maintenance of diving equipment.
2. Physics and physiology of diving.

3. Diving regulations and precautions.
4. Near-shore currents and waves.
5. Dangerous marine animals.
6. Emergency procedures, including buoyant ascent and ascent by air sharing.
7. Currently accepted decompression procedures.
8. Demonstrate the proper use of dive tables.
9. Underwater communications.
10. Aspects of freshwater and altitude diving.
11. Hazards of breath-hold diving and ascents.
12. Planning and supervision of diving operations.
13. Diving hazards.
14. Cause, symptoms, treatment, and prevention of the following: near drowning, air embolism, carbon dioxide excess, squeezes, oxygen poisoning, nitrogen narcosis, exhaustion and panic, respiratory fatigue, motion sickness, decompression sickness, hypothermia, and hypoxia/anoxia.
15. Suggested topics (from Sec. 5.20) at the DSO's discretion.

#### Equipment

The trainee will be subject to examination/review of:

1. Personal diving equipment
2. Task specific equipment

#### **5.40 Diver Permits/ Certifications**

1. UW requires that no person shall engage in scientific diving unless that person is authorized by the UW pursuant to the provisions of this standard. Only a person diving under the auspices of the University of Washington that subscribes to the practices of AAUS is eligible for a scientific diver certification.
2. **Scientific Diver-In-Training Permit**  
This is a permit to dive, usable only while it is current and for the purpose intended. This permit signifies that a diver has completed and been certified as at least an entry level diver through an internationally recognized certifying agency or scientific diving program, and has the knowledge skills and experience necessary to continue training as a scientific diver under supervision, as approved by the DSO. This permit is not meant as a mechanism to circumvent scientific diver training. Divers-in-Training depth authorization is 30 feet unless specified by DSO. Divers-in-Training must be accompanied by an active Scientific Diver and may only be buddied with another Diver-in-Training when involved in DSO authorized training or when under the supervision of the DSO or designee.
3. **Scientific Diver Certification**  
This permit signifies a diver has completed all requirements in Section 5.0 and is authorized by the University of Washington to engage in scientific diving without supervision, as approved by the DSO. Submission of documents and participation in aptitude examinations does not automatically result in certification. The applicant must convince the Diving Safety Officer and members of the DCB that they are sufficiently skilled

and proficient to be certified. This skill will be acknowledged by the signature of the Diving Safety Officer. Any applicant who does not possess the necessary judgment, under diving conditions, for the safety of the diver and their partner, may be denied University of Washington scientific diving privileges.

## **5.50 Depth Certifications**

### **1. Depth Certifications and Progression to Next Depth Level**

A certified diver diving under the auspices of the University of Washington may progress to the next depth level after successfully completing the required dives for the next level. Under these circumstances the diver may exceed their depth limit. Dives shall be planned and executed under close supervision of a diver certified to this depth, with the knowledge and permission of the DSO.

- a) Certification to 30 Foot Depth - Initial permit level, approved upon the successful completion of training listed in Section 4.00 and 5.00.
- b) Certification to 60 Foot Depth - A diver holding a 30 foot certificate may be certified to a depth of 60 feet after successfully completing, under supervision, 12 logged training dives to depths between 31 and 60 feet, for a minimum total time of 4 hours.
- c) Certification to 100 Foot Depth - A diver holding a 60 foot certificate may be certified to a depth of 100 feet after successfully completing, 4 dives to depths between 61 and 100 feet. The diver shall also demonstrate proficiency in the use of the appropriate Dive Tables.
- d) Certification to 130 Foot Depth - A diver holding a 100 foot certificate may be certified to a depth of 130 feet after successfully completing, 4 dives to depths between 100 and 130 feet. The diver shall also demonstrate proficiency in the use of the appropriate Dive Tables.
- e) Certification to 150 Foot Depth - A diver holding a 130 foot certificate may be certified to a depth of 150 feet after successfully completing, 4 dives to depths between 130 and 150 feet. The diver must also demonstrate knowledge of the special problems of deep diving, and of special safety requirements.
- f) Certification to 190 Foot Depth - A diver holding a 150 foot certificate may be certified to a depth of 190 feet after successfully completing, 4 dives to depths between 150 and 190 feet. The diver must also demonstrate knowledge of the special problems of deep diving, and of special safety requirements.
- g) Depth Authorization to 100 and 130 feet the diver shall also demonstrate proficiency in the use of appropriate decompression tracking methods and mastery of concepts related to deeper diving. At the discretion of the DSO, the diver may be required to conduct a dive in the deeper depth range under supervision while acting in the role of Lead Diver, to demonstrate proficiency in coordinating and supervising deeper diving operations.
- h) Authorizations to 150 and 190 feet may only be granted by the DCB, and shall be based at a minimum on similar provisions. For such authorizations, the DCB may require additional training and qualification in the use of nitrox (Section 7), decompression diving (Section 9), or mixed gas diving (Section 10) as pertinent to the activity.

## **5.60 Continuation of Certificate**

### **1. Minimum Activity to Maintain Certification**

- a) During any 12-month period, each certified scientific diver must log a minimum of 12 dives. At least one dive must be logged near the maximum depth of the diver's certification during each 6-month period. Divers certified to 150 feet or deeper may

satisfy these requirements with dives to 130 feet or over. Failure to meet these requirements may be cause for revocation or restriction of certification.

2. Re-qualification of Depth Certificate

- a) Once the initial certification requirements of Section 5.00 are met, divers whose depth certification has lapsed due to lack of activity may be re-qualified by procedures adopted by the University of Washington DCB.

3. Medical Examination

- a) All certified scientific divers shall pass a medical examination at the intervals specified in Section 6.0. After each major illness or injury, as described in Section 6.0, a certified scientific diver shall receive clearance to return to diving from a physician before resuming diving activities.

4. Emergency Care Training

The scientific diver must provide proof of training in the following:

- a) Adult CPR (must be current).
- b) Emergency oxygen administration (must be current)
- c) First aid for diving accidents (must be current)

### **5.70 Revocation of Certification**

A diving certificate may be revoked or restricted for cause by the Diving Safety Officer or the DCB. Violations of regulations set forth in this standard, or other governmental subdivisions not in conflict with this standard, may be considered cause. Diving Safety Officer shall inform the diver in writing of the reason(s) for revocation. The diver will be given the opportunity to present their case in writing for reconsideration and/or re-certification. All such written statements and requests, as identified in this section, are formal documents, which will become part of the diver's file.

### **5.80 Recertification**

If a diver's certificate expires or is revoked, they may be re-certified after complying with such conditions as the Diving Safety Officer or the DCB may impose. The diver shall be given an opportunity to present their case to the DCB before conditions for re-certification are stipulated.

### **5.90 Waiver of Requirements/Temporary Diver**

A temporary diver permit constitutes a waiver of the requirements of Section 5.0 and is issued only following a demonstration of the required proficiency in diving. It is valid only for a limited time, as determined by the Diving Safety Officer. This permit is not to be construed as a mechanism to circumvent existing standards set forth in this standard. The medical standards in Section 6 cannot be waived.

Requirements of Section 5.0 may be waived by the Diving Safety Officer if the person in question has demonstrated proficiency in diving and can contribute measurably to a planned dive. A statement of the temporary diver's qualifications shall be submitted to the Diving Safety Officer as a part of the dive plan. Temporary permits shall be restricted to the planned diving operation and shall comply with all other policies, regulations, and standards of this standard, including medical requirements.

## SECTION 6.00

### MEDICAL STANDARDS

#### 6.10 MEDICAL REQUIREMENTS

##### General

1. The University of Washington shall determine that divers have passed a current diving physical examination and have been declared by the examining physician to be fit to engage in diving activities as may be limited or restricted in the medical evaluation report.
2. All medical evaluations required by this standard shall be performed by, or under the direction of, a licensed physician of the applicant-diver's choice, preferably one trained in diving/undersea medicine.
3. New applicants must contact Employee Health Services to schedule the physical or make arrangements to receive the required paperwork. The new applicants will be directed by Employee Health Services to the correct forms for the physical. If a physician outside the University of Washington is utilized, all requirements and medical forms must be completed and submitted to Employee Health Services for approval.
4. The diver should be free of any chronic disabling disease and be free of any conditions contained in the list of conditions, listed on the following page and the SCUBA Medical Overview Form, for which restrictions from diving are generally recommended.
5. In such cases where conflict arises between the outside medical provider and the UW Diving Medical Officer (DMO), final authority for determining medical clearance to dive rests with the University's DMO.

#### 6.20 Frequency of Medical Evaluations

Medical evaluation shall be completed:

1. Before a diver may begin diving, unless an equivalent initial medical evaluation has been given within the preceding five (5) years (three (3) years if over the age of 40, two (2) years if over the age of 60), Employee Health Services has obtained the results of that examination, and those results have been reviewed and found satisfactory by the Campus Health Services medical personnel.
2. Thereafter, at five year intervals up to age 40, every three years after the age of 40, and every two years after the age of 60
3. Clearance to return to diving must be obtained from a physician after each major illness or injury or recompression treatment. Divers shall notify the DSO and have a medical diving physical and clearance before resuming diving activities. (A major illness or injury is one requiring medical attention and hospitalization or three (3) days bed rest, whether or not diving related.)

If the injury or illness is pressure related, then the clearance to return to diving must come from a physician trained in diving medicine. This clearance will be submitted to the Employee Health Services and may require approval from the DMO.

### **6.30 Information Provided Examining Physician**

The University of Washington shall provide a copy of the medical evaluation requirements of this standard to the examining physician.

### **6.40 Content of Medical Evaluations**

Medical examinations conducted initially and at the intervals specified in Section 6.10 shall consist of the following:

1. Applicant agreement for release of medical information to the DSO and the DCB. This can be found on the Medical Evaluation of Fitness for SCUBA Diving Report required for the physical.
2. Diving Medical History Form.
3. Diving physical examination (Section 6.10).

### **6.50 Conditions Which May Disqualify Candidates from Diving (Adapted from Bove, 1998)**

1. Abnormalities of the tympanic membrane, such as perforation, presence of a monomeric membrane, or inability to auto inflate the middle ears.
2. Vertigo including Meniere's disease.
3. Stapedectomy or middle ear reconstructive surgery.
4. Recent ocular surgery.
5. Psychiatric disorders including claustrophobia, suicidal ideation, psychosis, anxiety states, untreated depression.
6. Substance abuse, including alcohol.
7. Episodic loss of consciousness.
8. History of seizure.
9. History of stroke or a fixed neurological deficit.
10. Recurring neurologic disorders, including transient ischemic attacks.
11. History of intracranial aneurysm, other vascular malformation or intracranial hemorrhage.
12. History of neurological decompression illness with residual deficit.
13. Head injury with sequelae.
14. Hematologic disorders including coagulopathies.
15. Evidence of coronary artery disease or high risk for coronary artery disease.
16. Atrial septal defects.
17. Significant valvular heart disease - isolated mitral valve prolapse is not disqualifying.
18. Significant cardiac rhythm or conduction abnormalities.
19. Implanted cardiac pacemakers and cardiac defibrillators (ICD).
20. Inadequate exercise tolerance.
21. Severe hypertension.
22. History of spontaneous or traumatic pneumothorax.
23. Asthma.
24. Chronic pulmonary disease, including radiographic evidence of pulmonary blebs, bullae or cysts.

- 25. Diabetes mellitus.
- 26. Pregnancy

### **6.60 Laboratory Requirements for Diving Medical Evaluation and Intervals.**

1. Initial examination under age 40:
  - a. Medical History
  - b. Complete Physical Exam, emphasis on neurological and otological components
  - c. Urinalysis
  - d. Any further tests deemed necessary by the physician.
2. Periodic re-examination under age 40 (every five (5) years)
  - a. Medical History
  - b. Complete Physical Exam, emphasis on neurological and otological components
  - c. Urinalysis
  - d. Any further tests deemed necessary by the physician
3. Initial exam over age 40:
  - a. Medical History
  - b. Complete Physical Exam, emphasis on neurological and otological components
  - c. Detailed assessment of coronary artery disease risk factors using multiple-risk-factor assessment<sup>1,2</sup> (age, family history, lipid profile, blood pressure, diabetic screening, smoking history). Further cardiac screening may be indicated based on risk factor assessment.
  - d. Resting EKG
  - e. Chest X-ray
  - f. Urinalysis
  - g. Any further tests deemed necessary by the physician
4. Periodic re-examination over age 40 (every three (3) years); over age 60 (every two (2) years):
  - a. Medical History
  - b. Complete Physical Exam, emphasis on neurological and otological components
  - c. Detailed assessment of coronary artery disease risk factors using multiple-risk-factor assessment<sup>1,2</sup> (age, family history, lipid profile, blood pressure, diabetic screening, and smoking history). Further cardiac screening may be indicated based on risk factor assessment.
  - d. Resting EKG
  - e. Urinalysis
  - f. Any further tests deemed necessary by the physician

### **6.70 Physician's Written Report.**

1. After any medical examination relating to the individual's fitness to dive, University of Washington shall obtain a written report prepared by the examining physician, which shall contain the examining physician's opinion of the individual's fitness to dive, including any recommended restrictions or limitations. This will be reviewed by the Campus Health Services medical staff and placed in the diver's medical file.
2. The University of Washington shall make a copy of the physician's written report available to the individual upon request.



3. University employees (faculty, staff, and graduate students) with appointments that directly require scuba diving and, who are or will be actively involved in the support or conduct of scientific research operations, may receive diving medical exams through the Campus Health Services at no charge to the individual. If the employee elects to go to an outside physician they will pay for the exam and are required to send all original test reports to Employee Health for review and final clearance. Additional testing needed to clarify abnormal exam findings will be the responsibility of the diver.
4. University employees (faculty, staff, and graduate students) whose appointments do not require research diving, undergraduate students and visitors without reciprocity are responsible for the cost of the medical examination. Divers also must submit all the original test reports along with all required University of Washington SCUBA forms to Employee Health Clinic for final review and clearance.

## **SECTION 7.00**

### **NITROX DIVING GUIDELINES**

The following guidelines address the use of nitrox by scientific divers under the auspices of the University of Washington. Nitrox is defined for these guidelines as breathing mixtures composed predominately of nitrogen and oxygen, most commonly produced by the addition of oxygen or the removal of nitrogen from air.

#### **7.10 PREREQUISITES**

##### **Eligibility**

Only a certified Scientific Diver or Scientific Diver in Training (see Sections 4.00 and 5.00), diving under the auspices of the University, is eligible for authorization to use nitrox. After completion, review and acceptance of application materials, training and qualification, an applicant will be authorized to use nitrox within his/her depth authorization, as specified in Section 5.40.

##### **Application and Documentation**

Authorization to use nitrox shall be made through the DSO and or the DCB upon receiving copies of the certification cards and or verification of training.

#### **7.20 REQUIREMENTS FOR AUTHORIZATION TO USE NITROX**

Submission of documents and participation in aptitude examinations does not automatically result in authorization to use nitrox. The applicant must convince the DSO and members of the DCB that he/she is sufficiently skilled and proficient. The signature of the DSO on the authorization form will acknowledge authorization. After completion of training and evaluation, authorization to use nitrox may be denied to any diver who does not demonstrate to the satisfaction of the DSO or DCB the appropriate judgment or proficiency to ensure the safety of the diver and dive buddy.

Prior to authorization to use nitrox, the following minimum requirements should be met:

##### **Training**

The diver must complete additional theoretical and practical training in the use of nitrox beyond the Scientific Diver in Training air certification level, to the satisfaction of the DSO and DCB.

##### **Examinations**

Each diver should demonstrate proficiency in skills and theory in written, oral, and practical examinations covering:

1. Written examinations covering the information presented in the classroom training session(s) (i.e., gas theory, oxygen toxicity, partial pressure determination, etc.).
2. Practical examinations covering the information presented in the practical training session(s) (i.e., gas analysis, documentation procedures, etc.).

3. Open-water checkout dives, to appropriate depths, to demonstrate the application of theoretical and practical skills learned.

#### Minimum Activity to Maintain Authorization

The diver should log at least one (1) nitrox dive per year. Failure to meet the minimum activity level may be cause for restriction or revocation of nitrox authorization.

### 7.30 NITROX TRAINING GUIDELINES

Training in these guidelines should be in addition to training for Diver-In-Training authorization Standards (Section 4.00). It may be included as part of training to satisfy the Scientific Diver training requirements (AAUS Standards Section 5.00).

#### Classroom Instruction

1. Topics should include, but are not limited to: review of previous training; physical gas laws pertaining to nitrox; partial pressure calculations and limits; Equivalent Air Depth (EAD) concept and calculations; oxygen physiology and oxygen toxicity; calculation of oxygen exposure and Maximum (Safe) Operating Depth (MOD); determination of decompression schedules (both by EAD method using approved air dive tables, and using approved nitrox dive tables); dive planning and emergency procedures; mixing procedures and calculations; gas analysis; personnel requirements; equipment marking and maintenance requirements; dive station requirements.
2. The DCB may choose to limit standard nitrox diver training to procedures applicable to diving, and subsequently reserve training such as nitrox production methods, oxygen cleaning, and dive station topics to divers requiring specialized authorization in these areas.

#### Practical Training

The practical training portion will consist of a review of skills as stated for scuba (Section 4.00), with additional training as follows:

1. Oxygen analysis of nitrox mixtures;
2. Determination of MOD, oxygen partial pressure exposure, and oxygen toxicity time limits, for various nitrox mixtures at various depths;
3. Determination of nitrogen-based dive limits status by EAD method using air dive tables, and/or using nitrox dive tables, as approved by the DCB;
4. Nitrox dive computer use may be included, as approved by the DCB.

#### Written Examination (based on classroom instruction and practical training)

Before authorization, the trainee should successfully pass a written examination demonstrating knowledge of at least the following:

1. Function, care, use, and maintenance of equipment cleaned for nitrox use;
2. Physical and physiological considerations of nitrox diving (ex.: O<sub>2</sub> and CO<sub>2</sub> toxicity);

3. Diving regulations and procedures as related to nitrox diving, either scuba or surface-supplied (depending on intended mode);
4. Given the proper information, calculation of:
  - a) EAD for a given  $fO_2$  and actual depth;
  - b)  $PO_2$  exposure for a given  $fO_2$  and depth;
  - c) Optimal nitrox mixture for a given  $pO_2$  exposure limit and planned depth;
  - d) MOD for a given mix and  $pO_2$  exposure limit;
  - e) For nitrox production purposes, percentages/psi of oxygen present in a given mixture, and psi of each gas required to produce a  $fO_2$  by partial pressure mixing.
5. Decompression table and dive computer selection and usage;
6. Nitrox production methods and considerations;
7. Oxygen analysis;
8. Nitrox operational guidelines (Section 7.40), dive planning, and dive station components.

### **Open-water Dives**

A minimum of two open-water dives, supervised by the DSO or designee, using nitrox is required for authorization. The mode used in the dives should correspond to the intended application (i.e., scuba or surface-supplied). If the MOD for the mix being used can be exceeded at the training location, direct, in-water supervision is required.

### **Surface-Supplied Training**

All training as applied to surface-supplied diving (practical, classroom, and open-water) will follow the member organization's surface-supplied diving standards, including additions listed in Section 11.60.

## **7.40 SCIENTIFIC NITROX DIVING REGULATIONS**

### **Dive Personnel Requirements**

1. Nitrox Diver In Training - A Diver in Training, who has completed the requirements of Section 4.00 and the training and authorization sections of these guidelines, may be authorized by the DSO to use nitrox under the direct supervision a Scientific Diver who also holds nitrox authorization. Dive depths should be restricted to those specified in the diver's written authorization.
2. Scientific Diver - A Scientific Diver who has completed the requirements, training and authorization sections of these guidelines, may be authorized by the DSO to use nitrox.

Depth authorization to use nitrox should be the same as those specified in the diver's authorization, as described in Sec. 5.50.

3. Lead Diver - On any dive during which nitrox will be used by any team member, the Lead Diver should be authorized to use nitrox, and hold appropriate authorizations required for the dive, as specified in these Standards. Lead Diver authorization for nitrox dives by the DSO and/or DCB should occur as part of the dive plan approval process.

In addition to responsibilities listed in Section 1.20 of this manual, the Lead Diver should:

- a) As part of the dive planning process, verify that all divers using nitrox on a dive are properly qualified and authorized;
- b) As part of the pre-dive procedures, confirm with each diver the nitrox mixture the diver is using, and establish dive team maximum depth and time limits, according to the shortest time limit or shallowest depth limit among the team members.
- c) The Lead Diver should also reduce the maximum allowable pO<sub>2</sub> exposure limit for the dive team if on-site conditions so indicate (Section 7.40 Dive Parameters)

## Dive Parameters

### 1. Oxygen Exposure Limits

- a) The inspired oxygen partial pressure experienced at depth should not exceed 1.45 ATA. All dives performed using nitrox-breathing mixtures should comply with the current *NOAA Diving Manual* "Oxygen Partial Pressure Limits for 'Normal' Exposures"
- b) The maximum allowable exposure limit should be reduced in cases where cold or strenuous dive conditions, or extended exposure times are expected. The DCB should consider this in the review of any dive plan application, which proposes to use nitrox. The Lead Diver should also review on-site conditions and reduce the allowable pO<sub>2</sub> exposure limits if conditions indicate.
- c) If using the EAD method, the maximum depth of a dive should be based on the oxygen partial pressure for the specific nitrox breathing mix to be used.

### 2. Bottom Time Limits

- a) Maximum bottom time should be based on the depth of the dive and the nitrox mixture being used.
- b) Bottom time for a single dive should not exceed the National Oceanic and Atmospheric Administration (NOAA) maximum allowable "Single Exposure Limit" for a given oxygen partial pressure, as listed in the current NOAA Diving Manual.

### 3. Nitrox Decompression Tables and Gases

- a) A set of DCB approved nitrox decompression tables should be available at the dive site unless divers are all using nitrox dive computers.

- b) When using the EAD method, dives should be conducted using air decompression tables approved by the DCB.
- c) If nitrox is used to increase the safety margin of air-based dive tables, the MOD and oxygen exposure and time limits for the nitrox mixture being dived should not be exceeded
- d) Breathing mixtures used while performing in-water decompression, or for bailout purposes, should contain the same or greater oxygen content as that being used during the dive, within the confines of depth limitations and oxygen partial pressure limits set forth in Section 7.40.

#### 4. Nitrox Dive Computers

- a) Dive Computers may be used to compute decompression status during nitrox dives. Manufacturers' guidelines and operations instructions should be followed.
- b) Use of Nitrox dive computers should comply with dive computer guidelines included in the Appendix 8.
- c) Nitrox Dive computer users should demonstrate a clear understanding of the display, operations, and manipulation of the unit being used for nitrox diving prior to using the computer, to the satisfaction of the DSO or his/her designee
- d) If nitrox is used to increase the safety margin of an air-based dive computer, the MOD and oxygen exposure and time limits for the nitrox mixture being dived should not be exceeded.
- e) Dive computers capable of pO<sub>2</sub> limit and fO<sub>2</sub> adjustment should be checked by the diver prior to the start each dive to assure compatibility with the mix being used.

#### 5. Repetitive Diving

- a) Repetitive dives using nitrox mixtures should be performed in compliance with procedures required of the specific dive tables used.
- b) Residual nitrogen time should be based on the EAD for the specific nitrox mixture to be used on the repetitive dive, and not that of the previous dive.
- c) The total cumulative exposure (bottom time) to a partial pressure of oxygen in a given 24 hour period should not exceed the current *NOAA Diving Manual* 24-hour Oxygen Partial Pressure Limits for "Normal" Exposures.
- d) When repetitive dives expose divers to different oxygen partial pressures from dive to dive, divers should account for accumulated oxygen exposure from previous dives when determining acceptable exposures for repetitive dives. Both acute (CNS) and chronic (pulmonary) oxygen toxicity concerns should be addressed.

## 6. Oxygen Parameters

- a) Authorized Mixtures - Mixtures meeting the criteria outlined in Section 7.40 may be used for nitrox diving operations, upon approval of the DCB.

## 7. Purity

- a) Oxygen used for mixing nitrox-breathing gas should meet the purity levels for “Medical Grade” (U.S.P.) or “Aviator Grade” standards.
- b) In addition to the AAUS Air Purity Guidelines (Sec. 3.60), the following standard shall be met for breathing air that is either placed in contact with oxygen concentrations greater than 40%, or used in nitrox production by the partial pressure mixing method with gas mixtures containing greater than 40% oxygen as the enriching agent:
  - c) Air Purity: CGA Grade E (AAUS Sec. 3.60)
    - Condensed Hydrocarbons: 5mg/m<sup>3</sup>
    - Hydrocarbon Contaminants: No greater than 0.1 mg/m<sup>3</sup>

## 8. Gas Mixing and Analysis

- a) Personnel Requirements:
  - i. Individuals responsible for producing and/or analyzing nitrox mixtures shall be knowledgeable and experienced in all aspects of the technique.
  - ii. Only those individuals approved by the DSO and/or DCB and authorized in nitrox blending shall be responsible for filling nitrox cylinders.

## 9. Production Methods

- a) Production of nitrox by means other than a certified nitrox filling station must be approved by the DSO and/or the DCB.

## 10. Analysis Verification by User

- a) It is the responsibility of each diver to analyze prior to the dive the oxygen content of his/her scuba cylinder and acknowledge in writing the following information for each cylinder: fO<sub>2</sub>, MOD, cylinder pressure, date of analysis, and user’s name.
- b) Individual dive log reporting forms should report fO<sub>2</sub> of nitrox used, if different than 21%.

### **7.50 NITROX DIVING EQUIPMENT**

All of the designated equipment and stated requirements regarding scuba equipment required in these Standards shall apply to nitrox scuba operations. Additional minimal equipment necessary for nitrox diving operations includes:

#### 1. Labeled SCUBA Cylinders

## 2. Approved Oxygen Analyzers

### **Oxygen Cleaning and Maintenance Requirements**

#### 1. Requirement for Oxygen Service

- a) All equipment which during the dive or cylinder filling process is exposed to concentrations greater than 40% oxygen at pressures above 150 psi should be cleaned and maintained for oxygen service.
- b) Equipment used with oxygen or mixtures containing over 40% by volume oxygen shall be designed and maintained for oxygen service.

#### 2. Oxygen systems over 125 psig shall have slow-opening shut-off valves.

- a) This should include the following equipment: scuba cylinders, cylinder valves, scuba and other regulators, cylinder pressure gauges, hoses, diver support equipment, compressors, and fill station components and plumbing.

### **Scuba Cylinder Identification Marking**

Scuba cylinders to be used with nitrox mixtures should have the following identification documentation affixed to the cylinder.

1. Cylinders should be marked "NITROX", or "EANx", or "Enriched Air"
2. Nitrox identification color-coding should include a four (4)-inch wide green band around the cylinder, starting immediately below the shoulder curvature. If the cylinder is not yellow in, the green band should be bordered above and below by a one (1)-inch yellow band.
3. The alternate marking of a yellow cylinder by painting the cylinder crown green and printing the word "NITROX" parallel to the length of the cylinder in green print is acceptable.
4. Other markings, which identify the cylinder as containing gas mixes other than air, may be used as the approval of the DCB.
5. A contents label should be affixed, to include the current fO<sub>2</sub>, date of analysis, and MOD.
6. The cylinder should be labeled to indicate whether the cylinder is prepared for oxygen or nitrox mixtures containing greater than 40% oxygen.

### **Regulators**

Regulators to be used with nitrox mixtures containing greater than 40% oxygen should be cleaned and maintained for oxygen service, and marked in an identifying manner.

### **Other Support Equipment**

1. An approved oxygen analyzer is required which is capable of determining the oxygen content in the scuba cylinder to within 0.1%.



2. Two analyzers are recommended to reduce the likelihood of errors due to a faulty analyzer. The diver shall refer to the manufactures instructions to insure sufficient accuracy of the analyzer. Frequent calibrations may be necessary.
3. NOTE: Most oxygen analyzer have an electro-chemical detectors and hence a limited lifetime--from as low as six months to up to two years depending on usage. The date of the last sensor replacement should be marked on the analyzer housing.
4. All diver and support equipment should be suitable for the fO2 being used.

### **Compressor and Fill Station**

1. Compressor system
  - a) The compressor/filtration system MUST produce oil-free air.
  - b) An oil-lubricated compressor placed in service for a nitrox system should be checked for oil and hydrocarbon contamination at least quarterly.
2. Fill Station Components - All components of a nitrox fill station that will contact nitrox mixtures containing greater than 40% oxygen should be cleaned and maintained for oxygen service. This includes cylinders, whips, gauges, valves, and connecting lines. Records of these procedures shall be maintained and copies submitted to the DSO annually.

## SECTION 8.00

### HUMAN POWERED SUBMARINE DIVING OPERATIONS

#### 8.10 GENERAL POLICY

University of Washington Mechanical Engineering students research, develop, and construct a Human Powered Submarine (HPS) as part of their Major course work. Scuba diving is an essential part of HPS research and safety operations. The guidelines set forth in this section outline requirements for safe HPS diving operations and must be followed by any UW diver entering the water with the submarine.

#### 8.20 Participant Levels and Basic Requirements

1. Submarine Operator
  - a) Definition- any individual who will enter the submarine, while submerged or on the surface, and/or use scuba diving techniques for the purposes of inspection, maintenance, repair, or operation.
  - b) Training Requirements- shall meet the minimum requirements for certification as a UW Scientific Diver Certification from Section 5.00 of the UW Standards for Scientific Diving and shall have knowledge of and experience with the operation of all systems of the submarine.
2. Submarine Safety/Support Diver
  - a) Definition- an individual whose primary purpose is to ensure the safety of Submarine Operator/Divers and will use scuba diving techniques to support or assist with aspects of vehicle inspection, maintenance, repair, or operation, while submerged or on the surface.
  - b) Training Requirements- shall meet the minimum requirements for certification as a UW Scientific Diver Certification from Section 5.00 of the UW Standards for Scientific Diving and shall be trained in first aid and underwater rescue techniques to include in-water rescue breathing, cardiopulmonary resuscitation, basic first aid, and oxygen administration. Shall have knowledge of and experience with the operation of all emergency and egress systems associated with the submarine. Knowledge of and experience with submarine navigational and propulsion systems is recommended but not required.
3. Submarine Lead Diver
  - a) Definition- the individual who directly supervises and monitors water activities associated with the submarine.
  - b) Requirements- Shall meet all requirements for certification as a Submarine Safety/Support Diver and shall have completed all requirements for Scientific Diver Certification from Section 5.00 of the UW Standards for Scientific Diving. Knowledge of and experience with submarine navigational and propulsion systems is recommended, but not required.
4. Submarine Support Swimmer/Support Diver-in-Training
  - a) Definition- any individual who will enter the water for the purposes of inspection, maintenance, or repair of the submarine, or provide assistance to other members of the submarine team.

- b) Requirements- Shall meet the minimum requirements for certification as a UW Scientific Diver in-Training.

5. Other

- a) Any individual who will enter the water during submarine activities shall conform to UW requirements for scientific diving which most closely resemble their level of involvement (i.e. u/w photographer/videographer).

### 8.30 Additional Training Requirements

1. In addition to the minimum requirements stated above and those required by a standard UW checkout dive, divers engaged in work with the Human Powered Submarine shall be able to demonstrate the following skills:
  - a) Submarine Operator
    - i. Equalize body air spaces while performing the tasks associated with navigating, piloting, or propelling the vehicle.
    - ii. Clear the face mask while performing the tasks associated with navigating, piloting, or propelling the vehicle.
    - iii. Remove and replace the face mask while inside the vehicle.
    - iv. Remove, replace, and clear the air supply while inside the vehicle.
    - v. Monitor the primary and reserve air supply.
    - vi. Monitor the rate of and conduct a safe ascent (<1 ft/sec.) while inside the vehicle.
    - vii. Demonstrate proper exhalation techniques during an out of control/rapid ascent.
    - viii. Locate and secure the reserve air supply, without the use of visual aids/cues.
    - ix. Execute a switch from primary to reserve air supply in a timely fashion, without difficulty.
    - x. Release the emergency signal float/buoy.
    - xi. Release the emergency egress hatch and any/all interior restraint systems while breathing from either the primary or reserve air supply.
    - xii. Exit the vehicle and conduct an ascent to the surface while breathing from an air source supplied by a safety/support diver.
    - xiii. Exit the vehicle and conduct an emergency swimming ascent to the surface.
  - b) Safety/Support Diver
    - i. Monitor the primary and reserve air supply of the operator/diver.
    - ii. Release the emergency egress hatch and any/all interior restraint systems.
    - iii. Supply an air source to an operator/diver still inside the vehicle.
    - iv. Conduct a normal ascent while sharing air with the vehicle operator/diver.
    - v. Extricate and surface with an unconscious vehicle operator/diver.
    - vi. On the surface, perform rescue breathing for an unconscious, non-breathing diver.
    - vii. Recognize and respond to a distressed vehicle operator/diver while underwater.
    - viii. Recognize and respond to a distressed vehicle operator/diver on the surface.
    - ix. Demonstrate techniques for water egress with an unconscious diver.
    - x. Demonstrate proper first aid procedures for victims of pressure related and/or drowning injuries.

- c) Lead Diver
  - i. Meet the minimum requirements of Safety/support diver.
  - ii. Demonstrate proficiency in diving accident management.
  - iii. Submit a Dive Plan to include names, certification levels, and emergency contact information for all diving participants.
  - iv. Submit with the Dive Plan an Emergency Action Plan to include: on-site rescue procedures, dispatch procedures/response times for emergency medical services, and location of nearest hospital and hyperbaric facility.

## **8.40 SUBMARINE LIFE-SUPPORT SYSTEMS**

### **1. BREATHING MEDIA**

- a) All breathing media shall be compressed atmospheric air unless approved by DSO. Special air mixes such as oxygen-enriched air (Nitrox) are prohibited by ISR regulations and cannot be used during races.

### **2. AIR CYLINDERS**

- a) All breathing air cylinders shall be approved for use with scuba equipment and possess a current hydrostatic test and Visual Cylinder Inspection with appropriate stampings and stickers.

### **3. PRESSURE REGULATORS**

- a) All breathing air must be delivered via a scuba regulator. In concordance with UW standards, all regulators must be inspected/serviced to the manufacturer's specification by a qualified service technician and approved for use by the DSO.

### **4. BREATHING AIR SUPPLY**

- a) The primary air supply for each operator/diver shall be carried onboard the submarine. Volume of the air supply shall be sufficient to provide breathing air for a minimum of one vehicle speed run plus 150% in reserve capacity for each crew member. Diving will be terminated when any air supply reaches  $\leq 500$  P.S.I. All air pressure gauges shall be readily accessible if not continuously visible for ease of checking by both crew and support divers.

### **5. RESERVE AIR SUPPLY**

- a) A reserve air supply shall be carried for each submarine operator/diver. These systems shall be self-contained and worn securely on the body. Volume of the reserve air supply shall be sufficient to enable the diver to egress the submarine and surface. The reserve air supply may be utilized for entering the submarine and preparing for a run, however, diving will be terminated when any air supply reaches  $\leq 500$  P.S.I.
- b) *Note regarding air supply: The diving supervisor will have complete discretionary authority with regard to allowing divers to enter the water, especially with less than a full cylinder of air. Divers must have sufficient air to complete their task (sub race, support assignment, etc.) and return to the dive station with a sufficient reserve of air for safety.*

## **8.50 SUBMARINE SAFETY REQUIREMENTS**

### **1. SUBMARINE COLOR SCHEME**

- a) Regarding the Body/Hull, for the purposes of easy location, each submarine shall be painted with high-visibility coloration using light colors (i.e. white, yellow, orange, etc.). Florescent or contrasting schemes are advisable to make the submarine distinct.
- b) Propeller tips must be painted or marked in bright orange for easy recognition by safety/support divers.

## 2. EMERGENCY EGRESS

- a) Any and all exits that are to be used by the vehicle crew for emergency egress shall be clearly marked at the location of the handle or release mechanism by a 4" square orange patch bearing the word 'Rescue'. If this is not possible, the handle or release mechanism should be clearly marked with florescent tape at a minimum. The handle or release mechanism shall be easily accessible from both inside and outside the submarine. Safety and support divers must be familiar with the operation of the emergency egress mechanism(s).

## 3. CREW RESTRAINTS

- a) Any method of attachment of a crew member to the submarine, such as restraining harnesses or toe-clips, must have the release system clearly marked with orange paint or florescent tape. Safety/support divers must be familiar with the release mechanisms of any/all crew restraints.

## 4. CREW VISIBILITY

- a) View ports, windows, canopies, etc. shall be located on the submarine so that the crew has as unrestricted a view as possible, especially forward, for navigation purposes. Additionally, the crew face and head areas shall be visible to safety/support divers at all times.

## 5. STROBE LIGHT

- a) Each submarine shall carry a flashing white strobe light that is visible for 360 degrees in the horizontal plane. The light should flash at an approximate rate of once per second, be visible for at least thirty feet under normal visibility conditions, have sufficient power to flash for one hour at a minimum, and be operating whenever the submarine is submerged. If preferred, the design may incorporate more than one strobe light, so long as the flash is visible for all 360 degrees in the horizontal plane.

## 6. EMERGENCY BUOY

- a) All submarines shall carry a high visibility buoy that will release from the hull and float to the surface in the event of an emergency. The float must be attached to the submarine by thirty (30) feet of strong, highly visible line, at least 1/16" thick. Each crew member shall have a dead-man type switch that will automatically release the float in the event that they are disabled. Switch safety mechanisms may be employed during staging to prevent inadvertent release, but the switches MUST be activated whenever the submarine is operating.
- b) Buoy release will initiate an emergency rescue by the safety divers whose primary interest will be removing the crew member(s) from the submarine and to the surface as quickly as possible. If a buoy is released inadvertently, crew members should

make every attempt to indicate visually to the safety divers using the diver's OK signal.

## **8.60 SUBMARINE SAFETY INSPECTION**

1. The vehicle shall receive a safety inspection prior to entering the water. A second safety inspection shall be conducted in the water prior to crew entry. At minimum the safety inspection shall consist of an I inspection and functional test of the following components:
  - a) Life-support systems and air supplies
  - b) Emergency egress hatch and crew restraints
  - c) Emergency signal buoy

## **8.70 SUPPORT PERSONNEL**

1. Safety/Support Divers
  - a) During vehicle deployment and operation a minimum of two (2) Safety/Support Divers shall be in the water readily available to assist the submarine crew. Additional Safety/Support Divers should be staged nearby ready to enter the water in the event of an emergency.
  - b) Safety/Support Divers shall be equipped as outlined in Section 3.0 of the UW Diving Manual.
  - c) Support divers shall be equipped with octopus regulators so as to support submarine crew activities during ingress/egress of the submarine at depth. Octopus regulator hoses must be of sufficient length to accommodate the sharing of air while the operator/diver is inside the vehicle. All support divers are required to monitor their own air supply and shall not allow their air supply to fall below 500 P.S.I.

*Note regarding air supply: The lead diver will have complete discretionary authority with regard to allowing divers to enter the water, especially with less than a full cylinder of air. Divers must have sufficient air to complete their task (sub race, support assignment, etc.) and return to the dive station with a sufficient reserve of air for safety.*

2. Submarine Lead Diver
  - a) A qualified Lead Diver shall be on site and readily available at all times during water activities. The Lead Diver is responsible for ensuring that divers maintain compliance with UW diving standards including proper documentation of diving activities. The Lead Diver may also act as a Safety/Support diver.
  - b) The Lead Diver will ensure that emergency first aid equipment, including emergency oxygen, is available at the dive site.
  - c) The Lead Diver will ensure that participating divers record their activities on a standard UW Dive Log for submission to the DSO.

## SECTION 9.00

### STAGED DECOMPRESSION DIVING

Decompression diving shall be defined as any diving during which the diver cannot perform a direct return to the surface without performing a mandatory decompression stop to allow the release of inert gas from the diver's body.

The following procedures shall be observed when conducting dives requiring planned decompression stops.

#### 9.10 MINIMUM EXPERIENCE AND TRAINING REQUIREMENTS

##### Prerequisites:

1. Scientific Diver qualification according to Section 5.00.
2. Minimum of 100 logged dives.
3. Demonstration of the ability to safely plan and conduct dives deeper than 100 feet.
4. Nitrox certification/authorization according to AAUS Section 7.00 recommended.

##### Training

Training shall be appropriate for the conditions in which dive operations are to be conducted and shall include the following:

1. A minimum of six (6) hours of classroom training to ensure theoretical knowledge to include: physics and physiology of decompression; decompression planning and procedures; gas management; equipment configurations; decompression method, emergency procedures and omitted decompression.
  - a) It is recommended that at least one training session be conducted in a pool or sheltered water setting, to cover equipment handling and familiarization, swimming and buoyancy control, to estimate gas consumption rates, and to practice emergency procedures.
  - b) At least six (6) open-water training dives simulating/requiring decompression shall be conducted, emphasizing planning and execution of required decompression dives, and including practice of emergency procedures.
  - c) Progression to greater depths shall be by four (4)-dive increments at depth intervals as specified in Section 5.50.
  - d) No training dives requiring decompression shall be conducted until the diver has demonstrated acceptable skills under simulated conditions.
  - e) The following are the minimum skills the diver must demonstrate proficiently during dives simulating and requiring decompression:
    - i. Buoyancy control
    - ii. Proper ascent rate
    - iii. Proper depth control
    - iv. Equipment manipulation
    - v. Stage/decompression bottle use as pertinent to planned diving operation
    - vi. Buddy skills
    - vii. Gas management
    - viii. Time management
    - ix. Task loading
    - x. Emergency skills

- f) Divers shall demonstrate, to the satisfaction of the DSO or the DSO's qualified designee, proficiency in planning and executing required decompression dives appropriate to the conditions in which diving operations are to be conducted.
- g) Upon completion of training, the diver shall be authorized to conduct required decompression dives with DSO approval.

### **9.20 MINIMUM EQUIPMENT REQUIREMENTS:**

Valve and regulator systems for primary (bottom) gas supplies shall be configured in a redundant manner that allows continuous breathing gas delivery in the event of failure of any one component of the regulator/valve system.

Cylinders with volume and configuration adequate for planned diving operations.

One of the second stages on the primary gas supply shall be configured with a hose of adequate length to facilitate effective emergency gas sharing in the intended environment.

1. Minimum dive equipment shall include:
  - a) Snorkel is optional at the DCB's discretion, as determined by the conditions and environment.
  - b) Diver location devices adequate for the planned diving operations and environment.
  - c) Compass
2. Redundancy in the following components is desirable or required at the discretion of the DCB or DSO:
  - a) Decompression Schedules
  - b) Dive Timing Devices
  - c) Depth gauges
  - d) Buoyancy Control Devices
  - e) Cutting devices
  - f) Lift bags and line reels

### **9.30 MINIMUM OPERATIONAL REQUIREMENTS**

1. Approval of dive plan applications to conduct required decompression dives shall be on a case-by-case basis.
2. The maximum pO<sub>2</sub> to be used for planning required decompression dives is 1.6. A pO<sub>2</sub> of 1.4 or less shall be used during descent/bottom portion of dive and a maximum of 1.6 during decompression portion.
3. Divers gas supplies shall be adequate to meet planned operational requirements and foreseeable emergency situations.
4. Decompression dives may be planned using dive tables, dive computers, and/or PC software approved by the DSO/DCB.



5. Breathing gases used while performing in-water decompression shall contain the same or greater oxygen content as that used during the bottom phase of the dive.
6. The dive team prior to each dive shall review emergency procedures appropriate for the planned dive.
7. If breathing gas mixtures other than air are used for required decompression, their use shall be in accordance with those regulations set forth in the appropriate sections of this standard.
8. The maximum depth for required decompression using air as the bottom gas shall be 190 ft.
9. Use of additional nitrox and/or high-oxygen fraction decompression mixtures as travel and decompression gases to decrease decompression obligations is encouraged.
10. Use of alternate inert gas mixtures to limit narcosis is encouraged for depths greater than 150 ft.
11. If a period of more than six (6) months has elapsed since the last decompression dive, a series of progressive workup dives to return the diver(s) to proficiency status prior to the start of project diving operations are recommended.
12. Mission specific workup dives are recommended.

## **SECTION 10.00**

### **MIXED GAS DIVING**

Mixed gas diving is defined as dives done while breathing gas mixes containing proportions greater than 1% by volume of an inert gas other than nitrogen.

#### **10.10 MINIMUM EXPERIENCE AND TRAINING REQUIREMENTS**

Prerequisites:

1. Nitrox certification and authorization (Section 7.00)
2. If the intended use entails required decompression stops, divers will be previously certified and authorized in decompression diving (Section 9.00).
3. Divers shall demonstrate to the DCB's satisfaction skills, knowledge, and attitude appropriate for training in the safe use of mixed gases.

Classroom training including:

1. Review of topics and issues previously outlined in nitrox and required decompression diving training as pertinent to the planned operations.
2. The use of helium or other inert gases, and the use of multiple decompression gases.
3. Equipment configurations
4. Mixed gas decompression planning
5. Gas management planning
6. Thermal considerations
7. END determination
8. Mission planning and logistics
9. Emergency procedures
10. Mixed gas production methods
11. Methods of gas handling and cylinder filling
12. Oxygen exposure management
13. Gas analysis
14. Mixed gas physics and physiology

Practical Training:

1. Confined water session(s) in which divers demonstrate proficiency in required skills and techniques for proposed diving operations.
2. A minimum of six (6) open-water training dives.
3. At least one initial dive shall be in 130 ft or less to practice equipment handling and emergency procedures.
4. Subsequent dives will gradually increase in depth, with a majority of the training dives being conducted between 130 ft and the planned operational depth.
5. Planned operational depth for initial training dives shall not exceed 260 feet.
6. Diving operations beyond 260 ft requires additional training dives.

## **10.20 EQUIPMENT AND GAS QUALITY REQUIREMENTS**

1. Equipment requirements shall be developed and approved by the DCB, and met by divers, prior to engaging in mixed-gas diving. Equipment shall meet other pertinent requirements set forth elsewhere in this standard.
2. The quality of inert gases used to produce breathing mixtures shall be of an acceptable grade for human consumption.

## **10.30 MINIMUM OPERATIONAL REQUIREMENTS**

1. Approval of dive plan applications to conduct mixed gas dives shall be on a case-by-case basis.
2. All applicable operational requirements for nitrox and decompression diving shall be met.
3. The maximum  $pO_2$  to be used for planning required decompression dives is 1.6. It is recommended that a  $pO_2$  of less than 1.4 be used during bottom exposure.
4. Maximum planned Oxygen Toxicity Units (OTU) will be considered based on mission duration.
5. Divers decompressing on high-oxygen concentration mixtures shall closely monitor one another for signs of acute oxygen toxicity.

If a period of more than six (6) months has elapsed since the last mixed gas dive, a series of progressive workup dives to return the diver(s) to proficiency status prior to the start of project diving operations are recommended.

## SECTION 11.00

### OTHER DIVING TECHNOLOGY

Certain types of diving, some of which are listed below, require equipment or procedures that require training. Supplementary guidelines for these technologies are in development by the AAUS. Organizational member's using these, must have guidelines established by their DCB. Divers shall comply with all scuba diving procedures in this standard unless specified.

#### 11.10 BLUE WATER DIVING

1. Blue water diving is defined as diving in open water where the bottom is generally greater than 200 feet deep. It requires special training and the use of multiple-tethered diving techniques. Specific guidelines that should be followed are outlined in "Blue Water Diving Guidelines" (California Sea Grant Publ. No. T-CSGCP-014).

#### 11.20 DIVER PROPULSION VEHICLE

1. Divers planning to dive using a diver propulsion vehicle must be authorized in their use by the DSO or DCB.

#### 11.30 OVERHEAD ENVIRONMENTS

1. Where an enclosed or confined space is not large enough for two divers, a diver shall be stationed at the underwater point of entry and an orientation line shall be used.

#### 11.40 SATURATION DIVING

1. If using open circuit compressed air scuba in saturation diving operations, divers shall comply with the saturation diving guidelines of the organizational member.

#### 11.50 HOOKAH

1. While similar to Surface Supplied in that the breathing gas is supplied from the surface by means of a pressurized hose, the supply hose does not require a strength member, pneumofathometer hose, or communication line. Hookah equipment may be as simple as a long hose attached to a standard scuba cylinder supplying a standard scuba second stage. The diver is responsible for the monitoring his/her own depth, time, and diving profile.

#### 11.60 SURFACE SUPPLIED DIVING

1. Surface Supplied: Dives where the breathing gas is supplied from the surface by means of a pressurized umbilical hose. The umbilical generally consists of a gas supply hose, strength member, pneumofathometer hose, and communication line. The umbilical supplies a helmet or full-face mask. The diver may rely on the tender at the surface to keep up with the divers' depth, time and diving profile.

#### 11.70 Full Facemask and Helmet

1. Divers using a full facemask or diving helmet must receive training from DSO or designee in the use of that specific model of mask or helmet.

## **SECTION 12.00**

### **REBREATHERS**

This section defines specific considerations regarding the following issues for the use of rebreathers:

1. Training and/or experience verification requirements for authorization.
2. Equipment requirements.
3. Operational requirements and additional safety protocols to be used.
4. Application of this standard is in addition to pertinent requirements of all other sections of the AAUS Standards for Scientific Diving, Volumes 1 and 2.
5. For rebreather dives that also involve staged decompression and/or mixed gas diving, all requirements for each of the relevant diving modes shall be met. DCB reserves the authority to review each application of all specialized diving modes, and include any further requirements deemed necessary beyond those listed here on a case-by-case basis.
6. No diver shall conduct planned operations using rebreathers without prior review and approval of the DCB.
7. In all cases, trainers shall be qualified for the type of instruction to be provided. Training shall be conducted by agencies or instructors approved by DSO and DCB.

#### **12.10 DEFINITIONS AND GENERAL INFORMATION**

1. Rebreathers are defined as any device that recycles some or all of the exhaled gas in the breathing loop and returns it to the diver. Rebreathers maintain levels of oxygen and carbon dioxide that support life by metered injection of oxygen and chemical removal of carbon dioxide. These characteristics fundamentally distinguish rebreathers from open-circuit life support systems, in that the breathing gas composition is dynamic rather than fixed.
2. Advantages of rebreathers may include increased gas utilization efficiencies that are often independent of depth, extended no-decompression bottom times and greater decompression efficiency, and reduction or elimination of exhaust bubbles that may disturb aquatic life or sensitive environments.
3. Disadvantages of rebreathers include high cost and, in some cases, a high degree of system complexity and reliance on instrumentation for gas composition control and monitoring, which may fail. The diver is more likely to experience hazardous levels of hypoxia, hyperoxia, or hypercapnia, due to user error or equipment malfunction, conditions which may lead to underwater blackout and drowning. Inadvertent flooding of the breathing loop and wetting of the carbon dioxide absorbent may expose the diver to ingestion of an alkaline slurry ("caustic cocktail").
4. An increased level of discipline and attention to rebreather system status by the diver is required for safe operation, with a greater need for self-reliance. Rebreather system design

and operation varies significantly between make and model. For these reasons when evaluating any dive plan incorporating rebreathers, risk-management emphasis should be placed on the individual qualifications of the diver on the specific rebreather make and model to be used, in addition to specific equipment requirements and associated operational protocols.

5. Oxygen Rebreathers. Oxygen rebreathers recycle breathing gas, consisting of pure oxygen, replenishing the oxygen metabolized by the diver. Oxygen rebreathers are generally the least complicated design, but are normally limited to a maximum operation depth of 20fsw due to the risk of unsafe hyperoxic exposure.
6. Semi-Closed Circuit Rebreathers (SCR). SCR recycle the majority of exhaled breathing gas, venting a portion into the water and replenishing it with a constant or variable amount of a single oxygen-enriched gas mixture. Gas addition and venting is balanced against diver metabolism to maintain safe oxygen levels by means which differ between SCR models, but the mechanism usually provides a semi-constant fraction of oxygen (FO<sub>2</sub>) in the breathing loop at all depths, similar to open-circuit SCUBA.
7. Closed-Circuit Mixed Gas Rebreathers (CCR). CCR recycle all of the exhaled gas and replace metabolized oxygen via an electronically controlled valve, governed by electronic oxygen sensors. Manual oxygen addition is available as a diver override, in case of electronic system failure. A separate inert gas source (diluent), usually containing primarily air, heliox, or trimix, is used to maintain oxygen levels at safe levels when diving below 20fsw. CCR systems operate to maintain a constant oxygen partial pressure (PPO<sub>2</sub>) during the dive, regardless of depth.

## **12.20 PREREQUISITES**

Specific training requirements for use of each rebreather model shall be defined by DCB on a case-by-case basis. Training shall include factory-recommended requirements, but may exceed this to prepare for the type of mission intended (e.g., staged decompression or heliox/trimix CCR diving).

### **Training Prerequisites**

1. Active scientific diver status, with depth qualification sufficient for the type, make, and model of rebreather, and planned application.
2. Completion of a minimum of 50 open-water dives on SCUBA.
3. For SCR or CCR, a minimum 100-fsw-depth qualification is generally recommended, to ensure the diver is sufficiently conversant with the complications of deeper diving. If the sole expected application for use of rebreathers is shallower than this, a lesser depth qualification may be allowed with the approval of the DCB.
4. Nitrox training. Training in use of nitrox mixtures containing 25% to 40% oxygen is required. Training in use of mixtures containing 40% to 100% oxygen may be required, as needed for the planned application and rebreather system. Training may be provided as part of rebreather training.

## Training

Successful completion of the following training program qualifies the diver for rebreather diving using the system on which the diver was trained, in depths of 130fsw and shallower, for dives that do not require decompression stops, using nitrogen/oxygen breathing media.

Satisfactory completion of a rebreather training program authorized or recommended by the manufacturer of the rebreather to be used, or other training approved by the DCB. Successful completion of training does not in itself authorize the diver to use rebreathers. The diver must demonstrate to the DCB or its designee that the diver possesses the proper attitude, judgment, and discipline to safely conduct rebreather diving in the context of planned operations.

Classroom training shall include:

1. A review of those topics of diving physics and physiology, decompression management, and dive planning included in prior scientific diver, nitrox, staged decompression and/or mixed gas training, as they pertain to the safe operation of the selected rebreather system and planned diving application.
2. In particular, causes, signs and symptoms, first aid, treatment and prevention of the following must be covered:
  - a) Hyperoxia (CNS and Pulmonary Oxygen Toxicity)
  - b) Middle Ear Oxygen Absorption Syndrome (oxygen ear)
  - c) Hyperoxia-induced myopia
  - d) Hypoxia
  - e) Hypercapnia
  - f) Inert gas narcosis
  - g) Decompression sickness
3. Rebreather-specific information required for the safe and effective operation of the system to be used, including:
  - a) System design and operation, including:
  - b) Counterlung(s)
  - c) CO<sub>2</sub> scrubber
  - d) CO<sub>2</sub> absorbent material types, activity characteristics, storage, handling and disposal
  - e) Oxygen control system design, automatic and manual
  - f) Diluent control system, automatic and manual (if any)
  - g) Pre-dive set-up and testing
  - h) Post-dive break-down and maintenance
  - i) Oxygen exposure management
  - j) Decompression management and applicable decompression tracking methods
  - k) Dive operations planning
  - l) Problem recognition and management, including system failures leading to hypoxia, hyperoxia, hypercapnia, flooded loop, and caustic cocktail
  - m) Emergency protocols and bailout procedures

## Practical Training (with model of rebreather to be used)

A minimum number of hours of underwater time.

Type	Pool/Confined Water	O/W Training	O/W Supervised
Oxygen Rebreather	1 dive, 90 min	4 dives, 120 min.*	2 dives, 60 min
Semi-Closed Circuit	1 dive, 90-120 min	4 dives, 120 min.**	4 dives, 120 min
Closed-Circuit	1 dive, 90-120 min	8 dives, 380 min.***	4 dives, 240 min

\* Dives should not exceed 20 fsw.  
\*\* First two dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least one dive in the 80 to 100 fsw range.  
\*\*\* Total underwater time (pool and open water) of approximately 500 minutes. First two open water dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least two (2) dives in the 100 to 130 fsw range.

Amount of required in-water time should increase proportionally to the complexity of rebreather system used.

Training shall be in accordance with the manufacturer's recommendations.

## Practical Evaluations

1. Upon completion of practical training, the diver must demonstrate to the DCB or its designee proficiency in pre-dive, dive, and post-dive operational procedures for the particular model of rebreather to be used. Skills shall include, at a minimum:
  - a) Oxygen control system calibration and operation checks
  - b) Carbon dioxide absorbent canister packing
  - c) Supply gas cylinder analysis and pressure check
  - d) Test of one-way valves
  - e) System assembly and breathing loop leak testing
  - f) Pre-dive breathing to test system operation
  - g) In-water leak checks
  - h) Buoyancy control during descent, bottom operations, and ascent
  - i) System monitoring and control during descent, bottom operations, and ascent
  - j) Proper interpretation and operation of system instrumentation (PO<sub>2</sub> displays, dive computers, gas supply pressure gauges, alarms, etc, as applicable)
  - k) Unit removal and replacement on the surface.
  - l) Bailout and emergency procedures for self and buddy, including:
  - m) System malfunction recognition and solution
  - n) Manual system control
  - o) Flooded breathing loop recovery (if possible)
  - p) Absorbent canister failure
  - q) Alternate bailout options
  - r) Symptom recognition and emergency procedures for hyperoxia, hypoxia, and hypercapnia
  - s) Proper system maintenance, including:
  - t) Full breathing loop disassembly and cleaning (mouthpiece, check-valves, hoses, counterlung, absorbent canister, etc.)
  - u) Oxygen sensor replacement (for SCR and CCR)
  - v) Other tasks required by specific rebreather models



## Written Evaluation

1. A written evaluation approved by the DCB with a pre-determined passing score, covering concepts of both classroom and practical training, is required.

## Supervised Rebreather Dives

1. Upon successful completion of open water training dives, the diver is authorized to conduct a series of supervised rebreather dives, during which the diver gains additional experience and proficiency.
2. Supervisor for these dives should be the DSO or designee, and should be an active scientific diver experienced in diving with the make/model of rebreather being used.
3. Dives at this level may be targeted to activities associated with the planned science diving application. See the following table for number and cumulative water time for different rebreather types.

Type	Pool/Confined Water	O/W Training	O/W Supervised
Oxygen Rebreather	1 dive, 90 min	4 dives, 120 min.*	2 dives, 60 min
Semi-Closed Circuit	1 dive, 90-120 min	4 dives, 120 min.**	4 dives, 120 min
Closed-Circuit	1 dive, 90-120 min	8 dives, 380 min.***	4 dives, 240 min

\* Dives should not exceed 20 fsw.

\*\* First two dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least one dive in the 80 to 100 fsw range.

\*\*\* Total underwater time (pool and open water) of approximately 500 minutes. First two open water dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least two (2) dives in the 100 to 130 fsw range.

Maximum ratio of divers per designated dive supervisor is 4:1. The supervisor may dive as part of the planned operations.

## Extended Range, Required Decompression and Helium-Based Inert Gas

1. Rebreather dives involving operational depths in excess of 130 fsw, requiring staged decompression, or using diluents containing inert gases other than nitrogen are subject to additional training requirements, as determined by DCB on a case-by-case basis. Prior experience with required decompression and mixed gas diving using open-circuit SCUBA is desirable, but is not sufficient for transfer to dives using rebreathers without additional training.
2. As a prerequisite for training in staged decompression using rebreathers, the diver shall have logged a minimum of 25 hours of underwater time on the rebreather system to be used, with at least 10 rebreather dives in the 100 fsw to 130 fsw range.
3. As a prerequisite for training for use of rebreathers with gas mixtures containing inert gas other than nitrogen, the diver shall have logged a minimum of 50 hours of underwater time on the rebreather system to be used and shall have completed training in stage decompression methods using rebreathers. The diver shall have completed at least 12 dives requiring staged decompression on the rebreather model to be used, with at least four (4) dives near 130 fsw.
4. Training shall be in accordance with standards for required-decompression and mixed gas diving, as applicable to rebreather systems, starting at the 130 fsw level.

## Maintenance of Proficiency

1. To maintain authorization to dive with rebreathers, an authorized diver shall make at least one dive using a rebreather every eight (8) weeks. For divers authorized for the conduct of extended range, stage decompression or mixed-gas diving, at least one dive per month should be made to a depth near 130 fsw, practicing decompression protocols.
2. For a diver in arrears, the DCB shall approve a program of remedial knowledge and skill tune-up training and a course of dives required to return the diver to full authorization. The extent of this program should be directly related to the complexity of the planned rebreather diving operations.

## 12.30 EQUIPMENT REQUIREMENTS

### General Requirements

1. Only those models of rebreathers specifically approved by DCB shall be used.
2. Rebreathers should be manufactured according to acceptable Quality Control/Quality Assurance protocols, as evidenced by compliance with the essential elements of ISO 9004. Manufacturers should be able to provide to the DCB supporting documentation to this effect.
3. Unit performance specifications should be within acceptable levels as defined by standards of a recognized authority (CE, US Navy, Royal Navy, NOAA, etc....).
4. Prior to approval, the manufacturer should supply the DCB with supporting documentation detailing the methods of specification determination by a recognized third-party testing agency, including unmanned and manned testing. Test data should be from a recognized, independent test facility.

The following documentation for each rebreather model to be used should be available as a set of manufacturer's specifications. These should include:

- a) Operational depth range
  - b) Operational temperature range
  - c) Breathing gas mixtures that may be used
  - d) Maximum exercise level which can be supported as a function of breathing gas and depth
  - e) Breathing gas supply durations as a function of exercise level and depth
  - f) CO<sub>2</sub> absorbent durations, as a function of depth, exercise level, breathing gas, and water temperature
  - g) Method, range and precision of inspired PPO<sub>2</sub> control, as a function of depth, exercise level, breathing gas, and temperature
  - h) Likely failure modes and backup or redundant systems designed to protect the diver if such failures occur
  - i) Accuracy and precision of all readouts and sensors
  - j) Battery duration as a function of depth and temperature
  - k) Mean time between failures of each subsystem and method of determination
5. A complete instruction manual is required, fully describing the operation of all rebreather components and subsystems as well as maintenance procedures.
  6. A maintenance log is required. The unit maintenance shall be up-to-date based upon manufacturer's recommendations.

## **Minimum Equipment**

1. A surface/dive valve in the mouthpiece assembly, allowing sealing of the breathing loop from the external environment when not in use.
2. An automatic gas addition valve, so that manual volumetric compensation during descent is unnecessary.
3. Manual gas addition valves, so that manual volumetric compensation during descent and manual oxygen addition at all times during the dive are possible.
4. The diver shall carry alternate life support capability (open-circuit bail-out or redundant rebreather) sufficient to allow the solution of minor problems and allow reliable access to a pre-planned alternate life support system.

## **Oxygen Rebreathers**

1. Oxygen rebreathers shall be equipped with manual and automatic gas addition valves.

## **Semi-Closed Circuit Rebreather**

1. SCR's shall be equipped with at least one manufacturer-approved oxygen sensor sufficient to warn the diver of impending hypoxia. Sensor redundancy is desirable, but not required.

## **Closed Circuit Rebreather**

1. CCR shall incorporate a minimum of three independent oxygen sensors.
2. A minimum of two independent displays of oxygen sensor readings shall be available to the diver.
3. Two independent power supplies in the rebreather design are desirable. If only one is present, a secondary system to monitor oxygen levels without power from the primary battery must be incorporated.
4. CCR shall be equipped with manual diluent and oxygen addition valves, to enable the diver to maintain safe oxygen levels in the event of failure of the primary power supply or automatic gas addition systems.
5. Redundancies in onboard electronics, power supplies, and life support systems are highly desirable.

## **12.40 OPERATIONAL REQUIREMENTS**

### **General Requirements**

1. All dives involving rebreathers must comply with applicable operational requirements for open-circuit SCUBA dives to equivalent depths.
2. No rebreather system should be used in situations beyond the manufacturer's stated design limits (dive depth, duration, water temperature, etc.).
3. Modifications to rebreather systems shall be in compliance with manufacturer's recommendations.
4. Rebreather maintenance is to be in compliance with manufacturer's recommendations including sanitizing, replacement of consumables (sensors, CO<sub>2</sub> absorbent, gas, batteries, etc.) and periodic maintenance.
5. Dive Plan. In addition to standard dive plan components stipulated in AAUS Section 2.0, all dive plans that include the use of rebreathers must include, at minimum, the following details:

- a) Information about the specific rebreather model to be used
  - b) Make, model, and type of rebreather system
  - c) Type of CO<sub>2</sub> absorbent material
  - d) Composition and volume(s) of supply gases
  - e) Complete description of alternate bailout procedures to be employed, including manual rebreather operation and open-circuit procedures
  - f) Other specific details as requested by DCB
  - g) Buddy Qualifications.
6. A diver whose buddy is diving with a rebreather shall be trained in basic rebreather operation, hazard identification, and assist/rescue procedures for a rebreather diver.
  7. If the buddy of a rebreather diver is using open-circuit scuba, the rebreather diver must be equipped with a means to provide the open-circuit scuba diver with a sufficient supply of open-circuit breathing gas to allow both divers to return safely to the surface.

### **Oxygen Exposures**

1. Planned oxygen partial pressure in the breathing gas shall not exceed 1.4 atmospheres at depths greater than 30 feet.
2. Planned oxygen partial pressure set point for CCR shall not exceed 1.4 atm. Set point at depth should be reduced to manage oxygen toxicity according to the NOAA Oxygen Exposure Limits.
3. Oxygen exposures should not exceed the NOAA oxygen single and daily exposure limits. Both CNS and pulmonary (whole-body) oxygen exposure indices should be tracked for each diver.

### **Decompression Management**

1. DCB shall review and approve the method of decompression management selected for a given diving application and project.
2. Decompression management can be safely achieved by a variety of methods, depending on the type and model of rebreather to be used. Following is a general list of methods for different rebreather types:

Oxygen rebreathers: Not applicable.

SCR (presumed constant FO<sub>2</sub>):

- a) Use of any method approved for open-circuit scuba diving breathing air, above the maximum operational depth of the supply gas.
- b) Use of open-circuit nitrox dive tables based upon expected inspired FO<sub>2</sub>. In this case, contingency air dive tables may be necessary for active-addition SCR's in the event that exertion level is higher than expected.
- c) Equivalent air depth correction to open-circuit air dive tables, based upon expected inspired FO<sub>2</sub> for planned exertion level, gas supply rate, and gas composition. In this case, contingency air dive tables may be necessary for active-addition SCR's in the event that exertion level is higher than expected.

CCR (constant PPO<sub>2</sub>):

- a) Integrated constant PPO<sub>2</sub> dive computer.
- b) Non-integrated constant PPO<sub>2</sub> dive computer.
- c) Open-circuit (constant FO<sub>2</sub>) nitrox dive computer, set to inspired FO<sub>2</sub> Constant PPO<sub>2</sub> dive tables.
- d) Predicted using PPO<sub>2</sub> set point at the maximum planned dive depth.

- e) EAD correction to standard open-circuit air dive tables, based on the inspired FO<sub>2</sub> predicted using the PPO<sub>2</sub> set point at the maximum planned dive depth.
- f) Air dive computer, or air dive tables used above the MOD of air for the PPO<sub>2</sub> set point selected.

### **Maintenance Logs, CO<sub>2</sub> Scrubber Logs, Battery Logs, and Pre-And Post-Dive Checklists**

1. Logs and checklists will be developed for the rebreather used, and will be used before and after every dive.
2. Diver shall indicate by initialing that checklists have been completed before and after each dive.
3. Such documents shall be filed and maintained as permanent project records. No rebreather shall be dived which has failed any portion of the pre-dive check, or is found to not be operating in accordance with manufacturer's specifications.

Pre-dive checks shall include:

- a) Gas supply cylinders full
- b) Composition of all supply and bail-out gases analyzed and documented
- c) Oxygen sensors calibrated
- d) Carbon dioxide canister properly packed
- e) Remaining duration of canister life verified
- f) Breathing loop assembled
- g) Positive and negative pressure leak checks
- h) Automatic volume addition system working
- i) Automatic oxygen addition systems working
- j) Pre-breath system for three (3) minutes (five (5) minutes in cold water) to ensure proper oxygen addition and carbon dioxide removal (be alert for signs of hypoxia or hypercapnia)
- k) Other procedures specific to the model of rebreather used
- l) Documentation of ALL components assembled
- m) Complete pre-dive system check performed
- n) Final operational verification immediately before to entering the water:
- o) PO<sub>2</sub> in the rebreather is not hypoxic
- p) Oxygen addition system is functioning
- q) Volumetric addition is functioning
- r) Bail-out life support is functioning

### **Alternate Life Support System**

1. The diver shall have reliable access to an alternate life support system designed to safely return the diver to the surface at normal ascent rates, including any required decompression in the event of primary rebreather failure. The complexity and extent of such systems are directly related to the depth/time profiles of the mission. Examples of such systems include, but are not limited to:
  - a) Open-circuit bailout cylinders or sets of cylinders, either carried or pre-positioned
  - b) Redundant rebreather
  - c) Pre-positioned life support equipment with topside support

## **CO<sub>2</sub> Absorbent Material**

1. CO<sub>2</sub> absorption canister shall be filled in accordance with the manufacturer's specifications.
2. CO<sub>2</sub> absorbent material shall be used in accordance with the manufacturer's specifications for expected duration.
3. If CO<sub>2</sub> absorbent canister is not exhausted and storage between dives is planned, the canister should be removed from the unit and stored sealed and protected from ambient air, to ensure the absorbent retains its activity for subsequent dives.
4. Long-term storage of carbon dioxide absorbents shall be in a cool, dry location in a sealed container. Field storage must be adequate to maintain viability of material until use.

## **Consumables (e.g., batteries, oxygen sensors, etc.)**

1. Other consumables (e.g., batteries, oxygen sensors, etc.) shall be maintained, tested, and replaced in accordance with the manufacturer's specifications.

## **Unit Disinfections**

1. The entire breathing loop, including mouthpiece, hoses, counterlungs, and CO<sub>2</sub> canister, should be disinfected periodically according to manufacturer's specifications. The loop must be disinfected between each use of the same rebreather by different divers.

## **12.50 OXYGEN REBREATHERS**

1. Oxygen rebreathers shall not be used at depths greater than 20 ft.
2. Breathing loop and diver's lungs must be adequately flushed with pure oxygen prior to entering the water on each dive. Once done, the diver must breathe continuously and solely from the intact loop, or re-flushing is required.
3. Breathing loop shall be flushed with fresh oxygen prior to ascending to avoid hypoxia due to inert gas in the loop.

## **12.60 SEMI CLOSED CIRCUIT REBREATHERS (SCR)**

1. The composition of the injection gas supply of an SCR shall be chosen such that the partial pressure of oxygen in the breathing loop will not drop below 0.2 atm, even at maximum exertion at the surface.
2. The gas addition rate of active addition SCR (e.g., Draeger Dolphin and similar units) shall be checked before every dive, to ensure it is balanced against expected workload and supply gas FO<sub>2</sub>.
3. The intermediate pressure of supply gas delivery in active-addition SCR shall be checked periodically, in compliance with manufacturer's recommendations.
4. Maximum operating depth shall be based upon the FO<sub>2</sub> in the active supply cylinder.
5. Prior to ascent to the surface the diver shall flush the breathing loop with fresh gas or switch to an open-circuit system to avoid hypoxia. The flush should be at a depth of approximately 30 fsw during ascent on dives deeper than 30 fsw, and at bottom depth on dives 30 fsw and shallower.

## **12.70 CLOSED CIRCUIT REBREATHERS (CCR)**

1. The FO<sub>2</sub> of each diluent gas supply used shall be chosen so that, if breathed directly while in the depth range for which its use is intended, it will produce an inspired PPO<sub>2</sub> greater than 0.20 atm but no greater than 1.4 atm.

2. Maximum operating depth shall be based on the  $FO_2$  of the diluent in use during each phase of the dive, so as not to exceed a  $PO_2$  limit of 1.4 atm.
3. Divers shall monitor both primary and secondary oxygen display systems at regular intervals throughout the dive, to verify that readings are within limits, that redundant displays are providing similar values, and whether readings are dynamic or static (as an indicator of sensor failure).
4. The  $PPO_2$  set point shall not be lower than 0.4 atm or higher than 1.4 atm.

## SECTION 13.00

### SCIENTIFIC CAVE AND CAVERN DIVING STANDARD

This standard helps to ensure all scientific diving in overhead environments is conducted in a manner which will maximize the protection of scientific divers from accidental injury and/or illness and provide the basis allowing the working reciprocity between AAUS organizational members.

If a conflict exists between this standard and other standards in this manual, the information set forth in this standard only takes precedence when the scientific diving being conducted takes place wholly or partly within an underwater cave or cavern environment.

A dive team shall be considered to be cave or cavern diving if at any time during the dive they find themselves in a position where they cannot complete a direct, unobstructed ascent to the surface because of rock formations.

The member organization requires that no person shall engage in scientific cave or cavern diving unless that person holds a recognized certificate/authorization issued pursuant to the provisions of this manual.

The diver must demonstrate to the DCB or it's designee that the diver possesses the proper attitude, judgment, and discipline to safety conduct cave and cavern diving in the context of planned operations.

Operational requirements for cave and cavern diving have been established through accident analysis of previous cave diving accidents.

#### 13.10 DEFINITIONS

1. Alternate Gas Supply - Fully redundant system capable of providing a gas source to the diver should their primary gas supply fail.
2. Bubble Check - Visual examination by the dive team of their diving systems, looking for O-ring leaks or other air leaks conducted in the water prior to entering a cave, usually included in the "S" Drill.
3. Cave – A dive shall be considered a cave dive if any one or more of the environmental limits specified in the definition of cavern are exceeded or otherwise not followed. Linear penetrations limits shall not exceed the limits of each diver's training.
4. Cave Dive - A dive, which takes place partially or wholly underground, in which one or more of the environmental parameters defining a cavern dive are exceeded.
5. Cavern - An entrance and first chamber to a cave where:
  - a) Sunlight from the entrance is visible to all dive team members at all times during the dive.
  - b) Members of the dive team do not pass through any restrictions that don't allow the divers to swim side by side during the dive, nor are there any restrictions between the divers and the most expeditious exit to the surface.
  - c) Maximum depth achieved shall not exceed the depth ratings of dive team.
6. Cavern Dive - A dive which takes place partially or wholly underground, in which the following environmental parameters are met:
  - a) Natural sunlight is continuously visible from the entrance.
  - b) Environmental conditions will be evaluated by the DSO or designee and appropriate limits incorporated into the dive plan.



7. Dual Valve Manifold with Isolator Valve - A manifold joining two diving cylinders, that allows the use of two completely independent regulators. If either regulator fails, it may be shut off, allowing the remaining regulator access to the gas in both of the diving cylinders.
8. Gas Management - Gas planning rule which is used in cave diving environments in which the diver reserves a portion of their available breathing gas for anticipated emergencies (See Rule of Thirds, Sixths).
9. Guideline - Continuous line used as a navigational reference during a dive leading from the team position to a point where a direct vertical ascent may be made to the surface.
10. Jump/Gap Reel - Spool or reel used to connect one guide line to another thus ensuring a continuous line to the exit.
11. Knife/Line Cutter - Small, sharp blade capable of easily cutting a guideline and that is accessible to the diver.
12. Lava Tube - Type of cave or cavern formed by the surface hardening of a stream of flowing molten rock, which may later become flooded due to static sea level changes.
13. Line Marker - Any one of several types of markers attached to a guideline, which provides additional navigational information to the dive team, most commonly the direction out to the nearest surface.
14. Mine Diving - Diving in the flooded portions of a man-made mine. Necessitates use of techniques detailed for cave diving.
15. Penetration Distance - Linear distance from the entrance intended or reached by a dive team during a dive at a dive site.
16. Primary Reel - Initial guideline used by the dive team from open water to maximum penetration or a permanently installed guideline.
17. Restriction - Any passage through which two divers cannot easily pass side by side while sharing air.
18. Rule of Thirds - Gas planning rule which is used in cave diving environments in which the diver reserves 2/3's of their breathing gas supply for exiting the cave or cavern.
19. Rule of Sixths - Air planning rule which is used in cave or other confined diving environments in which the diver reserves 5/6's of their breathing gas supply (for DPV use, siphon diving, etc.) for exiting the cave or cavern.
20. Safety Drill - ("S" Drill) - Short gas sharing, equipment evaluation, dive plan, and communication exercise carried out prior to entering a cave or cavern dive by the dive team.
21. Safety Reel - Secondary reel used as a backup to the primary reel, usually containing 150 feet of guideline that is used in an emergency.
22. Scientific Cave or Cavern Diver in Training - Authorized to dive in the cave or cavern environment under the direct supervision of qualified instructional personnel for training purposes only.
- 23. Scientific Cavern Diver** - Authorization to dive in an overhead environment as defined in cavern.
24. Scientific Cave Diver - Authorization to dive in an overhead environment as defined in cave.

25. Side-mount Diving - A diving mode utilizing two independent SCUBA systems carried along the sides of the diver's body; either of which always has sufficient air to allow the diver to reach the surface unassisted.
26. Siphon - Cave into which water flows with a generally continuous in-current.
27. Solution Cave - Cave formed in carbonate or carbonate-cemented bedrock, formed by the dissolution of the rock by groundwater.
28. Spring - Cave with water flowing with a generally continuous outflow.
29. Sump - An area in a dry cave that can no longer be negotiated without the use of diving equipment.
30. Well - A vertical or nearly vertical shaft, usually manmade, through which a diver can access a dive site.

### **13.20 CAVE AND CAVERN ENVIRONMENT HAZARDS**

1. Current/Flow - Underwater caves have currents that vary in strength and direction. Of particular note is a condition known as siphoning. Siphoning caves have flow or current directed into the cave. This can cause poor visibility as a result of mud and silt being drawn into the cave entrance.
2. Silt - The presences of silt, sand, mud, clay, etc. on the cave floor can cause visibility to be reduced to nothing in a very short time.
3. Restrictions - Any passage through which two divers cannot easily pass side by side while sharing air make air sharing difficult.
4. Cave-ins - Cave-ins are a normal part of cave evolution; however experiencing a cave-in during diving operations is extremely unlikely.

### **13.30 MINIMUM EXPERIENCE AND TRAINING REQUIREMENTS**

#### **Cavern Diver**

##### Prerequisites

1. The applicant for training shall have met the requirements in Section 5.00 of the AAUS *Standards for Scientific Diving Certification and Operation of Scientific Diving Programs*, fourth edition (2003), and hold as a minimum a scientific diver permit.

##### Cavern Training

2. The applicant is to participate in the following areas of training, or their equivalent:
  - a) Classroom Lecture and Critique—The applicant shall participate in classroom discussion or equivalent type activities covering these topics: Policy for cavern diving, cavern environment and environmental hazards, accident analysis, psychological considerations, equipment, body control, communications, cavern diving techniques, navigation and guidelines, dive planning, cave geology, cave hydrology, cave biology, and emergency procedures.
  - b) Land Drills—the applicant shall participate in drills above water using the guideline and reel. Drills are to emphasize proper use of the reel, techniques and considerations for laying a guideline, guideline following, buddy communication, and emergency procedures.
  - c) Cavern Dives—a minimum of four (4) cavern dives, preferably to be conducted in a minimum of two (2) different caverns. Skills the applicant should demonstrate include: Safety drill (S-drill), gear matching, bubble check prior to entering the cavern on each dive,

proper buoyancy compensator use, proper trim and body positioning, hovering and buoyancy with hand tasks, specialized propulsion techniques (modified flutter kick, modified frog kick, pull and glide, ceiling walk or shuffle), proper guideline and reel use, ability to follow the guideline with no visibility, sharing air while following a guideline, and sharing air while following the guideline with no visibility, light and hand signal use, and ability to comfortably work in a cavern without assistance.

- d) Written Examination - A written evaluation approved by the DCB with a predetermined passing score, covering concepts of both classroom and practical training is required.

## **Cave Diver**

### **Prerequisites**

1. The applicant for training shall hold as a minimum a cavern diver permit.

### **Cave Training**

1. The applicant is to participate in the following areas of training, or their equivalent:
  - a) Classroom Lecture and Critique—The applicant shall participate in classroom discussion or equivalent type activities covering these topics: Review of the topics listed in cavern diver training and differing techniques and procedures used in cave diving, additional equipment procedures used in cave diving, cave diving equipment configurations, procedures for conducting diving operations involving complex navigation and use of line markers, advanced gas management and a thorough review of dive tables, decompression tables, and decompression theory.
  - b) Land Drills—the applicant shall participate in drills above water included in cavern training. Drills are to emphasize proper use of the reel in lost diver procedures, as well as line placements and station location as required for surveying.
  - c) Cave Dives—a minimum of 12 cave dives, to be conducted in a minimum of four (4) different cave sites with differing conditions recommended. Skills the applicant should demonstrate include: Review of skills listed in cavern training, and special techniques in buoyancy control, referencing and back-up navigation, air sharing in a minor restriction using a single file method, special propulsion techniques in heavy outflow, anti-silting techniques, line jumping techniques and protocols, surveying, and ability to critique their dives. Emergency procedures training shall include proficiency in lost line, lost diver, gas sharing, light failure, valve manipulation, and no/low visibility situations.
  - d) Written Examination - A written evaluation approved by the DCB with a predetermined passing score, covering concepts of both classroom and practical training is required.

## **13.40 EQUIPMENT REQUIREMENTS**

Equipment used for SCUBA in cave or cavern diving is based on the concept of redundancy. Redundant SCUBA equipment shall be carried whenever the planned penetration distances are such that an emergency swimming ascent is not theoretically possible.

### **Cavern Diving Equipment**

1. The following equipment shall be required, in excess of that detailed for open-water SCUBA diving in Volume 1, Section 3.00. Each member of the dive team shall have:
  - a) At minimum, a single tank equipped with an “H” valve or an alternate air supply.
  - b) A BCD capable of being inflated from the tank.

- c) Slate and pencil.
- d) Two battery powered secondary lights of an approved type.
- e) Knife or line cutter.
- f) One primary reel of at least 350 feet for each team.
- g) Snorkel—No snorkel shall be worn while inside underwater cave or cavern.

### Cave Diving Equipment

1. The following equipment shall be required, in excess of that detailed for cavern diving: Each member of the dive team shall have:
  - a) Cylinders with dual orifice isolation valve manifold or independent SCUBA systems each capable of maintaining enough gas for the diver during exit and ascent to the surface.
  - b) Two completely independent regulators, at least one of each having submersible tank pressure gauge, a five foot or longer second stage hose, low pressure inflator for the BCD.
  - c) A primary light with sufficient burn time for the planned dive.
  - d) Safety reel with at least 150 feet of line.
  - e) Appropriate submersible dive tables and/or dive computer (computers w/ backup tables).
  - f) Line markers.
  - g) Snorkel—No snorkel shall be worn while inside underwater cave or cavern.

## 13.50 OPERATIONAL REQUIREMENTS AND SAFETY PROTOCOLS

All members of the dive team must have met the applicable all sections of Volume One and applicable sections of Volume Two of the AAUS manual and be authorized for that type of diving by the DCB before conducting scientific cave dives.

### Cavern Diver Procedures

1. Cavern diving shall not be conducted at depths greater than 100 feet.
2. Dive teams shall perform a safety drill prior to each cave or cavern penetration that includes equipment check, gas management, and dive objectives.
3. Each team within the cavern zone must utilize a continuous guideline appropriate for the environment leading to a point from which an uninterrupted ascent to the surface may be made.
4. Gas management must be appropriate for the planned dive with special considerations made for; DPV's, siphon diving, rebreathers, etc.
5. The entire dive team is to immediately terminate the dive whenever any dive team member feels an unsafe condition is present.

### Cave Diving Procedures

1. Dive teams shall perform a safety drill prior to each cave or cavern penetration that includes equipment check, gas management, and dive objectives.
2. Diver teams must run or follow a continuous guideline from the surface pool to maximum penetration.
3. Gas management must be appropriate for the planned dive with special considerations made for: DPV's, siphon diving, rebreathers, etc.
4. Each diver must carry one primary and two back up lights.
5. Divers utilizing side mount diving or other dual independent diving systems must have the approval of the DSO or his/her designee.
6. The entire dive team is to immediately terminate the dive whenever any dive team member feels an unsafe condition is present.

## SECTION 14.00

### UNDER ICE DIVING

#### 14.10 PURPOSE AND GENERAL COMMENTS:

The purpose of these regulations is to provide information and a framework for safe diving in the under ice environment. While these diving regulations cover special conditions, the other provisions of the UW Diving Safety Manual apply also.

Much of the information in this document has been gained from under ice diving experience in the Arctic. Beginning in the late 1950's, the UW conducted under ice diving in the Arctic and has continued this specialty diving up to the present day. These dives were under ice, eight (8) to 20 feet thick, in shallow water in Prudhoe Bay, up to as far as 150 to 300 miles or more offshore in the Beaufort Sea, and in recent years, during the recovery of scientific equipment at the North Pole.

Clearly, diving under a hard ice cover increases the safety risks and consequently requires special procedures and equipment. In addition, low temperature and remote locations place added risk factors on this type of Self Contained Underwater Breathing Apparatus (SCUBA) diving. In early under ice diving, before the advent of modern dry suits, divers in custom fitted wet suits lasted only about 20 minutes before their hands became so cold and stiff that they were unable to manipulate their diving equipment and emergency gear. Special diving equipment designed to function in freezing water was imported from Sweden (Poseidon diving regulators and Unisuits).

In Arctic under ice diving, the temperature of the water just below the ice may be as low as -1.8 degrees C (29 degrees F) due to the depression of the freezing point of sea water by the salt content of the water. Since this water is often already at the freezing point, heat absorption by the expansion of the compressed gas breathing medium, as it passes through the regulator first (1<sup>st</sup>) stage valve, leads to the rapid formation of a layer of ice around the casing of the 1<sup>st</sup> stage of the regulator.

This layer of ice may affect the ambient pressure reference port of the SCUBA regulator and lead to a freeze up condition with subsequent failure of the regulator, most often in "free flow" condition. This free flow condition is manifested by an increase in "intermediate pressure" causing the downstream second (2<sup>nd</sup>) stage valve to be forced open--resulting in the rapid loss of air out the 2<sup>nd</sup> stage exhaust port. This phenomenon may be intermittent and manifested by voluminous puffing of air into the divers full face mask and hood.

Consequently, this critical piece of equipment, the diving regulator, must be carefully selected and prepared for this special environment. SCUBA regulators to be used for under ice diving must have special design provisions to reduce the likelihood of freezing malfunction of the regulator 1<sup>st</sup> stage. (See supplementary Information, Section 10.11 for more information). Also, to reduce the likelihood of internal freezing of 1<sup>st</sup> stage regulator mechanism, air compressors for under ice diving air are often equipped with an extra filter canister to remove excess moisture from the breathing air delivered by the compressor.

## **14.20. DIVE ENVIRONMENT**

Under ice diving may take place in many locations—frozen lakes, under the Arctic ice cap, Antarctic ice sheets, special experimental tanks, etc. Water depths may vary from 20 feet to 4000 meters.

The diving environment under the Arctic icecap may be quite variable with respect to the morphology of the underside of the ice, smooth rolling features or fractured blocks of ice pushed down to 100 feet below the surface by ice motion on the surface. Light conditions vary with the time of the year, ice thickness and snow cover-- often requiring the use of underwater lights. Depending on weather conditions, the ice may be actively moving and shifting, forming pressure ridges, etc. or be quiescent for days at a time.

Ice movement activity can change rapidly. Even though there may not be any local wind and the weather calm, thick plates of ice, in an ice covered ocean, may suddenly fracture due to forces transmitted over relatively long distances. In addition to the formation of rubble fields, this can result in rafting of large pieces of ice over and under each other and the closure of open leads. Always, it is safest to have more than one artificial access hole through the ice for divers. Even then, there is the risk of ice “rafting” and blocking off a diver access hole.

Generally, underwater visibility is excellent. In one instance, horizontal visibility was measured at 500 feet in crystal clear water. Divers could see clearly, a chain of Nansen water sample bottles descending into the depths from a nearby hydrographic hut on the ice. Also, vertical visibility may be excellent as evidenced by the reflection off the top of an instrument housing at 400 feet under the ice. These are the typical visibility conditions far out in the ice pack in March, and April. Later in the year, when the sun angle increases, visibility may be reduced due to a plankton bloom under the ice.

## **14.30 MEDICAL/PHYSICAL CONSIDERATIONS**

Often, under ice diving takes place in remote locations such as in the Arctic where conditions above and below the ice are harsh and physically demanding both in terms of physical work and heat loss to the environment. Still air temperatures during February, March and April in the Arctic typically may be -37 degrees C (-35 degrees F) during the day. The effect of the wind chill can increase the heat loss rate appreciably.

Participants should be in top physical condition without any medical conditions that might require an emergency evacuation. Physical examinations for field personnel should take into account the special conditions in this type of environment.

## **14.40 SAFETY**

These under ice diving regulations cover basic operations. Under ice diving operations vary considerably and consequently, the DTL (with the agreement of the divers) must be prepared to respond to changing conditions in the field to ensure the diving operation is carried out in a safe manner.

Two access holes through the ice are required, especially if scientific equipment is being launched through one hole for placement, or recovery under the ice. However, in rare circumstances if the scientific equipment is such that it would not block egress of divers in any emergency situation or

can be removed quickly to allow divers to exit the water, then one hole may be used for both the divers and equipment. In this case the whole must be a minimum of 48 inches in diameter.

The DTL and the divers should evaluate the situation and require a second entry hole if, in their opinion, the scientific equipment may be a potential safety problem. (Also, see Section 14.110 of this manual for further comments regarding diver entry holes.)

Voice communications between the divers and tenders on the surface of the ice are of paramount importance during under ice diving. Consequently, hard-wired voice communications are required for under ice diving.

All divers must be tethered with a safety and communications line during the dive. At no time may a diver unclip from the harness while under water without advising the Dive Manager (DM) on the surface that there is an emergency need to unclip from the tender/communications line.

Tenders must be familiar with under ice diving and the tasks to be accomplished on the dive. Also, they must be trained to operate the communications system in the event an emergency occurs and they need to take over operation of the communications. Tenders must be Active Scientific Divers.

In the event of a complete failure of the hard wire voice communications system, the divers must abort the dive and initiate the use of their spare components for the hard wired voice communication system.

If only one diver has a communications problem, i.e. failed microphone, the DM on the surface and the divers must decide whether to abort the dive or complete their underwater task. If the diver with the communications problem elects to abort the dive, then the team must terminate the dive.

However, if they are just about to complete their task, and the communication failure only affects one diver, they might (with the concurrence of the DDM on the surface), finish up the underwater task and then terminate the dive. If it is the start of the dive operation, then they should abort and replace the malfunctioning components of the hard wired voice communication system.

As a last resort in extreme circumstances, such as total communication failure and there is a need for recovery only, the dive team may resort to "line pull" communications. It is not a recommended communications technique due to problems affecting the line at the bottom corner of the entry hole which can lead to misinterpretations of the line pull communications.

Tenders must well versed in "line pull" signals used for underwater communications as well as how to tend the diver--when to add, hold or take up the safety line connected to the diver. Divers should carry a table sealed in plastic showing the line pull signals. There should also be a line pull signal table in the communication box available for tenders.

See Section 14.110 of this manual for table with "Line Pull" communication signals

Voice communications between divers and the surface should be concise and unambiguous. Divers should use terminology such as "Diver "A" calling surface—slack my line." This alerts the DM on the surface that a message is starting and who is talking. Often, a standard technique in voice communications is to state the name of the station being called followed by the station calling. In this case, "Surface, Diver "B":--take up my slack" and so on. An agreed upon system

for voice communications should be established and practiced prior to deployment of the diving operation.

“Slack” means the tender should let out more safety line slowly. Only the diver knows the condition of his safety line and must advise the DM regarding the condition of the diver’s safety line.

“Up Rope” means the tender should take up slack slowly until advised by the diver to “Hold”.

“Hold” means the tender should hold the line and be ready to support the weight of the diver if need be. The diver may drop down below the bottom of the ice to search for a scientific package in the distance and hence needs to be kept from sinking too deep. In under ice “blue water” dive conditions, it is difficult for the diver to judge distances and consequently may sink deeper than intended unless held in position by the dive tender.

Although Decompression Sickness (DCS) events are less probable due to typically shallow nature of under ice diving, fatigue and stress may increase the probability of a DCS event. Divers must be alert and capable of coherent, decisive action in the event of an emergency during the dive. Diver rest periods prior to diving should be included in the planning for the under ice diving operations.

In the Antarctic, the effect of a "polar low" (low barometric pressure) produces an average annual "pressure altitude" at sea level at McMurdo Station equivalent to an actual altitude of 200 meters (650 feet). During some periods, the "pressure altitude" at sea level at McMurdo may be equivalent to an actual altitude as high as 335 meters (1100 feet). Consequently, dives at or near the decompression limit are not permitted.

After long periods of arduous work on the surface helping out with the field operations on the surface, divers must take the time to be properly rested and hydrated prior to diving under the ice. They are not permitted to dive when fatigued.

Divers have the right to refuse any dive and must not be reticent to demand appropriate rest prior to diving under the ice regardless of aircraft schedules and other requirements not directly related to diving safety.

Emergency Oxygen must be available at the dive site with enough oxygen available to get the injured diver or divers to another oxygen supply or to a hospital or recompression chamber. Remote Emergency Medical Oxygen (REMO) kits or additional oxygen cylinders can address this requirement. .

Also, an extended temperature range Automatic Emergency Defibrillator (AED) kit should be available and divers trained in its use. Not all AEDs are designed for operating in the low temperatures encountered in the Arctic. Due to the low ambient temperatures, many temperature sensitive items may need to be marked “keep warm” and provided with special handling after their arrival on the ice.

#### **14.50 DIVE OPERATION PLANNING**

Anticipating under ice diving operations, the DTL must submit dive and emergency plans complete with a training schedule.



These plans must be submitted sufficiently prior to the field operation to allow evaluation by the University of Washington DSO and the DCB.

This submission of the dive plan before deployment will provide sufficient time for the DSO to evaluate the equipment and techniques to be used and for “in water” evaluation of the dive team members during the pre-deployment training of the under ice dive team.

Failure to submit Dive plans for under ice diving in a timely manner will result denial of under ice diving activities.

All diving equipment intended for this specialized under ice diving must be reviewed and approved by the DSO.

Diving in remote areas such as the North Pole, in the Arctic or in the Antarctic requires special attention to the dive plan and emergency evacuation plan. Due to logistics considerations, aircraft or surface evacuation may be delayed by many hours or possibly days, depending on weather conditions at both the remote site and the nearest site with medical facilities to deal with dive related injuries.

Because of possible delays, provisions must be made for sufficient oxygen (and more efficient use of oxygen using the DAN REMO unit) for several days and an extended temperature range AED unit to be available.

Emergency evacuation plans must include provisions for alternate evacuation scenarios depending on weather and evacuation mechanisms (Aircraft, surface, ships, etc.) available at the time of the emergency.

Dive team organization for under ice diving must be as follows:

A DTL, who is an Active Scientific Diver, must be designated and is responsible for preparing the field operations dive plan and dive team and submitting same to the DSO. The DTL is in overall charge of the under ice diving operations in the field.

For each dive a DM, who is an Active Scientific Diver, must be designated. The DM will be responsible for all aspects of that particular diving operation and in charge of the divers and tenders. Normally, the DM will operate the communications set on the surface and direct the tenders during the dive.

On the two-person diving team, a “Lead Diver” (LD) will be designated who will be in charge of the underwater work during the dive. Normally, the LD will be the most experienced under ice diver and will enter the water first.

Under ice diving operations will be controlled by availability of emergency transport by helicopter, fixed wing aircraft, or over ice/land vehicle and will be a function of the weather at both the dive site and the nearest medical facility or transfer point to reach medical facilities.

*In other words, the flying weather must be satisfactory for air operations at both the dive site as well as the home base of operations where medical treatment is available. This does not mean that air craft must be at the dive site, but in the event of an emergency, must be available to respond to the situation.*

## 14.60 DIVE EQUIPMENT

Due to the low temperature conditions encountered in under ice diving, equipment used in this type of diving must be especially prepared to minimize possible failures.

Each diver must have a complete set of equipment appropriate for the under ice dive operations. Backup or spare equipment to replace malfunctioning equipment should be included in dive planning and support equipment used in the field operation.

Under ice divers must wear a Buoyancy Control Device (BCD) and not rely on their dry suit inflation to maintain buoyancy. Normally, only a small amount of air is added to the dry suit to reduce the heat loss while diving. The primary device for buoyancy control is the standard BCD used in SCUBA diving. Dive team members should familiarize themselves with their dive buddy's BCD and the method for dumping weights prior to any under ice dive.

This equipment set must be approved by the DSO.

The best safety option is to provide uniformity of operation and diver familiarization with equipment emergency procedures. Regulators, BCD's, and weight release mechanisms for under ice diving should be identical. However, while diver preference for BCD's may allow some choice, the Safe second regulators and the emergency bailout systems should be located in the same location or side on each diver.

Breathing air regulators for under ice diving must have "anti-freeze" features designed into the regulator for cold water diving—anti-freeze caps or air bleed ports to minimize the likelihood of a 1<sup>st</sup> stage freezing malfunction. See Section 14.110 of this manual.

To prevent laryngeal spasm or loss of facial muscle control, a full face mask, (AGA, Poseidon, EXO, etc.) or other suitable mask with provisions for communication system is required.

A "hard wire" voice communication system is required for all under ice dives. In the event of the failure of the primary communication system, a backup voice communications system is required—(i.e. spare cables, microphones, deck box, etc.).

Divers with BCDs with integrated weight systems must put at least half their weights on a separate weight belt equipped with over center toggle buckle or a clamp buckle with only a short amount excess belt length outside the clamp buckle. The weight belt must be able to fall free and clear of any other accessories that might be attached to the diver's lower extremities such as a knife.

Each diver must have two completely separate air systems. The two separate systems may be connected to the full face mask with a Redundant Supply Valve (RSV). If a RSV is used, there must also be an additional second stage regulator as part of the emergency backup system. This allows for "bailout" if the RSV fails.

A separate bail out mask and 2<sup>nd</sup> stage attached to the pony bottle are required. This is required even if a RSV is used.

When using RSV's, a pressure relief valve or safe second regulator must be connected to the primary air system to prevent hose failure in the event of a freezing malfunction of the primary air supply system after the diver has switched to the secondary air supply system with the RSV unit.

Dry Suits must be in good condition and suitable for under ice diving. Dry seal gloves are recommended. If neck seals, wrist seals, or waterproof zippers are questionable, they should be serviced prior to under ice diving operations. Spare seals and adhesives must be included in the on-site spare equipment supplies.

Gauntlet three finger mitts or gloves may be used instead of dry gloves. If wet gloves are used they must be at least 5mm thick.

If a member of a dive team becomes cold, (e.g. his hands become stiff) and there is the danger of being unable to function in an emergency, the dive must be aborted.

Primary SCUBA tanks must provide, at least, 120 cu. ft. of breathing medium. Other combinations such as twin 80 cu. ft. tanks may be appropriate depending on the dive operation requirements. Low pressure steel tanks are acceptable, but each diver must have a minimum of 120 cu. ft. of breathing gas in the primary cylinder.

The required separate emergency air supply may be provided by a “pony” (bail out) bottle. A minimum size of 30 cu. ft. is required, but due to increased air consumption in under ice diving with a full face mask, larger sizes may be in order depending on the under ice diving operations. Past experience has shown that divers can use up, as much as, 160 cu.ft. (twin 80 cu. ft. tanks) in short order depending on the under ice work load. Consult with the DSO for questions regarding air supplies for under ice diving.

A safety harness, separate from the tending/communications line, must be worn around the diver’s body. The safety harness should be positioned around the diver’s upper body under the arms and across the chest with a lead off line to the connection point between the harness and the tending line. The lead off line must long enough for manipulation by the diver, but be positioned between the diver and his tanks to provide for removal of the diver from the diving access hole, even in the event that the diver is unconscious. This harness position should enable tenders to remove the diver from a 36 inch diameter hole in the ice without the diver turning crosswise at the bottom of the hole.

The safety harness should be a “double braid” line at least ½ inch thick and attached to the diver in a “figure 8” pattern over the shoulders with the loops clipped together in the front across the chest with a carabineer. Pre-sewn 48 inch slings are also acceptable. The release mechanism must be the same for all divers—usually, a carabineer works well.

The safety harness must be worn over the dry suit and under all other dive gear. The safety harness must be arranged so that it cannot slip off over the arms and head in the event the SCUBA equipment is removed. The diver must be able to remove all dive gear without disconnecting the safety harness. The safety harness may not be merely connected to one of the “D” rings on the divers BCD.

The tending/communications line with its hardware connection (carabineer) to the safety harness must be capable of lifting the diver out of the diving hole. (NOTE: A fully equipped under ice diver may weigh as much as 350lbs. in air).

The tending/communications line must be marked at 10 ft. intervals with distance indicators showing the distance of tending line paid out. The markers must be secured so as to prevent slippage or movement in either direction on the diver’s safety line.

To eliminate potential tangles, the communications cable should be enclosed inside a braided safety/strength member.

Each diver must carry an underwater light for signaling in the event of an emergency or for use should light conditions change during the dive.

In addition the required diver's knife, cutting tools, such as special scissors, bolt cutters or notched jaw cable cutters capable of cutting whatever line or wire that may be encountered must be available to the divers.

## **14.70 TRAINING**

Divers participating in under ice diving should be trained and thoroughly familiar with the specialized under ice diving equipment. Prior to field operations, six to 10 or more training dives with complete under ice diving equipment must be included in the dive plan. Particular attention must be paid to "bail out" practice—changing from primary air supply to back up or emergency air supply.

Each diver participating in under ice diving must be trained for the special conditions, equipment and emergency procedures required for this specialized diving.

Divers must have completed Dry Suit Training and be comfortable utilizing a dry suit.

Divers must be trained in the proper use and maintenance of the full face masks and communication system.

Full face masks provide for communications systems, but present a problem with dual air systems. Bailing out of a full face mask is not a simple task due to the manipulation of emergency backup systems and the potential of laryngeal spasm from contact with the cold water on the divers face. Back up air system may use a RSV to connect the regulator bail out, to mask and primary tank.

Each diver must participate in a sufficient number of training dives prior to deployment in the field to be comfortable with equipment and bailout procedures. If RSV's are used the diver must also be proficient in removing the full face mask and switching to a backup mask and regulator.

Additional training, for each diver, with any specialized underwater equipment is required prior to its use in the field. Any special underwater equipment must be inspected and approved by the DSO.

Tenders must be trained in proper line tending including line pull communications and when to pay out line, hold or retrieve line. Tenders must practice tending during at least two of the training dives.

## **14.80 EQUIPMENT PREPARATIONS**

All dive equipment must be maintained in proper working order for extreme cold environments. In addition to prevention of regulator freeze up, BCD inflator mechanisms should be overhauled prior to under ice diving, sprayed with silicone spray, and checked regularly. Air 2 and similar breathing devices on BCDs must be maintained as regulators and not as inflators.

The on-site DM is responsible for checking the diver's equipment prior to each dive. The DM is responsible to check the communications system prior to diver entry into the water.

Divers and tenders both must check equipment and air supplies prior to each dive.

A heated shelter is required at the dive site for the divers and dive equipment to prevent "cold soaking" exposure of the divers and dive equipment to the very low surface temperatures. It is important to minimize exposure of the divers and their equipment to low temperatures prior to the dive.

If this shelter is helicopter transported, then the dive equipment must be secured with appropriate clamps, straps or other devices during helicopter transport.

Also, the shelter must have oxygen, first aid kit, AED tools, and spare parts kits present.

#### **14.90 DIVING OPERATIONS**

Each dive team must consist of two divers, one of which will be designated LD, two tenders, and a DM, who manages the surface dive operations and communications. Also, under special circumstances, the DM may be a tender. The communications operator at the surface must be a Scientific Diver.

If the dive operation is remote from a base camp of operations, appropriate radio communications equipment must be present at the remote dive site in order to communicate with the base camp. The base camp must be monitoring the assigned communications frequency during and after the diving operation until the DM advises that the dive is over and there is no need for emergency assistance.

The actual two-person diving team must consist of, at least, one well experienced under ice diver.

Divers who have no under ice diving experience must participate in a familiarization dive under the ice with an experienced under ice diver prior to commencing underwater work.

The conditions must be clear for flying at the dive site and the main base to which injured divers will be taken in case of emergency.

The diver entry hole must be designated for divers only. No equipment must prevent the divers from exiting at any time during the dive. If there is any equipment under the ice which could slide into the hole and cannot be immediately removed by hand by the tenders at the surface, then a second diver entry hole is required. No equipment which could hinder the divers' immediate exit may be placed into or released from the diver entry hole.

Each under ice diver must have a separate tender. One tender may not to serve two divers. Tendere must be active Scientific Divers.

The DM must check both diver's equipment prior to their entering the water. After initial water entry, the LD should wait near the hole for the 2<sup>nd</sup> diver to enter.

If and when the DM advises the divers that the under ice dive is to be terminated for safety reasons, the divers must return to the entry hole and end the dive.

Divers must check each other's equipment at the bottom of the hole prior to commencing the diving operations. In particular, they should check for crossed lines, clear safe second regulators and check each other's equipment, especially to ensure air tank valves are fully open according to standard procedures. During this initial check, tenders should hold "fast" the tending line to prevent the diver from sinking and allow the divers to adjust their buoyancy.

Note: In the past while passing down through a 36 inch diameter hole, some SCUBA tank air valves were rotated slightly closed by contact with the sides of the entry hole resulting in air difficulties. If possible, tank valve handles should be positioned to prevent contact with the sides of the entry hole (i.e. rotation) during diver entry through a hole in the ice.

However, the tank valves positions should always be checked by the divers at the bottom of the hole prior to their departure to complete their underwater tasks. Once the all ready message is given by the divers, the tenders may relax their hold on the tending line according to the divers dictates and allow the divers to proceed with the dive.

On a regular basis, divers should ensure their safety line is not in danger of entanglement. Also, they must advise their tender regarding the amount of line to feed out or take in to prevent large loops in their safety line.

When commencing work around lines and cables (e.g. from vertical instrument arrays released from the ocean bottom and resting against the underside of the ice), a "notched jaw" cable cutter capable of severing the wires or Kevlar line with a single quick closure. (See Section 14.110 of this manual for information on this type of cutter) should be available to the divers.

Note: These cable cutters are not the same as bolt cutter—there is a notch in one jaw of the cutter that will hold the cable and produce a quick, clean shearing separation of the cable or wire being cut. One brand is H.K. Porter, shear type cable cutters—MTN series.

To provide mutual assistance, under ice divers should stay as close to each other during the dive commensurate with preventing tangling of safety lines.

Divers cannot dive more than 200 feet from the diver entry hole. Safety and communications lines must be 50 feet longer than the 200 foot limit.

When the divers return to the entry hole, prior to exiting, the most experienced diver should exit last—waiting at the bottom of the hole, while the less experienced diver exits. Divers are not to continue working or stray from the entry hole while the other diver exits. Divers must exit the water with no less than 500 psig in their primary cylinder.

If voice communications fail or divers have to switch to emergency backup air supply, the divers must abort the dive and return to the surface immediately.

#### **14.100 FIELD OPERATIONS**

When divers are in the water, the dive operation takes precedence over all other field operations until the divers are out of the water. If helicopters are used for diver support they may not be "borrowed" for other field operations when divers are in the water.

## 14.110 SUPPLEMENTARY INFORMATION

Any requests for a variance of these regulations for special circumstances must be submitted in writing to the UW DSO well in advance of the dive project. Such requests will be reviewed by the DSO, and possibly, by the DCB. Variance Request Forms (VRF) are available at <https://www.ehs.washington.edu/forms/index.shtm#topic> under “Diving Safety”.

### Regulator freezing mechanism

Most persons are aware of the basic physics effect that when a compressed gas is expanded through a nozzle or valve (diving regulator). The expansion of the gas absorbs heat from the surrounding area and leads to a rapid drop in temperature within the valve or nozzle. When diving in water that is already at or below the freezing point of fresh water, this can lead to a rapid buildup of ice around the 1<sup>st</sup> stage and to some extent is a potential problem in the second stage. However, due to the large pressure drop from the tank pressure to the pressure at the 2<sup>nd</sup> stage valve, the predominant manifestation of this phenomenon is seen in the thick layer of ice that may form around the casing of the first stage of the SCUBA diving regulator.

To allow a diver to breathe, SCUBA diving regulators have to maintain a set pressure over the ambient pressure in the hose between the 1<sup>st</sup> and 2<sup>nd</sup> stage of the regulator. Typically, they have a pressure reference port which allows for automatic adjustment of the pressure in the hose to the 2<sup>nd</sup> stage, maintaining this set value above the ambient pressure. This set pressure is often referred to as the “intermediate pressure” setting of the regulator.

Although intermediate pressures are variable depending on the regulator design, they often range from 125 to 180 PSI above the ambient pressure at any particular depth.

One technique used to provide this automatic adjustment of the pressure is to use a spring/diaphragm mechanism. When the regulator is turned on and quiescent, the forces on the diaphragm are balanced by air pressure on one side and the spring on the other side (water side).

As the diver descends in the water column, the pressure on the spring side of the diaphragm increases due to an increase in ambient pressure, the diaphragm moves inward and forces open the high pressure valve. The air pressure increases and pushes the diaphragm outward until the high pressure valve closes when the pressure on the air side equals the set pressure plus the ambient.

Piston type regulators work in the same way with the spring pushing on a piston with an O-ring seal. Changes in pressure allow the spring to push open the piston allowing the air pressure inside the regulator to balance the water pressure on the outside of the regulator.

If the spring is not protected from ambient water at the “ice point”, ice will form between the coils of the spring preventing it from closing the high pressure valve which leads to an ever increasing intermediate pressure with subsequent free flowing of air at the 2<sup>nd</sup> stage of the regulator. Consequently, regulators must have provisions for anti-freeze first stages. This is for both the primary and secondary regulators used on the main tank and pony bottle.

Recommended regulators are the Poseidon Xstream, and Poseidon Jet Stream regulators, which have proven themselves in extreme diving conditions encountered in under ice diving.

## **Special Tools for Under Ice Diving**

H.K. Porter notched jaw cable cutters

Extendable boat hook:

Safety device for use by tenders in an emergency.

### **Diver entry hole**

Cutting a diver entry hole in sea ice is not a trivial operation. We have tried many different methods, from explosives to special melter devices. For thin ice, (up to about 36 inches thick), a chain saw with a long blade is usually convenient, albeit quite dangerous for obvious reasons.

Explosives might sound like a suitable mean for opening a dive and equipment hole in the ice for diving, but, usually, the safety concern for handling and transporting explosives are not worth the trouble vs. the efficiency of this method. When blasting through ice, the ice usually is blown skyward and then returns to the place it left, requiring considerable work to “muck” out the slush and fragments of the original ice. In addition, we have experience dealing with “sensitized” explosives that did not detonate in the initial blast and consequently, are very dangerous to handle afterwards.

A simple method for diver entry holes in thick ice is to use a thermal melter. Basically, this device is a diesel fuel fired boiler that melts an annular hole in the ice, cutting at a rate of about six (6) feet per hour (with a 36 inch diameter cutter ring). After the melter cuts through to seawater, it is removed and the floating ice plug is extricated using a tripod, ice chisels and chainsaws to separate the plug into sections that can be lifted with a tripod and chainfall. To cut through 6 feet of ice with a 36 inch diameter melter ring and remove the plug requires about two (2) to 2 ½ hours.

A 36 inch diameter hole is about as small a hole as one might want to use for access through thick ice. A fully equipped diver with twin tanks, bail out tank and full arctic diving gear pretty much fills up that hole—his face mask is only a few inches from the side of the hole during entry.



## **SCUBA Diving Line Pull Signals**

**2-2-2 Pulls: I am fouled and need assistance of another diver**

**3-3-3 Pulls: I am fouled but can clear myself**

**4-4-4 Pulls: Haul me up immediately**

All signals are to be answered as received except for the emergency signal 4-4-4.

### **Tender to Diver**

**1 Pull: "Are you alright?"; when descending, one pull means "Stop".**

**2 Pulls: "Going down". During ascent, 2 pulls means "You have come up too far—go back down until we stop you.**

**3 Pulls: "Stand by to come up".**

**4 Pulls: "Come up"**

**2—1 Pulls: "I Understand"**

### **Diver to Tender**

**1 Pull: "I am alright or I am on bottom"**

**2 Pulls: "Lower or give me slack".**

**3 Pulls: "Take up my slack".**

**4 Pulls: "Haul me up".**

**2-1 Pulls: "I understand".**

**3-2 Pulls: "More air".**

**4-3 Pulls: "Less air".**

## APPENDIX 1

### DIVING FORMS

Diving forms are available on line at

<http://www.ehs.washington.edu/forms/index.shtm#topic>

#### **Diving Safety**

- [Diving Registration Form](#) (pdf)
- [AAUS Request for Diving Reciprocity Form](#) (pdf)
- [Annual Equipment and Maintenance Summary](#) (pdf)
- [Annual Renewal Information](#) (pdf)
- [Consent and Understanding of Risk Form](#) (pdf)
- [Dive log form](#) (Requires Log-in)(Fill-in online)
- [Dive Plan](#) (pdf)
- [Emergency Plan](#) (pdf)
- [Monthly Dive Summary](#) (pdf)
- [Open Water Checkout](#) (pdf)
- [Variance Request](#) (pdf)

For medical forms please contact the Employee Health Center at [emphlth@uw.edu](mailto:emphlth@uw.edu). For more information regarding the medical approval process please refer to the Medical section at the following URL: <https://www.ehs.washington.edu/rbsdiving/index.shtm>

## APPENDIX 2

### RECOMMENDED PHYSICIANS WITH EXPERTISE IN DIVING MEDICINE

List of local Medical Doctors that have training and expertise in diving or undersea medicine:

1. Edmond Kay M.D.  
Name  
  
828 West Emerson St. Seattle, WA 98119  
Address  
  
Cell 206-954-3750 Fax 206-238-8080  
Telephone
  
2. Divers Alert Network  
Name  
The Peter B. Bennett Center, 6 West Colony Place, Durham, NC 27705 USA  
Address  
Non-emergency medical questions 1-919-684-2948  
Telephone
  
3. \_\_\_\_\_  
Name  
\_\_\_\_\_  
Address  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Telephone
  
4. \_\_\_\_\_  
Name  
\_\_\_\_\_  
Address  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Telephone

## APPENDIX 3

### DEFINITION OF TERMS

**AAUS** - American Academy of Underwater Sciences is an organization that provides a forum for the regular exchange of ideas and experiences among underwater scientists. It is recognized by OSHA as the scientific diving standard setting organization.

**Acfm** - Actual cubic feet per minute.

**AGE** - Arterial Gas Embolism

**Air sharing** - The sharing of an air supply between divers.

**ATA(s)** - Abbreviation for “Atmospheres Absolute”, defines as the total pressure exerted on an object, by a gas or mixture of gases, at a specific depth or elevation, including normal atmospheric pressure.

**ASME** - American Society of Mechanical Engineers.

**Blue-Water Diving** - Specific diving technique where the divers are suspended in the water column without visual reference to the bottom. This technique is normally used for in-the-environment observation, manipulation and sampling of planktonic organisms.

**Boat Tender** - A qualified individual who will operate small boats for divers in areas of high current, night, or blue water diving.

**Bottom Time** - The total elapsed time in minutes from the time the diver leaves the surface in descent to the time the diver begins ascent.

**Bounce Dive** - A dive of relatively short duration. Generally less than 10 minutes.

**Breath-hold Diving** - A diving mode in which the diver uses no self-contained or surface-supplied air or oxygen supply.

**Buddy Breathing** - The sharing of a single air source between divers.

**Buddy Diver** - Second member of the dive team.

**Buddy system** - Two comparably equipped scuba divers in the water in constant communication, and close enough to render assistance if needed.

**Buoyant Ascent** - An ascent made using some form of positive buoyancy.

**Buoyancy Control Device (BCD)** - A floatation type vest that will allow the diver to establish neutral buoyancy in the water column. (See Section 3.20 Flotation Devices)

**Burst Pressure** - The pressure at which a pressure containment device would fail structurally.

**Certified Diver** - A diver who holds a recognized valid certification from an organizational member or recognized certifying agency.

**Certified Scientific Diver** - A diver who is recognized by the University as having current proficiency and medical qualifications to perform diving operations under the auspices of the University within provisions of the Diving Safety Manual.

**Compressor** - A machine used to compress air or gas to elevated pressures. This gas is normally stored in cylinders for diver use.

**Commercial Diver** - A diver hired for underwater work that is engaged in commercial diving operations and must adhere to OSHA regulations.

**Controlled Ascent** - Any one of several kinds of ascents including normal, swimming, and air sharing ascents where the diver(s) maintain control so a pause or stop can be made during the ascent.

**Cylinder** - An unfired pressure vessel for the storage of compressed gases.

**Decompression Chamber** - A pressure vessel for human occupancy. Also called a hyperbaric chamber or recompression chamber.

**Decompression Sickness** - A condition with a variety of symptoms that may result from gas and bubbles in the tissues of divers after pressure reduction.

**Decompression Meter** - A Dive Computer which has the design capabilities to provide decompression dive planning schedules, to provide data on safe decompression stops during the dive and on the ascent to the surface, and to provide a missed decompression or ascent rate warning. (See also Dive Computer)

**Deeper Spike Dive** - A diving technique where the deepest part of the dive does not occur at the beginning of the dive.

**Designated Person-in-Charge** - An individual at every dive site with the experience and training to organize and conduct the planned diving operation (may be dive team leader).

**Decompression Table** - 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. (Also called dive tables.)

**Dive** - A descent into the water, an underwater diving activity utilizing compressed gas, an ascent, and return to the surface.

**Dive Computer** - A microprocessor based device which computes a diver's theoretical decompression status, in real time, by using pressure (depth) and time as input to a decompression model, or set of decompression tables, programmed into the device.

**Dive Location** - A vessel, structure, shore base, or physical location from which a diving operation is conducted.

**Dive Plan** - A pre-arranged sequence of underwater events constituting the anticipated dive. The dive plan must incorporate emergency planning. (See Emergency Plan)

**Dive Physician** - UW, EH&S designated board certified hyperbaric physician.

**Dive Site** - The physical location of a dive team during a dive.

**Dive Teams** - Divers and immediate support persons who are exposed to hyperbaric conditions or control the exposure of others in diving operations, including the designated person-in-charge.

**Dive Timer** - A dive watch or other suitable timing device worn by each member of a dive team.

**Diver** - An individual in the water who uses apparatus, including snorkel, which supplies breathing gas at ambient pressure.

**Diver-Carried Reserve Breathing Gas** - A diver-carried independent supply of air or mixed gas (as appropriate) sufficient under standard operating conditions to allow the diver to reach the surface, or another source of breathing gas, or to be reached by another diver.

**Diver-In-Training** - An individual gaining experience and training in additional diving activities under the supervision of a dive team member experienced in those activities.

**Diving Control Board (DCB)** - The group of individuals who act as the official representative of the University of Washington in matters concerning the scientific diving program (see Section 1.20). The Executive Director of Health Sciences will appoint the members of the diving control board.

**Diving Manager (DM)** – Responsible for all aspects of particular diving operations and is in charge of the communications, divers and tenders.

**Diving Mode** - A type of diving required specific equipment, procedures, and techniques, for example, snorkel, scuba, surface-supplied air, or mixed gas.

**Diving Officer (DO)** - A staff member of Friday Harbor Laboratories responsible for overseeing diving operations at the field station.

**Diving Safety Officer (DSO)** - A staff member of EH&S that is responsible for the Diving Safety Program. (See Section 1.20 of this manual).

**Dive Team Leader (DTL)** - who is an Active Scientific Diver, must be designated and is responsible for preparing the field operations dive plan and dive team and submitting same to the DSO. The DTL is in overall charge of the diving operations.

**EAD** - An abbreviation for Equivalent Air Depth (see below).

**EH&S** - Environmental Health and Safety Department

**Embolism** - Dispersion of alveolar gas into the pulmonary venous system as a result of an over pressurization.

**Emergency Ascent** - An ascent made under emergency conditions where the diver exceeds the normal ascent rate.

**Emergency Communications** - A telephone or VHF-FM radio located at the dive site for contacting emergency medical and transportation personnel (EMS) in the event of an accident. Portable telephones and radios shall have the wattage needed to reach the nearest EMS available to the intended dive site location (typically the highest wattage available).

**Emergency Medical Services (EMS)** - Local city, county, state, or military agency that provides emergency medical and transportation assistance.

**Emergency Oxygen** - A portable oxygen system, capable of being used to ventilate a non-breathing diver or used to administer O<sub>2</sub> to an injured breathing diver, shall be available at each dive site. Training is required for usage of emergency oxygen equipment.

**Emergency Plan** - A pre-arranged plan for providing on-site emergency first aid, contacting the nearest EMS, and arranging transportation to the nearest emergency facility or operational hyperbaric recompression chamber.

**Enriched Air Nitrox (EANx)** - a name for a breathing mixture of air and oxygen when the percent of oxygen exceeds 21%. This term is considered synonymous with the term "nitrox" (see Section 7.00).

**Equivalent Air Depth (EAD)** - The depth at which air will have the same nitrogen partial pressure as the nitrox mixture being used. This number, expressed in units of feet seawater, will always be less than the actual depth for any enriched air mixture.

**fN<sub>2</sub>** - fraction of nitrogen in a gas mixture, expressed as either a decimal or percentage, by volume.

**fO<sub>2</sub>** - fraction of oxygen in a gas mixture, expressed as either a decimal or percentage, by volume.

**FSW** - Feet of seawater, or equivalent static head.

**Hookah Diving** - While similar to Surface Supplied in that the breathing gas is supplied from the surface by means of a pressurized hose, the supply hose does not require a strength member, pneumofathometer hose, or communication line. Hookah equipment may be as simple as a long hose attached to a standard scuba cylinder supplying a standard scuba second stage.

**Hyperbaric Chamber** - See decompression chamber.

**Hyperbaric Conditions** - Pressure conditions in excess of normal atmospheric pressure.

**In-water Stage** - A suspended underwater platform that supports a diver in the water.

**Lead Diver (LD)** - The certified scientific diver with experience and training to conduct the diving operations and who has been designated to be in charge of the diving operation.

**Line-Tended Diving** - A diving technique where the diver is tethered by a line or umbilical to a tender on the dive platform. (See Tender)

**Live-boating** - The practice of supporting a diver from a vessel that is underway.

**MAST** – Military Assistance to Safety and Traffic

**Maximum Allowable Working Pressure** - The maximum pressure to which a containment device may be exposed under operating conditions.

**Mixed-Gas Diving** - A diving mode in which the diver is supplied with a breathing gas other than air.

**MOD** - Maximum Operating Depth, usually determined as the depth at which the pO<sub>2</sub> for a given gas mixture reaches a predetermined maximum.

**MSW** - Meters of seawater or equivalent static head.

**Nitrox** - Any gas mixture comprised predominately of nitrogen and oxygen, most frequently containing between 21% and 40% oxygen. Also be referred to as Enriched Air Nitrox, abbreviated EAN or EANx.

**NOAA Diving Manual** - refers to the *NOAA Diving Manual, Diving for Science and Technology*, 2001 edition. National Oceanic and Atmospheric Administration, Office of Undersea Research, US Department of Commerce.

**No-Decompression Limits** - Time and depth limits that will permit the diver to ascend directly to the surface, without required decompression stops for off gassing excess nitrogen.

**Normal Ascent** - An ascent made with an adequate air supply at a rate not to exceed thirty feet per minute.

**Octopus Regulator** - See Safe Second Regulator.

**Organizational member** - An organization which is a current member of the AAUS, and which has a program that adheres to the standards of the AAUS as set forth in the AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs.

**Oxygen Clean** - All combustible contaminants have been removed.

**Oxygen Compatible** - A gas delivery system that has components (o-rings, valve seats, diaphragms, etc. ...) that are compatible with oxygen at a stated pressure and temperature.

**Oxygen Service** - A gas delivery system that is both oxygen clean and oxygen compatible.

**Oxygen Toxicity** - Any adverse reaction of the central nervous system (“acute” or “CNS” oxygen toxicity) or lungs (“chronic”, “whole-body”, or “pulmonary” oxygen toxicity) brought on by exposure to an increased (above atmospheric levels) partial pressure of oxygen.

**Pressure-Related Injury** - An injury resulting from pressure disequilibrium within the body as the result of hyperbaric exposure. Examples include: decompression sickness, pneumothorax, mediastinal emphysema, air embolism, subcutaneous emphysema, or ruptured eardrum.

**Pressure Vessel** - See cylinder.

**pN<sub>2</sub>** - Inspired partial pressure of nitrogen, usually expressed in units of atmospheres absolute.



**pO<sub>2</sub>** - Inspired partial pressure of oxygen, usually expressed in units of atmospheres absolute.

**Psi (g)** - Pounds per square inch (gauge).

**Reciprocity** - The process, subject to local ground rules, under which divers from one agency or institution, are normally granted equivalent diving privileges by another agency or institution under equally acceptable training and certification standards.

**Recompression Chamber** - A pressure vessel for human occupancy, such as a surface recompression chamber, or deep diving systems used to decompress divers and to treat decompression sickness.

**Reverse Dive Profile** – A dive profile that has a deeper dive preceded by a shallow dive.

**Safe Second Regulator** - An extra second stage regulator and low-pressure hose attached to a SCUBA regulator's first stage. This extra regulator is used in an emergency to share air as an alternative to buddy breathing.

**Safety Stop** - A two (2) to three (3) minute stop at 20 feet, during a no-decompression ascent at the end of a dive. During this stop, the diver's tissue gas load is reduced thereby reducing the possibility of bubble formation.

**Scientific Diver-in-Training** - A diver who has completed all of the initial certification requirements and is approved for diving under University auspices while accompanied by a University certified scientific diver. The diver must log 12 dives with certified scientific divers to complete the certification process.

**Scientific Diving** - Scientific Diving is defined (29 CFR 1910.402) as diving performed solely as a necessary part of a scientific, research, or educational activity by employees whose sole purpose for diving is to perform scientific research tasks.

**SCUBA Diving** - A diving mode independent of surface supply in which the diver uses open circuit Self-Contained Underwater Breathing Apparatus (SCUBA).

**Spike Dive** - A single dive profile with the shallow part of the dive prior to the deep dive of short duration.

**Standby Diver** - A fully equipped diver at the dive location capable of rendering immediate assistance to a diver in the water.

**Surface-Supplied Diving** - A diving mode in which the diver in the water is supplied with a compressed breathing gas from the surface.

**Swimming Ascent** - An ascent that can be done under normal or emergency conditions accomplished by simply swimming to the surface. May be aided by some positive buoyancy control device.

**Tank** - A pressure vessel for the storage of gases. (See Cylinder)

**Tender** - A surface support person responsible for handling a single diver's umbilical and for maintaining voice and/or standard line signal communications. The tender's attention must be solely on the diver while he/she is in the water. The tender must be an active Scientific Diver who is familiar with the required emergency equipment and plan, available at the site.

**Tethered Diving** - The diver is connected to the surface, drop line, or dive buddy via a line or umbilical. (See Line Tended Diving)

**Treatment Table** - A depth, time and breathing gas profile designed for recompression chamber treatment of pressure related injuries.

**Umbilical** - The composite hose bundle between a dive location and a diver or bell, or between a diver and a bell, which supplies a diver or bell with breathing gas, communications, power, or heat, as appropriate to the diving mode or conditions, and includes a safety line between the diver and the dive location.

**University Auspices** - University sanction of diving involving the use of University property, equipment, facilities, or support in connection with occupation, research, academic instruction or training, and certification for University diving.

**Visiting Diver Certification** - Short-term authorization to dive. This certification is valid only for the period specified.

**Volume Tank** - A pressure vessel connected to the outlet of a compressor and used as an air reservoir.

**Working Pressure** - The normal pressure at which the system is designed to operate.

## APPENDIX 4

### DIVING EMERGENCY MANAGEMENT PROCEDURES

#### A. GUIDELINES FOR FIELD MANAGEMENT DECISION MAKING

1. Accurate diagnosis is sometimes difficult for a diving accident; signs and symptoms may be equivocal, difficult to define, wax and wane, and change in location and nature and sometimes in character.
2. Decompression sickness tends to progress from minor to major involvement, however, may diminish in severity or show no change.
3. Several independent problems are often present together.
4. Delays in treatment bring risk of further involvement, render existing conditions more difficult to resolve, and may contribute to reoccurrence of symptoms after treatment.
5. The magnitude of exposure (or closeness to table limits) is not a reliable guide to the severity of the potential involvement. Even dive profiles well within the decompression limits have resulted in decompression sickness.
6. Denial or fear of potential hassle, embarrassment, errors in judgment, etc. precipitate many unnecessary delays.

#### B. RECOGNITION OF DECOMPRESSION SICKNESS

Symptoms will appear **50%** of the time within **1 hour** after the dive.

Symptoms will appear **90%** of the time within **6 hours** after the dive.

Symptoms will appear **99%** of the time within **12 hours** after the dive.

Symptoms may appear within **24 - 48 hours** after the dive, however this is rare. Symptoms occurring after this delay often result in non-recognition of their cause.

#### C. DOCUMENTATION

With pencil and paper reconstruct dive profiles and unusual occurrences, note significant medical history, and note current medications.

## I. DIVING FIRST AID AND TREATMENT

### A. GENERAL

When administering first aid, it is essential to evaluate the victim's condition accurately and elect an appropriate course of action. The information available from either the patient or the bystanders, the diagnostic signs, the physical mechanisms of injury, or an emergency medical alert card or tag may all have to be evaluated rapidly. Two rapid evaluations, primary and secondary, must be performed. The primary search is for immediate life-threatening problems, while the secondary examination is an evaluation of other injuries that do not pose a threat to life. Though several conditions can be considered life threatening, two in particular require immediate attention: respiratory arrest (cardiac arrest) and severe bleeding.

An important factor in administering first aid, and one often overlooked, is the attitude of the persons administering the aid. They should help to inspire confidence by presenting a panic-free appearance. In serious injuries, victims should not be told the extent of their injuries. Knowing the actual extent of the injuries could cause unnecessary excitement and panic and lead to complications and deepening shock.

### B. INJURY SURVEY

#### 1. Primary Survey Sequence

- \* Check for adequate breathing; establish an open airway.
- \* Check for pulse; if none, begin CPR.
- \* Check for severe bleeding injury.

#### 2. Secondary Survey Sequence

The purpose of the secondary survey is to find any additional unseen injuries that might cause serious complications if aggravated by mishandling. The secondary survey is a careful and cautious head-to-toe examination, during which the victim is checked very carefully for wounds, blood, swelling, fractures, nerve damage, neck and back injury.

### C. FIRST AID

#### 1. Hypothermia

As cold exposure continues both in and out of the water, hypothermia (loss of body heat) causes progressive symptoms. This progression will affect the diver's memory, time estimation and judgment causing him/her to be unreliable, particularly in an emergency situation. Frequently the diver may not realize the condition he/she is in. As always, prevention is the key.

Signs and Symptoms: shivering, confusion, lack of coordination, lack of consciousness, dilated pupils, irregular heartbeat.

The near-drowning victim may only appear to be dead. The cold-immersed victim may be cold to the touch, have apnea (no breathing), cyanosis (blue skin), fixed and dilated pupils, and barely or impalpable pulses. Clinically, the victim appears dead.

Treatment - Recoveries have been reported in cold-water submersions (near-drowning) after victims have spent as long as 40 minutes under water. Standard CPR should be administered and continued throughout the rewarming period in a medical facility. This may require as long as one (1) to two (2) hours.

An effective rewarming technique consists of providing warmed air or gas for inhalation. This can be done by mouth-to-mouth resuscitation, even if the diver is still breathing spontaneously.

If a shower or bath is available use the following techniques:

- Do not remove the suit, but instead, carry the dressed victim to the showers.
- Direct the shower spray to the trunk, trying not to get hot water on the extremities.
- The water temperature should be about 110 F, which is readily tolerated.
- For a bath, leave the diving suit on and place the victim in the bath with the extremities outside the bath.
- As recovery begins, the vital signs should be monitored.
- When noticeable improvement has occurred, remove the victim from the bath or shower and wrap in a blanket for further rewarming.

Watch closely for recurring symptoms, the release of cold blood from the extremities during rewarming can cause a dangerous fall in body core temperature.

In less severe cases, hot beverages can be given and while this will provide negligible amounts of heat, it will help to correct dehydration.

## 2. **Vertigo**

True vertigo is a disorder of spatial orientation characterized by a sense that either the individual or the surrounding is rotating. Vertigo can result from cold water entering the external ear canal, unequal ear clearing during ascent or descent, inner ear barotrauma, ear drum rupture with cold water entering the middle ear, or injury to the central nervous system.

Signs and Symptoms: nausea, vomiting, visual disturbance, fainting, generalized sweating, ear pain, hearing loss, ringing.

Treatment - When under water, the diver's response to true vertigo should be to immediately stabilize by grasping a firm object for tactile orientation and then establish which way is the surface.

Once dizziness is experienced during diving, examination by a specialist is necessary before any further diving is attempted.

## 3. **Carbon Monoxide (CO) Poisoning**

While there are usually no symptoms prior to unconsciousness, there may be the following:

Signs and Symptoms: headache, nausea, dizziness, weakness, feeling of tightness in the head, confusion, clumsiness, shortness of breath, abnormal redness or blueness of lips, fingernails and skin, unconsciousness, cessation of breathing

The classic sign, "cherry-red" lips, may or may not be seen, and is therefore not a reliable diagnostic aid.)

Treatment - A source of fresh air or CPR should be provided for the victim, and, if available, oxygen. Some after effects such as a headache and nausea may persist after exposure. If a recompression chamber is available, treatment using U.S. Navy Treatment Table 5 or 6 is indicated.

#### 4. **Lung Over-pressure Accidents**

Lung (pulmonary) over-pressure accidents occur when the breath is held during ascent or when local air is trapped in a part of the lung and expands during ascent. When the gas pressure in the air sacs of the lung (alveoli) exceeds ambient water pressure by about 100 mmHg, air is forced from the alveoli into the lung tissue (mediastinal and subcutaneous emphysema), through a tear in the pleura (pneumothorax), or into pulmonary veins (gas embolism). A pressure of 100 mmHg represents only about 4 fsw. Thus, lung over-pressure accidents have occurred in surprisingly shallow depths.

##### a) **Gas Embolism**

When divers hold their breath or have local air trapping in their lungs during ascent, the pressure-volume relationships discussed above can occur. Alveoli can rupture or air can somehow be forced across apparently intact alveoli. If air bubbles enter the pulmonary veins, they are swept to the left side of the heart and pumped out into the aorta. Bubbles can enter the coronary arteries supplying the heart muscle, but more commonly are swept up the carotid arteries causing an embolism the brain. As the bubbles pass into smaller arteries, they reach a point where they can move no further, and they begin to stop circulation. Symptoms of gas embolism thus occur immediately or within three (3) to five (5) minutes after surfacing. This is an absolute medical emergency and requires immediate treatment. One, a few, or all of the symptoms may be present. Both gas embolization and decompression sickness are disorders that affect the whole body. Symptom-producing organs may vary, but the whole body is nonetheless involved.

Signs and Symptoms: Visual disturbances such as blurring, dizziness, chest pain, cough or shortness of breath, numbness and tingling, headache, sudden unconsciousness (usually immediately after surfacing, possibly before surfacing), bloody, frothy sputum, loss of sensation over part of body, blindness (partial or complete), confusion, cessation of breathing, paralysis or weakness.

Treatment - A potential rescuer must consider the fact that most embolism victims are also near-drowning victims and that the victim may need stabilization and medical management at the nearest medical facility.

100 % oxygen should be administered, if available, and the patient should be moved, as rapidly as possible, to a recompression chamber with a 6-ATA capability.

This is a minute-to-minute emergency transfer. The speed and the effectiveness of the patient's recovery from the injury decreases with each minute lost in getting him/her under pressure. If air transportation is required, the patient must not be exposed to decreased cabin pressure; an aircraft capable of being pressurized to sea level must be used. If a helicopter or unpressurized aircraft is used, it must not exceed a few hundred feet of altitude.

Always proceed as rapidly as possible to the nearest adequate facility. Cases have been reported of excellent results, even after several hours delay. Early oxygen

therapy is vital and may reduce symptoms, but this must not change the treatment plan. Subtle symptoms may remain or return in the future. Victims are not to be taken back into the water for treatment.

b) **Mediastinal Emphysema**

Mediastinal emphysema (air under the skin of the chest) may result from a ruptured pleural bleb or injury to the lung, esophagus, trachea, or main stem of the bronchus. Though not serious in itself, it demonstrates that the lung has been over-pressurized and close examination for gas embolism symptoms or signs is required.

Signs and Symptoms: pain under the breastbone (which may radiate to the neck, neck, bone, or shoulder), shortness of breath, faintness, blueness or cyanosis of the skin, lips, or fingernails, difficult breathing, shock, swelling around the neck, A brassy quality to the voice, A sensation of pressure on the windpipe, swollen area beneath the skin that feels like crumpled cellophane.

Treatment - Unless air embolism is also present, recompression is not necessary for mediastinal emphysema. Seek medical assistance and administer oxygen if necessary.

c) **Subcutaneous Emphysema**

Subcutaneous emphysema has the same cause as gas embolism but is not nearly as serious. This condition results when air escapes into the tissues just under the skin (subcutaneous), normally in the area of the neck and collarbone.

Signs and Symptoms: feeling of fullness in neck area, change in sound of voice, swelling or inflation around the neck, crackling sensation when skin is moved, difficulty in breathing or swallowing.

Treatment - Unless complicated by air embolism, recompression is not necessary. Seek medical assistance and administer oxygen if breathing is impaired.

d) **Pneumothorax**

A pneumothorax is the result of air between the lung and the inner wall of the chest cavity. As the air expands during ascent there is partial or total collapse of the lung. In serious cases, the heart may be displaced. Even without pressure from expanding gas, the ruptured lung may partially collapse interfering with the normal respiratory process.

Signs and Symptoms: sudden onset of cough, shortness of breath, sharp pain in the chest usually made worse by breathing, swelling of neck veins, blueness (cyanosis) of skin, lips and fingernails, pain in chest (usually high on the side under the arm), A tendency to bend the chest toward the side involved, rapid, shallow breathing, irregular pulse.

Treatment - Unless complicated by air embolism, recompression is not necessary. Transport to the nearest health care facility for insertion of a chest tube. Severely limit activity levels and if breathing is impaired, administer oxygen.

## 5. **Decompression Sickness (DSC)**

Decompression sickness is also known as caisson disease, compressed air illness, or by the slang term "the bends" and is the result of the inert portion of the breathing gas (nitrogen, helium, etc.) being absorbed by the body tissues, forming macroscopic bubbles on ascent.

As long as the diver remains under pressure, the absorbed inert gas presents no problem. Should the pressure be reduced more quickly than tissue can release the absorbed inert gas, bubbles can form in the tissues and bloodstream, causing decompression sickness symptoms. Controlled ascent in accordance with a proven decompression table permits the body to rid itself of excess inert gas at a rate that will keep the gas in solution.

Immediate recompression is not a matter of life and death as with gas embolism. However, the faster the victim is recompressed, the faster the rate of recovery and the less the chances of permanent damage.

Signs and Symptoms: unusual fatigue, skin itch and/or blotchy rash, pain in arms or legs, dizziness, staggering, numbness and paralysis, shortness of breath, coughing spasms, collapse or unconsciousness.

*Note: The signs and symptoms of decompression sickness are extremely variable and in many cases resemble those of gas embolism.*

Symptoms that appear five (5) minutes or longer after a dive indicate decompression sickness rather than gas embolism. The circumstances surrounding the dive, i.e., depth, time and nature of ascent, may also assist in making a proper diagnosis. In either case, administer oxygen and arrange for transfer to a recompression chamber.

Treatment - Just as in air embolism, decompression sickness requires urgent recompression for complete treatment. However, patient stabilization and early medical care at the nearest medical facility should be accomplished before transportation to a chamber.

Immediate 100% oxygen breathing by the injured diver must be emphasized as a vital and highly effective treatment. Early oxygen treatment has will allow for a considerably better outcome.

Recompression treatment of all forms of decompression sickness can be effective, even if delayed. Successful treatment has occurred as much as four days later, although early treatment is easier and more effective.

Prevention - Divers can help to reduce the incidence of decompression sickness by knowing and following established limits for depth and time at depth.

The hazard of flying at altitudes as low as 1,220 m (4,000 feet) even after safe depth-time dives should also be recognized.



## 6. Near-Drowning

The term near-drowning is used when a victim is recovered from the water unconscious and not breathing. This condition may result from the aspiration of water or from a reflex spasm of the larynx, caused by diver panic, fear or stress. Either condition prevents oxygenation of the blood, which will lead to asphyxia.

Signs and Symptoms: unconsciousness, blue skin (cyanosis), cessation of breathing, history of submersion.

Treatment - There must be immediate clearing of the patient's airway and resuscitation or CPR initiated. Time is of the essence to reduce permanent brain damage. The duration of submersion a human can withstand without permanent brain damage is unknown. There are reports of survival following 10 to 40 minutes of submersion.

Note: Vomiting of stomach contents is not uncommon during drowning or resuscitation. Great care must be taken to prevent aspiration of the stomach contents into the airway of the patient or the rescuer.

If it does not interfere with effective resuscitation or CPR, administration of oxygen can be beneficial.

Air Embolism must be considered while diagnosing the near-drowning victim. Therefore, while the initial concern is for patient stabilization, the additional treatment procedures for gas embolism must not be forgotten.

Even if the patient becomes conscious and says he is fine, medical assistance must be sought. Rescuers must remain cautious of secondary shock and late recurring symptoms of near drowning such as the Adult Respiratory Distress Syndrome (ARDS), pneumonia, etc.

## II. PLANNING FOR EMERGENCY RESCUE AND TRANSPORTATION

The purpose of this section of the manual is to assist all persons engaged in diving operations under University auspices with developing the required Emergency Plan. This information is presented as recommendations for dive location emergency aid, and for the rapid summoning of medical and rescue agency assistance.

It shall be the responsibility of the University divers to examine all the emergency information in this manual and assure that it remains current and applicable to the planned diving operation, and to update or supplement the information as required. **All Emergency Facilities Must Be Checked For Availability.**

### A. RESCUE PROCEDURES

#### 1. General

While the main concern is for the injured, the rescuer should not take unnecessary risks, which could result in placing themselves at risk.

- a. The majority of diving accidents occur on ascent and at or near the surface, so dive team members should be prepared to effect in-water rescues.

- b. The injured diver must be made positively buoyant and relieved of all items carried or attached.
- c. In-water mouth-to-mouth or other resuscitation techniques should be done with the proper technique to provide dry, effective resuscitation. All equipment of the injured and the rescuer should be removed as soon as possible, as this improves the effectiveness of the resuscitation technique.
- d. It is critical to avoid rough handling of spine/bone injuries or persons in shock when exiting the water.
- e. If possible, emergency aid should be sought concurrently with the rescue, but if alone, the rescuer should not leave the injured diver.

## 2. Conscious Diver

A conscious diver must receive continual positive verbal support, help in attaining positive buoyancy and assistance to safety.

- a. Diver able or unable to assist - Talk to them in positive conversational tones all the time while approaching and establishing positive buoyancy. Relieve them of items carried or attached to belts and use a tired swimmers assist to move them to safety. Firm physical hand contact and support, frequent eye contact, and frequent conversation can be very reassuring and help prevent panic.
- b. Struggling/panicky diver - Due to panic or injury this diver may be extremely dangerous to the rescuer. A safe rescue in this case requires proper training and frequent practice.
  - (1) Use any method possible to lend assistance without coming into direct contact. Verbally talk them back into control, push an inflated B.C. or alternate floatation devise to them. Sometimes a panicked diver will swim/thrash toward the rescuer, who can keep backing away until they reach a float, boat, or beach exit.
  - (2) If direct contact is used the rescuer should have their B.C. deflated and regulator in. The victim should be approached from behind. If swarmed onto by the victim, swim down to escape.
- c. Exiting the Water - Attempt to have the diver in a calm state before exiting the water. Provide assistance and verbal direction for removing equipment and /or exiting. Keep a very close watch for the signs of shock.

## 3. Unconscious Diver

When approaching a supposedly unconscious diver, shake them first to make sure that they are indeed in trouble.

- a. If the unconscious diver is on the surface, first roll them face up, then drop the weight belt, establish an open airway, and check for breathing. If the diver is not breathing start in-water resuscitation and shout for help. While conducting resuscitation start removing the victim's and your own SCUBA. This will make the rescue easier while going to the nearest location where CPR can be started.

- b. An unconscious diver on the bottom should have the weight belt removed and dropped well clear of the diver. If the diver is found face down, leave them face down until reaching the surface. The rescuer should try to keep the ascent rate normal. The expanding gas in the lungs of an unconscious diver will automatically vent on the way to the surface. After arriving on the surface proceed as above by starting resuscitation.
- c. Periodically throughout the rescue call for help.
- d. When the victim is out of the water and in a place where CPR can be done, move the victim's hood aside and check the carotid artery for a pulse. If there is none, start CPR. This can be done through the suit if need be. A rescue should be done with speed.
- e. Continue to monitor vital signs and administer first aid and CPR, as required. Administer oxygen as soon as possible. In most accidents, the injured should be treated for shock and kept warm. If alone, do not leave the victim but as soon as possible request emergency assistance at the scene, or transport for medical treatment. Continue CPR as long as is necessary, and attend to the injured until competent help arrives. For the severely ill, do not administer anything by mouth, except fluids with electrolytes. They have been shown to be very beneficial for the first aid treatment of decompression sickness. The administration of oxygen to the decompression/embolism injured victim will increase their chances of survival. Experience has shown that the first four to six hours following a decompression accident are most critical.
- f. The attending dive team member or person-in-charge should accompany the injured diver to the treatment center to describe the circumstances of the accident to medical personnel. At the very least, personal identification, dive profile, symptoms, time of rescue, time of treatment started, progression of symptoms, etc. should be written down and sent with the injured diver.

## B. COMMUNICATIONS

### 1. General

It cannot be overemphasized that obtaining rapid emergency care and transporting the injured diver to the proper treatment facility are imperative.

- a. Contact the appropriate authorities and rescue personnel immediately. State your exact location, the nature of the emergency, and request medical assistance and transportation as necessary. If the telephone line is busy, call the operator and state that you have a life or death situation and request a clear line.
- b. Since hospital treatment, and particularly hyperbaric facilities, may be limited or located at some distance from the dive location, a communication system shall be available at the dive location.
- c. Once communication is established, it should be maintained or available for call-back in case further instructions or directions to the location are needed. If you are

calling from a pay phone or cellular phone, give them your telephone number for call back if you or they need to hang up.

2. Police and Fire Department

In the greater Seattle and many other Washington areas, 911 is the emergency services number to call. In other state areas, telephone the nearest law enforcement agency or recognized emergency aid unit. You must indicate to the responding unit that this injury could be the result of a diving incident and that the person needs to be transported to a hyperbaric treatment facility as soon as possible.

3. U.S. Coast Guard

In the case of a shore based, small boat, or ship-at-sea diving emergencies with marine radio (VHF) availability, call the nearest Coast Guard station for emergency assistance. A CB radio is not capable of contacting the Coast Guard and is therefore not recommended. In a pinch a CB can be used to contact someone who can relay the message.

4. Diving Alert Network (DAN)

DAN operates as a 24 hour, seven (7) days a week emergency consultation service for diving accidents and as a clearinghouse for information on diving accidents and diving accident treatment. This service provides help to the diver and/or physician on the diagnosis, immediate care, transportation, and hyperbaric treatment facility location. DAN is located at F.G. Hall Lab., Duke University Medical Center and is sponsored by public memberships, NOAA, NIOSH, DOE, and Undersea Medical Society. (DAN (919) 684-8111)

## C. EVACUATION SYSTEMS AND METHODS

Coordination of a diving medical emergency evacuation from an outlying area to the nearest medical facility or hyperbaric chamber is often a complex operation involving several organizations.

An alternative route for evacuation is often necessary for reasons of weather, systems overload, communications, mechanical failure or human error.

1. General

Many evacuation agencies prefer to deal with persons of medical responsibility (EMT's, paramedics, nurses, doctors, etc.), though many successful evacuations have been carried out by laymen. When a layman is involved in requesting transport, it is important that he or she carefully, completely, and concisely relate the pertinent information about the accident and the condition of the victim. One should relate only what has been observed (i.e., the victim is unconscious and or he has weakness in his arm, etc.)...Do not give a diagnostic opinion such as the victim has decompression sickness or an air embolism.

2. Air Evacuation

While air evacuation is a primary means of transportation the following limitations should be considered.

- a. Weather may preclude take-off, landing or even location of the accident site, and may render a helicopter basket rescue too dangerous.

- b. The distance from the aircraft's home base to rescue site, and then to the treatment center, can place a helicopter at a disadvantage due to fuel capacity, time or both.
  - c. Unsuitable landing conditions may require the patient be transported to an intermediate location.
  - d. It is not recommended that unpressurized aircraft transport a diving accident victim at an altitude greater than 1000 feet. However, the nature of the terrain may require a decision to go over the high terrain, at a risk of worsening the condition of the patient, or go around the obstacle, thereby requiring more fuel and perhaps adversely affecting the patient by the time delay. (Given the choice, many knowledgeable individuals would choose the time delay. In making such a choice, the DAN (919) 684-8111 is a useful source for consultation.)
3. Air Evacuation Agencies
- a. U.S. Coast Guard (USCG)  
The USCG Rescue coordinates emergency evacuation in and around the Puget Sound, Hood Canal, San Juan Islands, and Strait of Juan de Fuca area. The Rescue Coordination Center (RCC) efficiently handles all necessary evacuation logistics including announcement of impending arrival, choice of landing site and permission to land. They will also verify if ambulance transport has been arranged. In cases of life-threatening emergencies the RCC will direct the helicopter to the nearest treatment facility.
  - b. Military Assistance to Safety and Traffic (MAST)  
Maintains a wide range of evacuation capabilities for out of state and inland areas. MAST Prefers to let the Coast Guard handle problems that are in water pick-ups in the Puget Sound area. They also prefer that medically responsible individuals (doctors, nurses, paramedics) request transport. Like the Coast Guard, MAST efficiently handles all transportation logistics.
  - d. Canadian Coast Guard (CCG) (RCC-Victoria) Aircraft and Marine Distress  
Works with the USCG RCC to coordinate any military or civilian evacuation agency. They also handle evacuation from British Columbia and Yukon Territory to appropriate facilities. CCG will evacuate diving accidents to Fleet Diving Unit Victoria or Vancouver Hospital.
  - e. Other military evacuation agencies (i.e., Navy, Air Force) should be coordinated through the USCG RCC.
  - f. Civilian Air Evacuation  
Evacuation agency must handle logistics from their base of operations.
  - g. If the patient dies, a medical person should inform the flight crew so that they take no unnecessary risks.

4. Ground Evacuation  
Ground transport is often the most reliable and sometimes the fastest mode of transportation. It is especially useful in transport to an intermediate medical facility. Local ambulance is the primary vehicle and appropriate local phone numbers should be obtained. State or local police are also a useful transportation information source, although transportation is not their primary responsibility. (Washington State Patrol transportation coordination center - (206) 455-7700.) Using state/local police requires careful examination of the situation including the condition of the patient and what you are requesting them to do for you (i.e. short distance transport, assistance in evacuation, securing transportation.)
5. Boat Evacuation  
Boat transport is most likely to be an intermediate vehicle, though if a chamber is close at hand it may serve as a primary vehicle. In the Pacific Northwest, use of ferries may be required (due to inclement weather for flying).
6. On-Site Pickup
  - a. Evacuation agency will want as much information about patient condition as possible (i.e., vitals, sex, age, etc., nature of injury, nature of accident).
  - b. Where possible, best results are obtained if the critical patient is delivered to the nearest hospital.
    - (1) Patient can be stabilized.
    - (2) Physician evaluation is available.
    - (3) Medical consultation and evacuation agency communication are in place.
    - (4) Parking lots and open fields provide easily accessible landing sites.
    - (5) Remote pick-ups require communications and accurate locations.
  - c. Communications can be established through VHF FM Ch. 16, HF MB 2182, ship-to-shore patch, or other VHF FM channel. CB radio is not reliable. Cellular phone is preferred.
  - d. Location of Ground Site or Boat Requires:
    - (1) Coastal navigation fix
    - (2) Coordinates
    - (3) Location from prominent landmarks
    - (4) Description of boat

e. Helicopter Evacuation Procedures

- (1) Try to establish communications with the helicopter. If your boat is unable to furnish the necessary equipment/frequency, try to work through another boat or a shore station.
- (2) Maintain speed of 10 to 15 knots, do not slow down or stop.
- (3) Maintain course into wind about 20 degrees on port bow.
- (4) Put all antennas down if possible, without losing communications and remove other obstructions that might tangle lines.
- (5) Secure all loose objects on/around decks.
- (6) Provide flat surface for stretcher.
- (7) Always let the lifting device (stretcher) touch the boat or water before handling it to prevent electric shock.
- (8) Do not secure lifting device or cable to boat.
- (9) Place life jacket on patient.
- (10) Tie patient in basket, face up.
- (11) If patient cannot communicate, place in the stretcher as much information as you can about him/her, such as name, address, what happened, and what medication/treatment has been given.
- (12) If a patient is a diving accident victim, insure that the flight crew is given the dive profile for the day, time of injury, sequence and times of symptoms, and treatment/medication given. Also be sure that the flight crew will deliver the victim to a hyperbaric facility.

D. SELECTION OF DIVING TREATMENT FACILITIES

The ultimate destination of a diving accident victim is a hyperbaric facility. You may be required to direct the evacuation agency to a chamber complex, or as in the case of the Coast Guard, the ultimate destination is the decision of the RCC. The agency or individual responsible for the evacuation should inform this treatment center of their intention to transport, expected time of arrival, and the condition of the patient.

1. Primary Treatment Facilities

- a. Primary treatment center in the Northwest United States is:

**Virginia Mason Hospital  
(206) 583-6543**

Distance to Boeing Field - 5 miles - (206) 296-7380

Distance to Harborview Hospital helipad - 0.7 mile - (206) 223-3074

- b. Primary treatment centers in British Columbia, Canada are:

**Vancouver General Hospital  
Emergencies (604) 875-8411,  
Dr. M. Lepawsky (604) 875-4111 or 325-8111 - Chamber (604) 873-5441**

**Victoria B.C. Fleet Diving Unit  
Commanding Officer (604) 388-2379 - Chamber 388-1781**

- c. Portland, Oregon area chamber location

**Providence Medical Center (monoplace chamber)  
Ask for Hyperbaric Chamber (503) 230-6061**

- d. U.S. Navy and Air Force bases often maintain hyperbaric chambers for use by military personnel. These chambers have been used by civilians in cases of emergency. However, they prefer that the general public not rely on their facility because civilian personnel will not be treated in lieu of military personnel requiring treatment. Also, if the case is not an emergency it will always be referred to civilian facilities when possible.

2. Secondary Treatment Facilities

Selection of chamber facilities not mentioned above should be considered carefully. A list of chambers is provided below in Part I.

- a. Double Lock Chambers

- (1) Select chamber facilities that are double lock with physician supervision immediately available and competent personnel to operate the facility.
- (2) If medical personnel are not immediately available, be sure the facility has adequate means to contact medical consultants.

- b. Single Lock or Monoplace Chambers

- (1) If a double lock chamber is not available, a monoplace chamber may be used if it is of the type, which is, compressed on 100% O<sub>2</sub> and medical supervision is available.
- (2) Other single lock chambers compressed on air are not recommended even for transportation.

- c. Other Chambers

Questions about types of chambers or location outside the Pacific Northwest can be answered through the DAN (919) 684-8111.



3. Once an ultimate destination is determined, either the party requesting transportation or the evacuating agency must:
  - a. Announce the impending arrival and Estimated Time of Arrival (ETA) to the receiving institution.
  - b. Choose a landing site or drop off point.
  - c. Request permission to land or dock.
  - d. Arrange for transport from drop off point to the receiving institution.
  - e. Inform customs and immigration if crossing an international border. Customs and immigration usually do not delay patient transport if this transport is carried out by a recognized transportation agency. During air evacuation, the pilot is responsible for contacting customs and immigration and this is usually done when a flight plan is filed.

#### E. TRANSPORTATION FROM DROP OFF SITE

Transport from landing, docking or other drop-off site to the final destination is usually handled by ambulance. It is normally the responsibility of the transporting agency to contact the ambulance company and arrange schedules. However, if one is not familiar with the local aid units, he or she may request assistance from the receiving hospital or institution.

Ambulance units for the Virginia Mason Hospital are:

Shepard Ambulance - (206) 322-0330  
(Under normal circumstances)

Medic II - 911  
(If condition is life-threatening or if electronic monitoring is required).

The VMH or Harborview Hospital (nearest helipad) often takes the responsibility of notifying the ambulance units.

#### F. MISSING DIVER

In the event of a missing University diver or presumed fatality, notify the appropriate law enforcement agency immediately, and organize a search. Do not undertake a search where weather, current, or depth conditions may compromise the safety of the search group. University personnel should not participate in the search and recovery group, unless specifically authorized. The DSO, Director, EH&S, and (if diving from there) the Director, FHL should be contacted. All diving equipment involved in a University diving accident shall be kept in an as-found condition and impounded for inspection and test.

## G. EMERGENCY TELEPHONE NUMBERS

University Police Department	(206) 543-9331 or 911
Seattle Fire/Aid and Police Department	911
King County Police (Sheriff)	911 or (206) 296-3311
Washington State Patrol	911 or (206) 455-7700
Virginia Mason Hospital (Emergency Room)	(206) 583-6433
Hyperbaric Unit 24-Hour Consultation	(206) 583-6543
U.S.C.G. Rescue Coord. Center, Washington, Oregon	(206) 220-7001
U.S.C.G. Rescue Coord. Center, Juneau, Alaska	(907) 463-2000
Rescue Coord. Center, British Columbia (Victoria)	(604) 363-2995
Divers Alert Network (DAN)	(919) 684-8111
U.W. Diving Safety Officer	(work) (206) 616-3776
	(cell) (208) 371-8977
Diving Medical Officer Dr. Edmond Kay	(Cell phone) (206) 954-3750
Director, Friday Harbor Laboratories (FHL) Billie Swalla	(206) 616-0764 (cell) (206) 769-6939
Director, Environmental Health & Safety (EH&S) Dr. Jude Van Buren	(206) 616-4146

## H. EMERGENCY RADIO FREQUENCIES

U.S. Coast Guard	VHF Channel 16
Canadian Coast Guard	HF Channel 16
Citizen Band (CB)	Channel 9

## I. RECOMPRESSION CHAMBERS

This listing of Pacific Northwest shore-based recompression chambers may change without notice. If planning dives in remote areas, always call to find out what chambers are operational near your dive site and what kind of transportation is available.

*Note: Always phone or radio ahead to be sure a chamber is available before transporting a diver to it.*

### **Primary sites of medical treatment for decompression sickness:**

#### Alaska

Anchorage Providence Hospital	(907) 562-2211
Bartlett Memorial Hospital, Juneau	(907) 586-2611
Dr. William Palmer	(907) 586-1895
Ketchikan General Hospital, Ketchikan	(907) 225-5171
Martech International, Anchorage	(907) 561-1970

#### British Columbia

Fleet Diving Unit Pacific, Victoria	(604) 388-1781
<b>Vancouver General Hospital, Vancouver</b>	<b>(604) 875-4111</b>

#### Oregon

<b>Providence Hospital, Portland</b>	<b>(503) 230-6061</b>
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Washington

Diver's Institute of Technology, Seattle (206) 783-5543  
USAF Regional Hospital (Emergency Room) (509) 247-5661  
Fairchild AFB, Spokane (Chamber) (509) 247-5406  
U.S. Naval Torpedo Station, Keyport (206) 396-2552  
(24 hrs) (206) 296-2551

**Virginia Mason Hospital, Seattle (206) 583-6543**

J. SPECIAL PROCEDURES FOR FRIDAY HARBOR LABORATORY

1. Unusual Symptoms

When divers have unidentifiable or unusual feelings/symptoms after diving, they should:

- a. Remain in the accompaniment of divers in case the symptoms become worse.
- b. Phone the Virginia Mason Hospital Emergency Room, Seattle or DAN to ask if the symptoms could be diving related and if treatment is needed.
- c. If oxygen and/or transportation and treatment are recommended contact the Diving Officer and Lab's Director.

2. Minor Symptoms

Follow all of the above steps but treat with oxygen as soon as possible.

3. Major Symptoms of Air Embolism or Decompression Sickness

The diver must receive immediate first aid treatment and transportation

- a. First aid treatment can be greatly assisted by the FHL Emergency Unit.
- b. For transportation, call the USCG RCC (206) 220-7001.
- c. Contact the Diving Officer, Lab's Director, and/or official. Also contact the University's EH&S SOC by calling the UWPD (206) 543-9331.

4. FHL Key Phone Numbers

Emergency	911 (360) 378-4141	FHL Office	(360) 378-2165
FHL Caretakers - Mike and Michelle Herko (Home) (360)378-3482 (Cell) (360) 298-0220			
Pema Kitaeff, FHL DO 206-543-0876 , (Cell) 206-349-9977			
Fred Ellis, Chief of FHL Maintenance (360)378-3491 UW 206-616-0756			
Kristy Kull, FHL Boating Officer 206-543-0876, (cell) (562) 972-6229			
Meegan Corcoran, Marine Operations Manager (cell) 360-929-9034			
Billie Swalla, FHL Director (206) 616-0764 (cell) (206) 769-6939			
Megan Dethier, FHL Associate Director (206) 543-8096. 360-298-2018			

### III. DIVING EMERGENCY EQUIPMENT LISTS

A first aid kit or assistance, emergency oxygen, and emergency communications shall be readily available at all dive sites. The type and amount of emergency equipment will vary depending on the length of time to medical assistance.

#### A. DIVER'S FIRST AID KIT CONTENT LIST

A first aid kit should be included in every diver's equipment gear bag. The suggested contents listed below are more appropriate for treating non-life threatening injuries and should be supplemented if emergency medical assistance is not readily available, as when operating in remote sites. (Contact the Occupational Health Nurse or the DSO for suggested items for remote diving.)

- \* Sterile compress pads (for severe bleeding)
- \* Roller gauze bandage 2 inch
- \* Assorted Band-Aids
- \* Adhesive tape 1 inch
- \* Assorted gauze pads (sterile)
- \* Triangular bandage
- \* Elasticized wrap
- \* Antiseptic soap
- \* Iodine prep pad
- \* Cold pack (liquid/crystal)
- \* Hot pack (liquid/crystal)
- \* Matches (water-proof/butane lighter)
- \* Scissors (bandage type)
- \* Tweezers
- \* Assorted pins and needles
- \* Small flashlight
- \* Decongestant
- \* Aspirin or Tylenol
- \* Fresh water (small bottle)
- \* Emergency phone numbers
- \* Pencil and paper (for notes)
- \* Money (for pay phones)

#### Optional items

- \* Sunscreen cream (with para-aminobenzoic acid)
- \* Chapstick
- \* Swimmers ear solution
- \* Sea sick pills
- \* Adolph's Meat Tenderizer
- \* Vinegar
- \* Blanket
- \* First Aid book
- \* Sea Snake Bite Antidote

## B. EMERGENCY OXYGEN KIT CHECK LIST

An emergency oxygen system shall be available on-site.

- \* Super or Jumbo D size oxygen cylinder
- \* Multi-Function Regulator
- \* Constant Flow Control
- \* Non-Rebreather mask
- \* Pocket Mask with Supplemental Oxygen Inlet
- \* Tru-Fit Mask
- \* Cylinder Wrench
- \* Equipment Manual
- \* Pencil and water proof paper (for notes)
- \* Emergency Field Management Flow Chart
- \* Demand Inhalator Valve

## C. EMERGENCY COMMUNICATIONS EQUIPMENT CHECK LIST

A telephone or VHF radio shall be available at each dive site. The effectiveness of portable cellular telephones and VHF radios are very dependent upon the unit's wattage. The U.S. Coast Guard recommends 6 watts for VHF radios for the best chance of successful reception. Even with this high wattage there will be dead spots where reception is not possible. This is also true for the cellular telephones and the higher 3 watt units are recommended. Both of these systems are very line of sight to the receiver or relay oriented. Functioning pay phones at the dive site are acceptable. More remote operations will require other communication systems that will need to be established or designed before the operations.

All communications systems should be tested at the dive site to assure that communications are possible. If the dive site is in a dead spot for all communications, then plans shall be developed and tested for an emergency move outside of the dead spot.

- \* VHF radio, 6 watt, Channel 16 plus at least one alternate channel; OR
  - \* Cellular telephone, 3 watt; OR
  - \* Pay telephone
- \* Telephone numbers for EMS, transportation, hyperbaric chamber, Diver Alert Network.

## APPENDIX 5

### UNIVERSITY OF WASHINGTON DIVING INJURY/INCIDENT REPORT

See <http://www.ehs.washington.edu/ohsoars/index.shtm> for instructions and the Online Accident Reporting System (OARS)

## APPENDIX 6

### VISITOR DIVING REGULATIONS

All visitors intending to engage in diving under University of Washington auspices must apply for and receive permission to dive from the:

**Dividing Safety Officer (DSO)** – William Love  
Environmental Health & Safety  
Box 357165  
1705 N.E. Pacific St  
Magnuson Health Sciences Center T-287  
Seattle, WA 98195  
Phone (206) 616-3776 or FAX (206) 221-3068  
E-mail [wlove@uw.edu](mailto:wlove@uw.edu)

Or

**Dividing Officer (DO)** – Pema Kitaeff  
Friday Harbor Laboratories  
620 University Rd.  
Friday Harbor, WA 98250  
Phone (206)543-0876 (360) 378-2165 or FAX 543-1273  
E-mail [pema@u.washington.edu](mailto:pema@u.washington.edu)

Visitors intending to engage in diving at the University's FHL must indicate this on their application forms and receive approval to dive.

In addition to receiving approval from the Marine Superintendent and vessel captain, visitors intending to engage in diving from University research vessels must complete their University diving certification process before arriving at the vessel.

Visiting divers, from an institution with a diving safety program that is in compliance with OSHA's requirements for commercial or scientific diving or is an organizational member of the American Academy of Underwater Sciences, may receive a reciprocity waiver of some of the certification requirements.

#### A. VISITING DIVER WITHOUT RECIPROCITY

Application - The applicant must provide written evidence of sponsorship by an appropriate University organizational unit. This should be accomplished at least 30 days prior to any diving activity.

Certified Diver Training - The applicant must provide evidence of diving proficiency for the intended diving activity. This evidence can usually be supplied by submitting the completed University Diving Registration and Consent Form (See Appendix 1), a copy of a recognized SCUBA certification card, and a copy of diving logs (last 12 dives).

Certified First Aid and CPR Training - The applicant must also provide evidence of training in First Aid including Oxygen administration for diving accidents and CPR.

Physical Examination - The applicant must also provide evidence of current physical fitness for diving equal to that required for the University diver (See Section 6). It is expected that this physical examination will be furnished by the applicant or by the applicant's parent institution.

The examination will be conducted using the information provided in Appendix 2, Information to Medical Personnel and using the history and examination forms found at the EH&S website <http://www.ehs.washington.edu/forms/index.shtm#topic> . If the physical examination is not completed before arrival or if the examination is incomplete then the applicant may arrange to complete the examination through the Occupational Health Nurse, the DO, or the DSO. In this event, the applicant should be prepared for a two-week processing time for the physical examination results.

Arrival and Check-Out - The applicant will present his credentials upon arrival at the University or its field station. If all documents are in order, the visitor will be informed of the requirements for diving in accordance with University regulations, and if not already accomplished, will execute the Diving Registration and the Consent and Understanding of Risk forms. The applicant will then complete a written exam (testing for basic SCUBA safety, diving related first aid and emergency procedures, and University diving operations) and an open water check-out dive (See <http://www.ehs.washington.edu/forms/index.shtm#topic> Forms for skills list).

## B. VISITING DIVER WITH RECIPROCITY

Application - The applicant must provide written evidence of sponsorship by an appropriate University organizational unit. This should be accomplished at least 30 days prior to any diving activity.

Scientific Diver Certification - The diver presents a card or letter indicating current scientific diver certification at the parent institution. This or attached document must indicate the date of the latest medical examination and be signed by the DSO or a member of the DCB.

Reciprocity - The diver has an AAUS Diving Reciprocity Form (Appendix 1) filled out and signed.

Arrival and Check-Out - Before or upon arrival at the University campus, University research vessel, or FHL, the visitor must present the reciprocity form plus proof of certification from the parent institution. The diver will then complete the Diving Registration and the Consent and Understanding of Risk forms, receive a brief orientation to the local environment, to shipboard operations and to the university safety procedures and, at the discretion of the DO, have an open water dive to review skills and rescue techniques.

## C. DIVING REGULATIONS AND PROCEDURES

Visiting divers must, at a minimum, adhere to regulations and procedures in the University of Washington Diving Safety Manual. Should there be a conflict between the requirements of the parent institution's and the UW's policy and procedure, this should be brought to the attention of the DSO or DO at FHL.

## D. DIVING EQUIPMENT

The University's regulations require that all equipment used by the visiting diver meet the regulations set forth in the Diving Safety Manual. Diving cylinders must bear registration numbers, current hydrostatic and internal inspection test dates. The diver should be equipped with an adequate personal flotation device, depth gauge, submersible pressure gauge, dive timer, knife, wet or dry suits, etc., as required for the particular diving activity and this environment.



## E. DIVE LOGS

All visiting divers will observe the University diving log out procedures and file logs of all dives under University auspices with the University vessel captain, the DO or the DSO before departing.

## APPENDIX 7

### AIR CONSUMPTION CALCULATIONS

Knowledge of the amount of air needed to successfully complete a task can be critically important. Projects may require task completion as part of the data validation or may require the use of air run equipment such as pneumatic roto hammers and core drills or air suction sampling or excavation dredging. A premature termination of the dive due to insufficient air supply can not only provide a risk to the divers, but also major time and data loss for the researcher.

Pacific Northwest field sites located at depths below 60 feet and where the bottom times approach the decompression limits are particularly susceptible, especially when many of the local field sites are almost always subject to currents resulting in the diver having to work harder to complete the task.

Calculating the needed volume of air is relatively uncomplicated for both the diver and the equipment. There are three components to consider in the calculation: the diver's or the tools typical air consumption rate, the maximum absolute pressure expected at the field site, and the internal volume and working pressure of the cylinder supplying the gas.

#### A. DIVER/TOOL CONSUMPTION RATES

By running a series of tests in conjunction with planned dives, each researcher will develop an average of the amount of air he/she will use conducting research dives. These tests are typically conducted by recording the cylinder pressure drop over a reasonable time interval (10 minutes is frequently recommended) while swimming or working at a fixed depth. This test is repeated a number of times to generate an average consumption rate. The NOAA Diving Manual also recommends testing at three cylinder pressures: high, middle, and low pressure ranges for a more accurate average.

In practice, the diver will note a starting pressure and dive time on an underwater slate and then make a similar notation ten or so minutes later. This test is supposed to be conducted at one depth, but this may not be possible on some field studies. For example: transect lines are frequently laid out with one end shallower than the other. In the case where the study requires a variation in depth the elapsed time for the test may need to be longer to have a more realistic task specific average rate. The fixed depth or in the other case the maximum depth must also be noted. The diver will then have an average consumption rate at that depth in psi gauge pressure per minute.

Calculating consumption rates at different ambient pressures based on the average consumption rate is relatively easy. Converting the average consumption rate at depth to an equivalent consumption rate at the surface will provide a value easily converted for any dive depth.

DEFINITIONS: Atm	Atmosphere
Ata	Atmosphere absolute
DRMV	Depth Respiratory Minute Volume
Psig	pounds per square inch gauge pressure
SRMV	Surface Respiratory Minute Volume

Example

$$\text{DRMV} = \frac{(\text{Your consumed pressure})}{(\text{Your elapsed time})} = \frac{\text{psig}}{\text{min}} > \frac{1000 \text{ psi}}{10 \text{ min}} = 100 \text{ psig/min}$$

$$\text{Ata (salt water)} = \frac{(\text{dive depth ft.})}{33 \text{ ft.}} + 1 \text{ Atm} > \frac{66 \text{ ft} + 1 \text{ Atm}}{33 \text{ ft}} = 3 \text{ ATM}$$

$$\text{Ata (fresh water)} = \frac{(\text{dive depth ft.})}{34 \text{ ft}} + 1 \text{ Atm} > \frac{66 \text{ ft} + 1 \text{ Atm}}{34 \text{ ft}} = 2.94 \text{ ATM}$$

$$\text{SRMV} = \frac{\text{DRMV}}{\text{Ata}} = \frac{\text{psig/min}}{\frac{\text{depth ft.} + 1}{33 \text{ ft}}} > \frac{100 \text{ psig/min}}{3 \text{ ATM}} = 33.3 \text{ psig/min}$$

The above information is commonly provided in basic SCUBA classes and is used to calculate the psi needed or consumed on a dive to a maximum depth. However what is commonly not communicated is that this average SRMV rate is specific for the cylinder used. For example: If the tests are conducted using a 3,000 psi 80 cubic foot cylinder, then the values are accurate only while using this type or size of cylinder. Many times only one type of cylinder is used by a diver and the SRMV in psi/min calculated above is all that is needed to calculate the volume in psi gauge that is needed for the dive.

$$\text{DRMV} = \text{SRMV} \times (\text{Ata at depth}) = (\text{SRMV}) \text{ psig/min} \times \frac{\text{depth ft.} + 1}{33 \text{ ft.}}$$

$$\text{Example: } 33.3 \text{ psig/min} \times \frac{66 \text{ ft.} + 1}{33 \text{ ft.}} = 100 \text{ psig/min}$$

$$\text{Available Bottom Time} = \frac{(3,000 - \text{reserve}^*) \text{ psig}}{\text{DRMV psig}}$$

$$\text{Example: } \frac{(3000 - 500) \text{ psig}}{100 \text{ psig/min}} = 25 \text{ min}$$

$$\text{Psig needed} = ((\text{DRMV}) \text{ psig/min} \times (\text{bottom time})) + (\text{reserve}^*) \text{ psig}$$

$$\text{Example: } (100 \text{ psig/min}) (25 \text{ min}) + (500 \text{ psig}) = 3000 \text{ psig}$$

\* 500 psig should be used as a cylinder reserve.

Tools and equipment supplied with or can be tested for psig/min consumption rates would also find the above calculations useful if the calculations were not tied to the cylinder type. Many tools are supplied with rates of cubic feet per minute at a specified psi.

The diver's consumption rate would also be more useful if it was not tied to a specific type of cylinder. This would permit the diver to have a reasonable expectation of the bottom time available when diving with different equipment to different depths. This can be accomplished by factoring in the test cylinder's internal volume while developing the average surface consumption rate, resulting in a consumption rate in cubic feet per minute.

- DEFINITIONS: Da - duration in minutes  
 Va - available volume in standard cubic feet  
 Cd - consumption at depth in standard cubic feet per minute  
 Ca - consumption at surface in standard cubic feet per minute

$$Cd \text{ (rate at depth)} = \text{DRMV psig/min} \times \frac{\text{(inter volume) cu. ft.}}{14.7 \text{ psig}}$$

Example:  $\frac{(100 \text{ psig/min})}{\text{ATM}} \times \frac{(.389) \text{ ** ft}^3}{14.7 \text{ psig}} = 2.65 \text{ ft}^3/\text{min}$

$$Ca \text{ (rate at surface)} = \text{SRMV} \frac{\text{psig}}{\text{min}} \times \frac{\text{(internal volume) cu. ft.}}{14.7 \text{ psig}}$$

Example:  $\frac{33.3 \text{ psig/min}}{1} \times \frac{(.389) \text{ ** ft}^3}{14.7 \text{ psig}} = .88 \text{ ft}^3/\text{min}$

The internal volume of a specific cylinder can be found in the table E-1 below.

The "C" rate in ft<sup>3</sup> can be used to calculate the SCUBA air supply duration in minutes by:

$$DA = \frac{Va}{Ca}$$

Example:  $\frac{79.87 \text{ **}}{88} = 90.76 \text{ min at Surface}$        $\frac{79.87 \text{ **}}{2.65} = 30.18 \text{ min at Depth (66 ft.)}$

\*\*from table E-1 for Alum 80.

Table E-1

## SCUBA CYLINDER VOLUME

ALLOY	LISTED VOLUME	SIZE CU.FT.	CU. FT. 10%O.F.	SERVICE PRESS.	OVER PRESS.	CUBIC FEET
Steel	15	14.24	15.65	3000	3300	.069
Alum.	14	14.06	-----	2015	-----	.102
Alum.	50	50.43	-----	3000	-----	.246
Steel	45	40.99	45.05	2015	2216	.297
Steel	38	37.86	-----	1000	-----	.307
Steel	42	38	41.77	1800	1980	.308
Steel	52.2	47.43	52.14	2250	2475	.308
Steel	53	47.43	52.14	2250	2475	.308
Alum.	63/50	63.13	-----	3000	-----	.308
Steel	71.4	65.15	71.55	2250	2475	.318
Alum.	72	72.39	-----	3000	-----	.353
Steel	55	44.79	49.79	1800	1980	.363
Alum.	80	79.87	-----	3000	-----	.389
Alum.	80	80.7	-----	3000	-----	.393
Steel	71.2	65.08	71.55	2250	2475	.422
Alum.	71.2	71.55	-----	2475	-----	.422
Steel	75.8	69.39	76.29	2400	2640	.422
Steel	94.6/96	86.63	95.25	3000	3300	.422
Steel	95.1	85.98	95.62	2400	2640	.529
Steel	104	96.01	105.55	2400	2640	.584

## APPENDIX 8

### DIVE TABLES AND DIVE COMPUTER WORKSHOP GUIDELINES

#### A. REPETITIVE DIVING TABLES

A set of dive tables, either the ones contained in this section or others approved by the DSO, are required at every dive site. *The following tables are from the U.S. Navy Air Decompression Table Handbook revised September 1995.*

##### U.S. NAVY REPETITIVE DIVE TABLES

The U.S. Navy 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 increase, they tend to be less accurate and require careful application." (U.S. Navy Diving Manual)

##### Rules during ascent

1. Always ascend at a rate of 30 fpm (20 seconds per 10 fsw). Minor variations in the rate of travel between 20 and 40 fsw/min are acceptable.
2. If the rate of ascent is greater than 30 fpm, Stop the Ascent and allow the time to catch up to your depth, then continue.
3. If the rate of ascent is less than 20 fpm, add the ascent time to the bottom time of the dive.

No Decompression Limits and Repetitive Group Designation Table for No-Decompression Air Dives																	
Depth ft.	Depth m	No D Limits	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10	3		60	120	210	300											
15	4.6		35	70	110	160	225	350									
20	6.1		25	50	75	100	135	180	240	325							
25	7.6		20	35	55	75	100	125	160	195	245	315					
30	9.1		15	30	45	60	75	95	120	145	170	205	250	310			
35	10.7	310	5	15	25	40	50	60	80	100	120	140	160	190	220	270	310
40	12.2	200	5	15	25	30	40	50	70	80	100	110	130	150	170	200	
50	15.2	100		10	15	25	30	40	50	60	70	80	90	100			
60	18.2	60		10	15	20	25	30	40	50	55	60					
70	21.3	50		5	10	15	20	30	35	40	45	50					
80	24.4	40		5	10	15	20	25	30	35	40						
90	27.4	30		5	10	12	15	20	25	30							
100	30.5	25		5	7	10	15	20	22	25							
110	33.5	20			5	10	13	15	20								
120	36.6	15			5	10	12	15									
130	39.6	10			5	8	10										
140	42.7	10			5	7	10										
150	45.7	5			5												
160	48.8	5				5											
170	51.8	5				5											
180	54.8	5				5											
190	59.9	5				5											

## Residual Nitrogen Timetable for Repetitive Air Dives

э																A	0:10 12:00																																
Locate the divers repetitive group from the previous dive along the diagonal line above the table. Read horizontally to the surface interval. Go vertically downward to the new group. Continue down to the depth or the repetitive dive. The time given is the Residual Nitrogen time to be applied to the repetitive dive.																э																B	0:10 3:20	0:10 3:21	1:40 12:00														
																э																C	0:10 1:39	1:40 4:49	1:40 12:00														
																э																D	0:10 1:09	1:10 2:38	1:40 5:48	1:40 12:00													
																э																E	0:10 0:54	0:55 1:57	1:40 3:24	1:40 6:34	1:40 12:00												
																э																F	0:10 0:45	0:46 1:29	1:30 2:28	1:40 3:58	1:40 7:06												
<b>Repetitive group at the beginning of the surface interval</b>																э																G	0:10 0:40	0:41 1:15	1:16 1:59	2:00 2:58	2:00 4:25	2:00 7:35	2:00 12:00										
э																э																H	0:10 0:36	0:37 1:06	1:07 1:41	1:42 2:24	1:42 3:20	1:42 4:49	1:42 8:00										
э																э																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	5:13 12:00							
э																э																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 8:50	5:41 12:00						
э																э																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	5:49 12:00					
э																э																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	4:36 9:12	4:36 12:00				
э																э																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	6:19 12:00			
э																э																N		0:10 0:24	0:25 0:39	0:40 0:54	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	6:33 12:00			
э																э																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 3:33	3:34 4:17	4:18 5:16	5:17 6:44	6:45 9:54	6:45 12:00		
э																э																Z		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	6:57 12:00
New Group \		Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A																																
Repet. Dive Depth Feet    Meters		□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□																																
10	3.0	**	**	**	**	**	**	**	**	**	**	**	**	279	159	88	39																																
20	6.1	**	**	**	**	**	**	**	399	279	208	159	120	88	62	39	18																																
30	9.1	**	**	469	349	279	229	190	159	132	109	88	70	54	39	25	12																																
40	12.2	257	241	213	187	161	138	116	101	87	73	61	49	37	25	17	7																																
50	15.2	169	160	142	124	111	99	87	76	66	56	47	38	29	21	13	6																																
60	18.2	122	117	107	97	88	79	70	61	52	44	36	30	24	17	11	5																																
70	21.3	100	96	87	80	72	64	57	50	43	37	31	26	20	15	9	4																																
80	24.4	84	80	73	68	61	54	48	43	38	32	28	23	18	13	8	4																																
90	27.4	73	70	64	58	53	47	43	38	33	29	24	20	16	11	7	3																																
100	30.5	64	62	57	52	48	43	38	34	30	26	22	18	14	10	7	3																																
110	33.5	57	55	51	47	42	38	34	31	27	24	20	16	13	10	6	3																																
120	36.6	52	50	46	43	39	35	32	28	25	21	18	15	12	9	6	3																																
130	39.6	46	44	40	38	35	31	28	25	22	19	16	13	11	8	6	3																																
140	42.7	42	40	38	35	32	29	26	23	20	18	15	12	10	7	5	2																																
150	45.7	40	38	35	32	30	27	24	22	19	17	14	12	9	7	5	2																																
160	48.8	37	36	33	31	28	26	23	20	18	16	13	11	9	6	4	2																																
170	51.8	35	34	31	29	26	24	22	19	17	15	12	10	8	6	4	2																																
180	54.8	32	31	29	27	25	22	20	18	16	14	11	10	8	6	4	2																																
190	59.9	31	30	28	26	24	21	19	17	15	13	10	10	8	6	4	2																																
** If no RNT is given then Repetitive Group has not changed and 2nd dive is considered a continuation of the first dive.																																																	
<b>Residual Nitrogen Times (Minutes)</b>																																																	

**Emergency Decompression Stops** - The following stops shall be made in the event the no-decompression limits are accidentally exceeded. All stops are to be made at 10 ft for the time prescribed.

Depth (fsw)	Bottom Time (min)	Decompression Time at 10fsw (min)/Group		Depth (fsw)	Bottom Time (min)	Decompression Time at 10 fsw (min)/Group
40	210	2 / N		100	30	3 / I
	230	7 / N			40	15 / K
	250	11 / O				
50	110	3 / L		110	25	3 / H
	120	5 / M			30	7 / J
	140	10 / M				
60	70	2 / K		120	20	2 / H
	80	7 / L			25	6 / I
	100	14 / M				
70	60	8 / K		130	15	1 / F
	70	14 / L			20	4 / H
	80	18 / M				
80	50	10 / K		140	15	2 / G
	60	17 / L			20	6 / I
	70	23 / M				
90	40	7 / J				
	50	18 / L				
	60	25 / M				



## DIVE COMPUTER GUIDELINES

1. Only those makes and models of Dive Computers specifically approved by the DCB may be used.
2. Any diver desiring the approval to use a Dive Computer as a means of determining decompression status must apply to the DCB, complete an appropriate practical training session and pass a written examination.
3. Each diver relying on a Dive Computer to plan dives and indicate or determine decompression status must have his/her own unit.
4. On any given dive, both divers in the buddy pair must follow the most conservative Dive Computer.
5. If the Dive Computer fails at any time during the dive, the dive must be terminated and appropriate surfacing procedures should be initiated immediately.
6. A diver should not dive for 18 hours before activating a new Dive Computer used it to control their diving. This is required to clear residual nitrogen, out of the diver's system, to match the zero nitrogen uptake of the new Dive Computer.
7. Once the Dive Computer is in use, it must not be switched off until it indicates complete out gassing has occurred or 18 hours have elapsed, whichever comes-first.
8. When using a Dive Computer, non emergency ascents are to be at a rate specified for the make and model of dive computer being used.
10. Whenever practical, divers using a Dive Computer should make a stop between 10 and 30 feet for 5 minutes, especially for dives below 60 fsw.
11. Multiple deep dives require special consideration.