The University of Michigan

Hyperbaric Chamber

Attendant's Handbook

THE UNIVERSITY OF MICHIGAN

Hyperbaric Chamber Attendant's Handbook

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PREFACE

The University of Michigan Hyperbaric Chamber Attendant's Handbook is intended to serve as a convenient guide for use in operating a hyperbaric chamber and in the treatment of diving casualties. The information in this handbook is condensed for quick reference. This handbook is patterned after the *U.S. Navy Recompression Chamber Operator's Handbook;* however, specific modifications have been made for compatibility with The University of Michigan facilities and civilian operational procedures. The primary sources of information for this handbook are the *U.S. Navy Diving Manual* (NAVSHIPS 0994-001-9010) and the *U.S. Navy Recompression Chamber Operator's Handbook* (NAVSHIPS 009-014-5010); portions of this handbook are quoted directly from these publications to insure accuracy and proper procedure. Consult these references for a complete discussion of this subject.

SECTION I: INTRODUCTION

The University of Michigan's hyperbaric chamber facility is located in 1038 G.G. Brown Building on the university's north campus. The primary functions of the facility are to provide emergency recompression treatment in support of university diving activities; support diver engineering and hyperbaric research; and serve as an educational aid in engineering, diving, and medical courses. In addition, the hyperbaric chamber is frequently used to treat casualties of commercial or sport diving activities and University Medical Center patients suffering from medical problems such as gangrene, carbon monoxide poisoning, and smoke inhalation. In the field, the chamber is used for routine surface decompression, diver evaluation, and diver training.

The present chamber was acquired by The University of Michigan Sea Grant Program's Underwater Operations Project with research funds granted by the National Sea Grant Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Continuing responsibility for operation and maintenance of the chamber is being undertaken by the Underwater Operations Project. The medical staff is provided by the Pulmonary Division of The University of Michigan Medical Center. Trained medical and technical personnel are on call 24 hours a day for handling emergencies.

Since the function of the hyperbaric chamber facility involves emergency medical treatment, the facility should be prepared for initiation of treatment on short notice. Personnel trained and qualified to conduct recompression treatment must be made available at all times. In order to maintain a sufficient number of trained and qualified personnel for chamber operation, the Michigan Sea Grant Program's Underwater Operations Project sponsors several Hyperbaric Chamber Attendant's Training Courses annually. Trainees receive instruction in special first-aid procedures, chamber operation, reading decompression and treatment tables, simulated treatment of diving accidents, handling oxygen, chamber maintenance, chamber safety procedures, and associated topics. The course staff includes the university's hyperbaric physicians and trained chamber operators.

The hyperbaric chamber must be maintained ready for immediate use. After each use, it must be closely checked, cleaned, and reconditioned as necessary. Pre-dive and post-dive maintenance procedures are discussed in this handbook.

In conducting a recompression treatment, all attending personnel must work as a team for the benefit of the patient. Outside attendants normally control descent, operate the chamber, monitor the time and depth, and maintain communications with inside personnel. The physician may accompany the patient or he may designate a medical technician or chamber attendant to monitor the patient inside the chamber. The overall treatment is coordinated by the senior member of the team who is designated as the chamber supervisor.

Effective recompression treatment requires that every member of the team be thoroughly trained and proficient in the performance of his duties. It is desirable that all members of the non-medical team be able to carry out all duties associated with the operation of the chamber.

PERSONNEL REQUIREMENTS

The number of people required to run the chamber varies slightly according to its use. However, the minimum team necessary to conduct any hyperbaric chamber operation involving placement of personnel under pressure consists of the following members:

Chamber Attendant No. 1 – responsible for operation of the gas supplies, pressurization, ventilation, and decompression; stationed outside;

Chamber Attendant No. 2 – responsible for keeping individual and overall times on the operation, maintaining a complete record, and communicating with personnel inside the chamber;

Chamber Supervisor – completely in charge at the scene of operation.

When the number of qualified personnel available is limited, the Chamber Supervisor may assume the responsibilities of one of the attendants. In some cases, the physician may also assume the role of Chamber Supervisor. It is necessary, however, to emphasize that at least *two* qualified individuals must be in attendance *outside* the chamber, and that one individual must assume the responsibility of Chamber Supervisor whenever personnel are under pressure in the chamber.

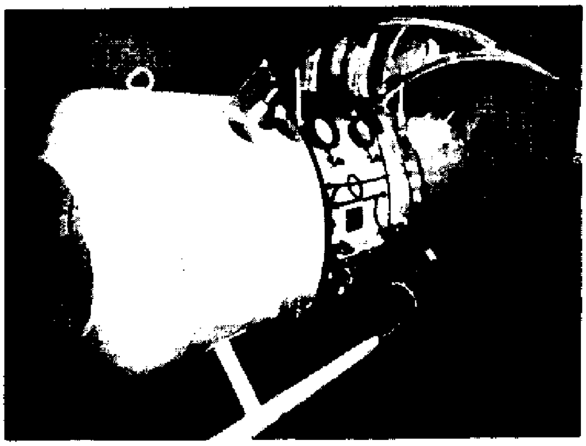
During treatment of diving accident victims and other therapeutic applications, a physician familiar with hyperbaric medicine must be in attendance either inside or outside the chamber. The physician, if stationed outside the chamber, may assume the responsibilities of one of the designated chamber attendants or the Chamber Supervisor, if he is so qualified and no other personnel are available. In addition, patients must be accompanied *inside* the chamber by a physician, medical technician, or other individual designated by the on-site physician.

When pressurizing personnel for research, training, or demonstration purposes, it is desirable to use an *Inside Attendant* who is familiar with the diagnosis of diving-related sicknesses and monitors the chamber occupants. At Navy facilities the Inside Tender usually pressurizes and depressurizes the chamber by using inside valving. However, a number of civilian chambers, such as the university's, are not equipped with inside valving, and the outside attendant assumes this responsibility.

When pressurizing personnel for non-medical purposes, a qualified physician must be "on-call" to provide medical assistance or consultation if required. The Chamber Supervisor, a Diving Coordinator, or a Diving Safety Committee may request the physician's presence at the chamber for specific activities.

CHAMBER DESCRIPTION

The University of Michigan's 12-foot, cylindrical, two-compartment chamber has an outside diameter of 54 in and can accommodate a patient and attendant or up to five students in its 7.5 ft inner compartment (Fig. 1). It is equipped with an oxygen breathing-overboard discharge system, portable oxygen analyzer, external lighting and USCG approved phones for communications. An outer compartment allows transfer of personnel and medical supplies without affecting



the inner compartment's pressure. The chamber is constructed in accordance with appropriate ASME codes for unfired pressure vessels and is U.S. Coast Guard certified. The chamber has a working pressure of 130 psi or 292.5 ft of sea water and is hydrostatically tested to 1.5 times the working pressure. The 5000 lb chamber is skid mounted and fitted with a control panel cover, oxygen cylinder rack, and lifting pad-eyes for portability.

A variety of chambers are available for both civilian and U.S. Navy use. Chambers will vary in size, piping, working pressure, materials, accessories, and air or gas supply systems. All chambers should be constructed to at least the minimum standards designated in appropriate ASME codes. Those used on vessels or installations falling under USCG jurisdiction must be USCG approved. Chambers at U.S. Navy facilities are constructed in accordance with specific military specifications and must be certified by appropriate U.S. Navy and/or government agencies. For details on U.S. Navy hyperbaric facilities consult U.S. Navy (1970a, 1970b, 1972, 1973).

In civilian hyperbaric chamber facilities there will be considerable variation in chamber design, piping, and gas supply systems. Consequently, each facility is responsible for preparing appropriate training and operational materials. This handbook will discuss the specific operation of the University of Michigan's two-compartment hyperbaric chamber. It may serve as a guide for other facilities in preparation of similar handbooks.

GAS SUPPLY SYSTEM

Primary air for pressurization and ventilation of the chamber is provided by two high-capacity, low-pressure electric air compressors (550 cfm, 100 psi each) and emergency air is contained in a series of high-pressure cylinders (18-300 cf cylinders). When the chamber is used in the field, it is supplied by a high-capacity, low-pressure portable air compressor and/or a high-capacity, high-pressure compressor, and a series of high-pressure cylinders; adequate emergency air is maintained in high-pressure cylinders. Medical oxygen (USP) is supplied from a cylinder mounted in a rack on the chamber. At least two, 220 cf cylinders of medical oxygen are retained as a reserve supply.

TERMINOLOGY AND SYMBOLS

Terminology used in this handbook is based on that commonly used by divers and chamber attendants.

Units of measure are generally expressed in the U.S. Customary System; international (metric) system conversion factors are given below. The following symbols will be used in this handbook:

Symbol	*Unit*
cf	cubic feet
cfm	cubic feet per minute
scf	standard cubic feet
scfm	standard cubic feet per minute
acfm	actual cubic feet per minute
psi	pounds per square inch
psig	pounds per square inch, gauge
fsw	feet sea water
fpm	feet per minute
atm	atmospheres
ata	atmospheres absolute

The conversion of commonly used U.S. units to international (metric) units is as follows:

U.S. Units		*Metric Unit*
1 cubic foot	=	28.317 liters (ℓ)
	=	0.28317 cubic meters (m^3)
1 psi	=	70.3 gm/cm^2
	=	0.0703 kg/cm^2

The conversion of commonly used U.S. units to other U.S. units is as follows:

1 atmosphere (atm)	=	33 fsw
	=	14.7 psi
	=	760 mmHg

The term "standard cubic feet" refers to the number of cubic feet of gas measured at a pressure of one atmosphere and temperature of 0°F. "Actual cubic feet" refers to the number of cubic feet measured at chamber pressure.

SECTION II: CHAMBER OPERATION

Prior to every operation of the chamber, a predive check of the facility must be conducted. This procedure should take only a few minutes, provided that the personnel are experienced and the chamber is properly maintained. The patient and attendant enter the chamber and treatment is initiated only after the facility is checked. If personnel must enter or leave the chamber during treatment, the procedures discussed at the end of this section should be followed.

PRE–DIVE CHECKLIST

Chamber

- Clean
- Free of all extraneous equipment
- Free of noxious odors
- Doors and seals undamaged, seals lubricated
- Pressure gauges inspected or calibrated within 12 months (check inspection tag or label)
- Power on

Air Supply System (Fig. 2, 3, 4)

- Primary air supply operational (see Appendix B)
- Secondary air supply operational and regulator set at 200 psi
- Secondary air supply adequate for one pressurization and one hour of ventilation at maximum required rate
- Filter by-pass valve–closed
- Primary air system supply valve–open
- Bleed moisture separator on filter system
- Primary chamber supply valve–open
- Inner and outer compartment supply valves–closed
- Equalization valve–closed (if so equipped; not on UofM chamber)
- Inside emergency chamber exhaust valve–closed
- Outside emergency chamber exhaust valve–open
- Fittings clean
- Filter clean (check chamber log)

A piping schematic of a typical U.S. Navy chamber air supply exhaust system is shown in Figure 5 for comparison.

Exhaust System

- Terminates clear of chamber
- Mufflers attached
- Exhaust valves–closed

Oxygen Supply System (Fig. 6)

- Cylinder full; marked as breathing or medical oxygen (USP); cylinder valve–open
- Replacement cylinder on hand
- Oxygen masks (or inhalators) installed and functioning
- Regulator set at 75 psig
- Fittings tight

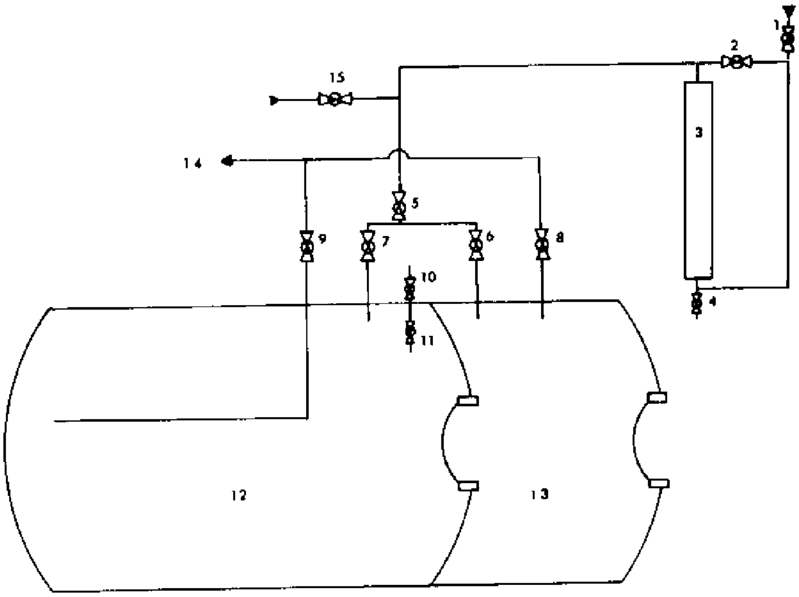


Figure 2 Piping schematic of University of Michigan chamber air supply and exhaust system.

(1) Primary air supply valve, (2) Filter by-pass valve, (3) Filter, (4) Filter bleeder valve, (5) Chamber master air supply valve, (6) Outer compartment air supply valve, (7) Inner compartment air supply valve, (8) Outer compartment exhaust valve, (9) Inner compartment exhause valve, (10) Outside emergency exhaust valve, (11) Inside emergency exhaust valve, (12) Inner compartment, (13) Outer compartment, (14) Exhaust pipe and muffler, (15) Emergency air supply valve.

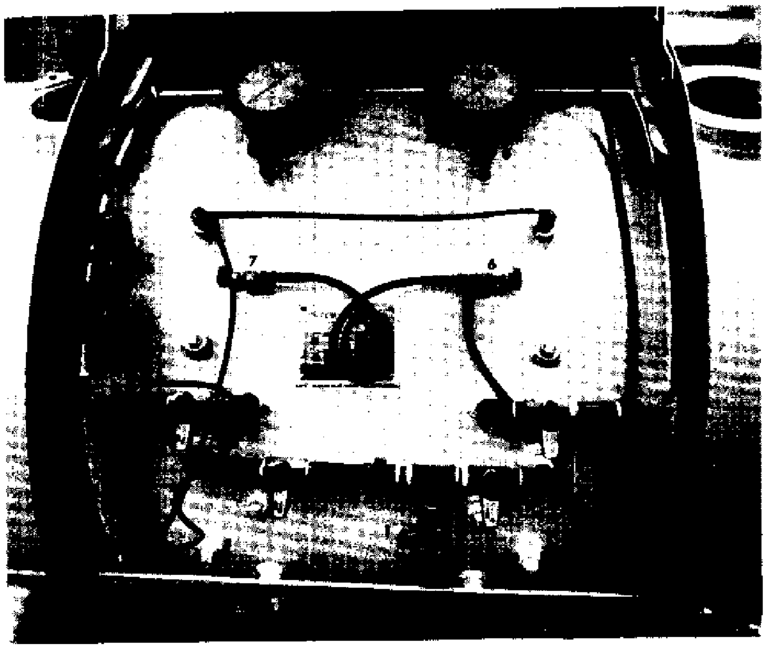


Figure 3 Control panel of University of Michigan chamber.

(1) Chamber master air supply valve, (2) Inner compartment air supply valve, (3) Outer compartment air supply valve, (4) Inner compartment exhaust valve, (5) Outer compartment exhaust valve, (6) Inner compartment oxygen supply valve, (7) Outer compartment oxygen supply valve, (8) Inner compartment pressure gauge, (9) Outer compartment pressure gauge, (10) Sound-powered telephone, (11) Light switch.

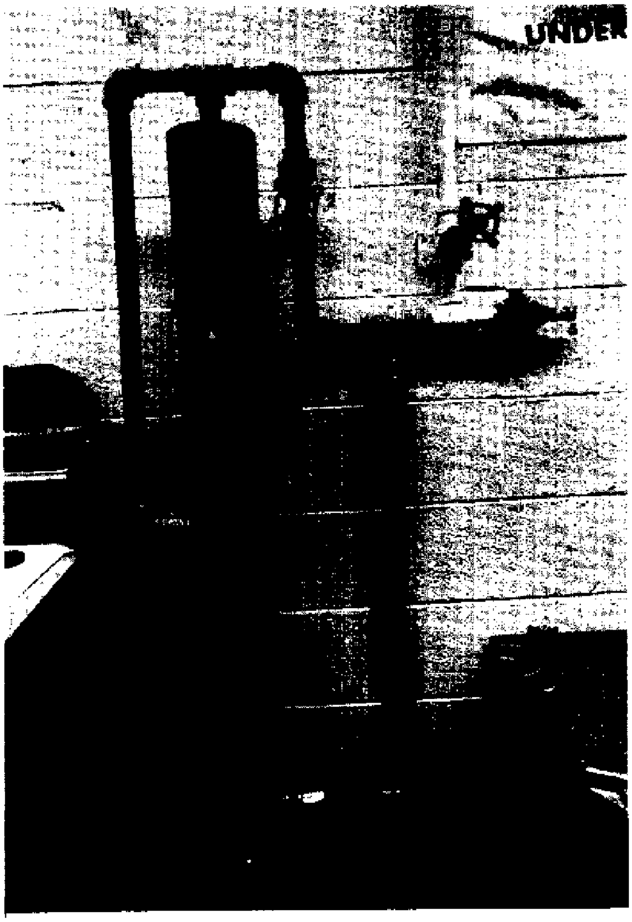


Figure 4 Air Supply—Filter Unit.

(1) Primary air supply valve, (2) Filter by-pass valve, (3) Filter, (4) Filter bleeder valve, (5) Fitting for connection of portable emergency air supply.

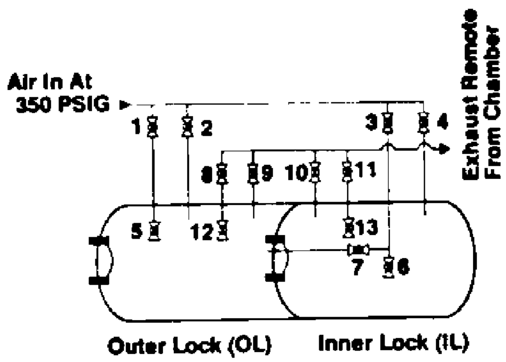


Figure 5 U.S. Navy chamber piping schematic. Air supply and exhaust system.

(1) Two-valve air supply, outside valve (OL), (2) One-valve air supply (OL), (3) Two-valve air supply, outside valve (IL), (4) One-valve air supply (IL), (5) Two-valve air supply, inside valve (OL), (6) Two-valve air supply, inside valve (IL), (7) Inner/outer lock equalization valve, (8) Two-valve exhaust, outside valve (OL), (9) One-valve exhaust (OL), (10) One-valve exhaust (IL), (11) Two-valve exhaust, outside valve (IL), (12) Two-valve exhaust, inner valve (OL), (13) Two-valve exhaust, inner valve (IL). (U.S. Navy, 1973)

FIGURE 6

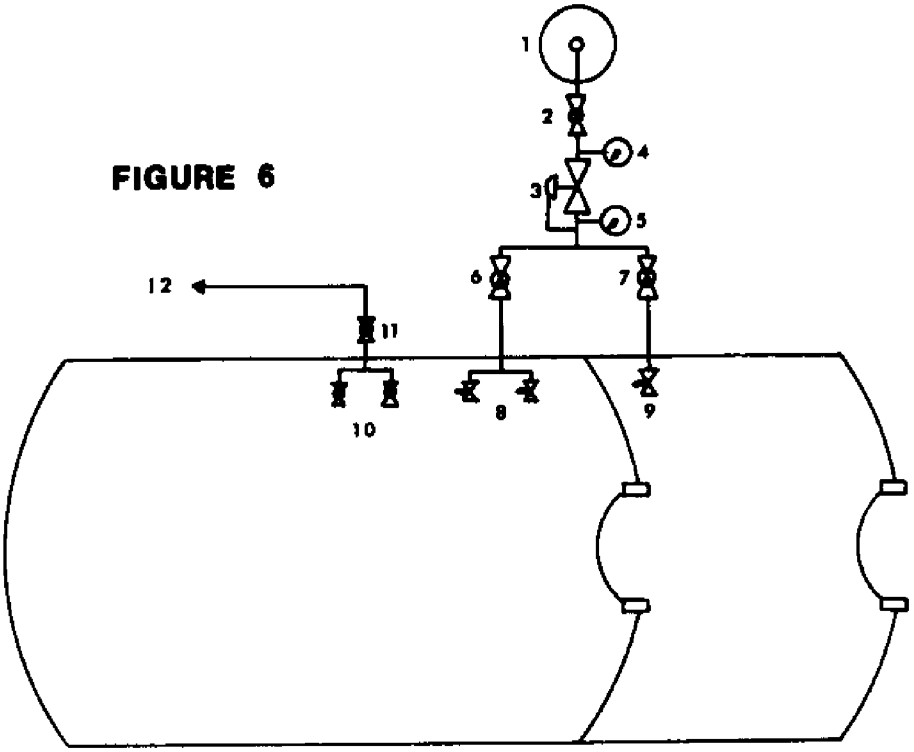


Figure 6 Piping schematic of University of Michigan Chamber's oxygen supply and exhaust system.

(1) "Breathing Oxygen" high pressure cylinders, (2) Oxygen cylinder valve, (3) Oxygen regulator, (4) High pressure oxygen gauge, (5) Low pressure oxygen gauge, (6) Inner compartment outside oxygen supply valve, (7) Outer compartment outside oxygen supply valve, (8) Oxygen manifold valves, inner compartment, (9) Oxygen manifold valve, outer compartment, (10) Oxygen exhaust valve manifold, (11) Oxygen exhaust outside valve, (12) Oxygen exhaust.

Figure 7 U.S. Navy chamber piping schematic: Oxygen and helium-oxygen supply system.

(1) "Breathing Oxygen" high-pressure cylinders, (2) Oxygen cylinder valve, (3) Cylinder location valve, (4) Oxygen regulator (75 psig), (5) Oxygen manifold valves (inner lock), (6) Oxygen manifold valves (outer lock), (7) 80% helium–20% oxygen high-pressure cylinders, (8) He–O_2 cylinder valve, (9) He–O_2 regulator (75 psig), (10) He–O_2 manifold valves (inner lock), (11) He–O_2 manifold valves (outer lock), (12) Oxygen supply gauge, (13) He–O_2 supply gauge (U.S. Navy, 1973).

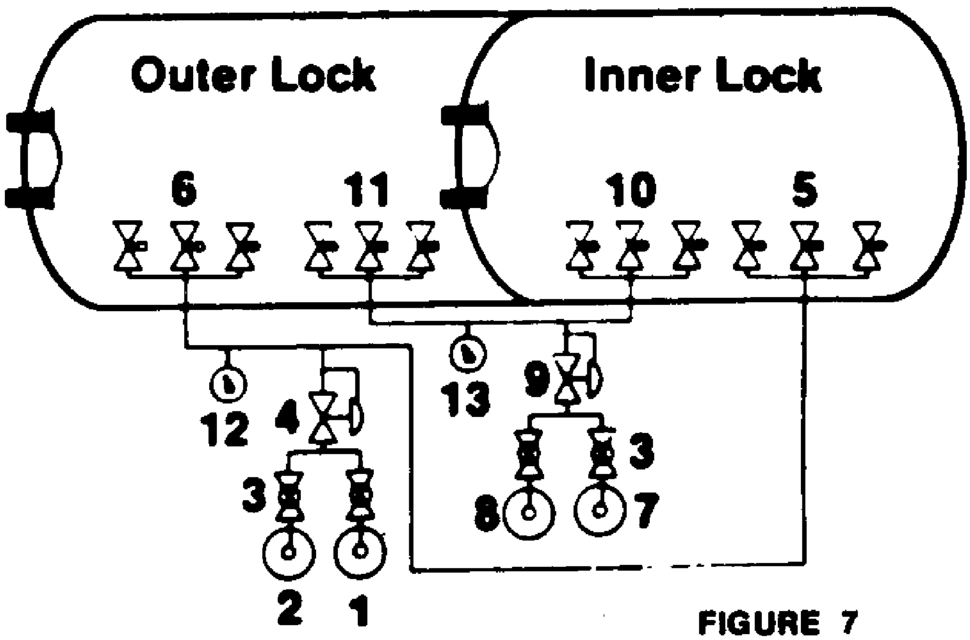


FIGURE 7

- Oxygen manifold valves closed
- Overboard discharge valves closed

A piping schematic of a typical U.S. Navy chamber oxygen and oxygen-helium supply system is shown in Figure 7 for comparison.

Electrical System

- Power to chamber—on
- Lights operational

Communications Systems

- All phones operational

Fire Prevention System

- Proper extinguisher or sand and water container in chamber
- Fire-resistant mattress and blankets in chamber
- Minimum amount of combustible material in chamber; preferably enclosed in metal container
- Fire-resistant clothing worn by all chamber occupants (if possible)
- No visible signs of oil in chamber

Miscellaneous—Inside Chamber

- Primary medical kit
- Additional medical equipment and supplies as required by physician
- Ear protectors for noise
- Oxygen analyzer (when oxygen is to be used; if initial depth exceeds 66 fsw, the analyzer should be locked in at depth oxygen is to be used
- Emergency light (check batteries)

Miscellaneous—Outside Chamber

- Stopwatches
  - –Cumulative time
  - –Treatment time
  - Decompression time personnel leaving chamber
  - –Spare
- Treatment tables
- Decompression tables
- Record book or sheets
- Additional medical supplies
- Appropriate containers for body waste- may be locked in as needed
- Paper and pencils
- Emergency room lighting
- Display "NO SMOKING- OXYGEN IN USE" sign on chamber room door and on the chamber.

TENDING THE PATIENT

When conducting a recompression treatment, the inside attendant will generally be a physician, medical technician, or other person familiar with advanced first aid and diving accidents. The inside attendant must be familiar with all treatment procedures and signs, symptoms, and treatment of all diving-related sicknesses.

The inside attendant insures that the patient is lying down in a position which permits free blood circulation to all his extremities. He will close the chamber door and signal the outside attendant to begin pressurization at the normal rate:

Decompression Sickness—pain only (Type I) or serious symptons (Type II)--25 fpm.
Gas Embolism—as fast as possible.

The inside attendant will monitor the patient's condition during the descent. It may be necessary for him to request that the rate be decreased to allow the patient to equalize. If the patient is not a trained diver, it will be necessary to instruct him in equalization methods prior to pressurization. If the patient is unconscious or unable to equalize, the physician may elect to perform a myringotomy (perforate the eardrums) prior to or during pressurization. In order to simplify communication procedures, the inside and outside attendants generally agree on basic hand signals. Normally, if the inside attendant holds up a clinched fist, he is requesting the outside attendant to stop pressurization in order to allow the occupant's ears to equalize. The standard diver's "OK" hand signal means resume pressurization. The outside attendant will adjust the rate of pressurization in accordance with the degree of difficulty experienced by the occupants.

During the phases of treatment, the inside attendant must constantly watch for signs of relief of the patient's symptoms. Drugs which will mask the signs of the patient's sickness should be avoided. Observation of these signs is the principal method of diagnosing the patient's sickness and the depth and time of their relief designates the treatment table to be used. All observations should be reported to and recorded by the outside attendant. *The final recommendation as to which treatment table should be used must be made by the attending physician. Once the treatment has been prescribed, it may be altered only by the attending physician.*

During decompression of the patient, the inside attendant may breathe oxygen beginning at the 40 ft stop. If Table 5, 5A, 6, or 6A is used, the attendant normally breathes air throughout the treatment. If the treatment involves a repetitive dive for the attendant or if Table 6 or 6A are lengthened during treatment, the attendant must breathe oxygen during the last 30 min of treatment.

Other responsibilities of the inside attendant include:

- Communication with outside personnel
- Observing the patient for signs of oxygen toxicity
- Providing first aid as required by the patient
- Providing normal assistance to the chamber as required
- Administering oxygen
- Maintaining a clean chamber
- Transferring body waste as required

PATIENT EXAMINATION

Normally the patient will be examined in the hospital or outside the chamber by the attending physician prior to pressurization. When the sickness is in question, or when serious symptoms or signs of gas embolism are present, treatment may be started immediately. The patient, in this situation, is examined inside the chamber. The minimum examination includes:

1. A discussion with the patient to determine the cause of the accident, how he feels, and his general psychological responses.
2. Testing the patients
   - eyesight
   - hearing
   - reflexes
   - muscular coordination
   - strength
   - balance
   - pulse rate
   - blood pressure
   - respiration rate

TENDING THE CHAMBER

The outside attendants are responsible for:

- Maintaining and controlling the air supply to the chamber
- Maintaining the oxygen supply to the chamber
- Keeping times on all phases of the treatment (descent, stops, ascent, overall treatment)
- Keeping a complete record of the treatment
- Communicating with inside personnel
- Pressurizing and decompressing personnel entering and leaving the chamber during treatment
- Pressurizing and depressurizing the chamber
- Ventilating the chamber
- Monitoring the oxygen level in the chamber
- Monitoring the amount of remaining oxygen
- Monitoring continually the chamber gauges and decompression stops
- Operating the medical lock (if available)

Regulator Settings

When the primary air supply is high-pressure air from storage cylinders, a high-flow capacity regulator is used to reduce the air from cylinder pressure to chamber pressure. The air supply regulator should be set to maintain a minimum supply pressure of 50 psig over the maximum chamber pressure. A setting of 350 psig is considered ideal for air supplied from high pressure air cylinders. Regulator settings for the oxygen supplies are dependent on the inhalators installed in the chamber. Most inhalators should be supplied with gas between 75 and 100 psig over the chamber pressure. If the patient is experiencing difficulty breathing, the pressure may be adjusted upon the request of the inside attendant.

Chamber Ventilation

Ventilation of the chamber with fresh air is necessary to maintain safe levels of carbon dioxide and oxygen inside the chamber. The rates at which air must be circulated through the chamber depend on the number of personnel inside the chamber, their level of activity, and the gas which they are breathing. The size of the chamber does not influence the amount of air required for ventilation. Note that increasing depth increases the actual mass of air required for chamber ventilation; however, when the amount of air is expressed in volumes as measured at chamber pressure, increasing pressure does not change the number of cubic feet required. The following rules apply (all volumes are expressed in cfm as measured at chamber pressure):

1. When breathing air or helium-oxygen in the chamber
   a. 2 cfm for each person at rest
   b. 4 cfm for each person not at rest
2. When breathing oxygen by mask in the chamber (no overboard discharge system)
   a. 12.5 cfm for each person at rest
   b. 25.0 cfm for each person not at rest
   c. No additional ventilation for each man not breathing oxygen
3. When breathing oxygen by mask in a chamber with an overboard discharge system installed use ventilation rates for air breathing.

4. When breathing oxygen by mask in a chamber with oxygen monitoring equipment available, ventilate as required to maintain oxygen concentrations in the chamber below 25 percent.

5. When ventilation is interrupted
   a. Not to exceed 5 minutes during any 30 minute period
   b. When resumed, twice the required cfm for twice the period of interruption, then resume normal rate.

The ventilation requirements for normal chamber operations are as follows (assuming one sedate patient and one active attendant):

CHAMBER DEPTH (FSW)	VENTILATION RATE (ACFM)	(SCFM)
165	6	36
140	6	31
120	6	29
100	6	24
80	6	21
60 (air)	6	17
60 (O_2)	12.5	35
50 (air)	6	15
50 (O_2)	12.5	31
40 (air)	6	13
40 (O_2)	12.5	28
30 (air)	6	12
30 (O_2)	12.5	24
20 (air)	6	10
20 (O_2)	12.5	20
10 (air)	6	9
10 (O_2)	12.5	16

When decompressing from 60 to 30 FSW and 30 to 0 FSW on Table 5, 6, 5A, or 6A, use the approximate rate for the nearest depth given on the above table.

Constant ventilation is by far the most effective method of ventilation in terms of the amount of air required for ventilation. However, it has the disadvantage of exposing the chamber occupants to a constant source of noise. At the high ventilation rates required for oxygen breathing, this noise can reach the ranges where hearing damage may become a real hazard for the chamber occupants. Most chambers are equipped with baffle systems or mufflers to reduce the noise to a minimum. If high noise levels do occur, especially during exceptionally high ventilation rates, the occupants of the chamber should be required to wear ear protectors. In some model ear protectors it may be necessary to drill a small hole in the central cavity to prevent sealing around the ear which could cause an ear squeeze.

As an alternative to constant ventilation procedures recommended by the U.S. Navy, civilian and commercial divers or chamber attendants frequently use a very high ventilation rate for one or two minutes out of every five minutes. The length of ventilation time per five minute period will depend on the capacity of the air supply system, the gas being breathed in the chamber, and the activity level of the occupants. Most individuals find the periodic ventilation scheme desirable over constant ventilation from a standpoint of comfort. It should, however, be used with discretion and an oxygen monitoring device is highly recommended to insure that oxygen concentrations do not exceed 25 percent.

The above rules for chamber ventilation are not intended to limit ventilation. If air is reasonably plentiful, more air than specified should generally be used to insure lower concentrations of carbon dioxide and oxygen. There is seldom any danger of having too little oxygen in the chamber. Even with no ventilation and a high carbon dioxide level, the oxygen present will be adequate for a long time. The rules given also assume that air circulation in the chamber is reasonably good during ventilation. Having the inlet near one end and the outlet near the other end helps promote good ventilation.

The quantity of air ventilated through the chamber is controlled by regulating the precalibrated exhaust valve outside the chamber (see APPENDIX C for calibration procedure) or by a flow meter. Once the air supply rate is established, the air supply valve is regulated to maintain a constant chamber pressure.

Entering and Leaving the Chamber During Treatment

During extensive treatments, medical personnel may prefer to periodically lock into the chamber to examine the patient or administer medication and then come back out, rather than remain inside throughout the treatment. Also, inside attendants may fatigue and need relief. This procedure is only possible with two compartment chambers.

In operation the outer compartment of a two-compartment chamber is kept at atmospheric pressure while the patient and attendant are inside the inner compartment. Personnel entering the chamber go into the outer lock and securely close the door. The outer compartment is then pressurized at a rate controlled by the occupant's ability to equalize, but not to exceed 75 fpm. The outside attendant must record the time that pressurization begins in order to determine the decompression schedule for these personnel when they are ready to leave the chamber. When the pressure in the outer and inner compartments is equal, the inside door will open.

To leave the chamber, the personnel again enter the outer lock and the inside attendant closes and secures the door. When they are ready to start the ascent, one outside attendant records the time and consults the U.S. Navy Standard Air Decompression Tables. The other outside attendant then begins to slowly depressurize the outer compartment. Constant observation or communication is maintained with the inside attendant to insure that a seal has been made on the inner door. The outside attendant may also determine if the inner door is sealing properly by simultaneously monitoring the depth gauges of both compartments. If the inner compartment gauge starts to drop, then the door isn't sealed and depressurization must be stopped. Outer lock pressure is controlled through decompression by the outside attendant.

Some chambers are also equipped with a small medical lock or compartment for the purpose of transferring medical supplies, food, liquids, and waste into and out of the pressurized chamber. In small chambers such as the university's, the outer compartment may be used for this purpose.

The medical compartment generally consists of a cylindrical pressure shell with doors hinged on either end. Two valves penetrate the lock which permits it to be equalized with either chamber pressure or atmospheric pressure.

To load the medical compartment the outside attendant requests that the inside attendant close the inside valve and open the outside valve to insure that the compartment is depressurized. Then he opens the outside door, places the material in the compartment and closes and bolts the door. The inner door, at this time, is sealed shut by the internal pressure of the chamber. The outside attendant then closes the outside valve and informs the inside attendant that the compartment is ready for pressurization. The inside attendant releases the inner door latch and opens the inside valve which allows pressurization of the compartment with chamber air. Under normal conditions the compartment should be pressurized slowly (approximately 25 fpm to minimize the latent heat buildup and loss due to the heat of compression and expansion.

When the compartment pressure equals the chamber pressure, the inside door will unseal and can be opened. To pass materials out of the chamber, the procedure is reversed.

POST-DIVE MAINTENANCE CHECKLIST

Chamber

- Clean inside with vegetable base soap and warm fresh water and wipe dry
- Remove all but necessary support items from chamber
- Clean and lubricate door seals and seats
- Check viewports for damage; replace as necessary
- Open exhaust valves and secure exhaust systems
- Air out chamber
- Close outer door

Air Supply System

- Close all air supply lines to chamber
- Shut down primary air compressors and refuel (if required)
- Inspect primary air system and report repair or maintenance requirements to proper authorities
- Deactivate regulators and bleed air from lines of high-pressure systems (as required)
- Record filter time in appropriate book
- Change filter materials, if necessary
- Recharge high-pressure cylinders and record pressure of air in bank

Oxygen Supply System

- Close cylinder valves
- Bleed lines and deactivate regulator
- Replace empty oxygen cylinders, as required, with "BREATHING OXYGEN"
- Insure that spare full oxygen cylinders are available
- Remove oxygen inhalators from the chamber
- Wash and disinfect oxygen masks
- Close oxygen supply and overboard discharge valves

Electrical and Communications System

- Power to chamber—off
- Secure phones
- Check for damage to wiring, pressure-proof light housing, etc.
- Replace light bulbs as necessary

Fire Prevention System

- Secure fire extinguishing equipment
- Clean and dry blankets, mattresses and clothing
- Encase all flammable materials in chamber in fire resistant container

Miscellaneous

- Initiate repairs or replacement as required
- Stow ear protectors

- Replenish consumables
- Restock and stow medical kit
- Stow oxygen analyzer
- Allow stop watches to run down and stow
- Enter records in appropriate books or files; stow record books
- Stow decompression and treatment tables
- Clean and stow containers for body waste
- Replace batteries in portable emergency light
- Replenish paper and pencil supply at control desk.

SAFETY PRECAUTIONS FOR CHAMBER OPERATION

1. Take all precautions against fire.
2. Provide fire extinguishing equipment or materials inside the chamber.
3. Use fire retardant and nonstatic materials in the chamber when possible.
4. Ventilate the chamber according to specified rates and gas mixtures.
5. Remain alert for the symptoms and signs of oxygen toxicity:
   - Vision abnormality (such as "tunnel vision")
   - Hearing abnormality
   - Nausea
   - Twitching (usually in lips or other facial muscles, but may affect any muscle; the most frequent and clearest sign of oxygen toxicity)
   - Irritability (or behavior changes)
   - Dizziness
   - Convulsions
6. Assure proper decompression of all personnel leaving the chamber before treatment is completed
7. Insure that the chamber and its auxiliary equipment are in operational condition at all times.
8. Insure that all personnel are trained in the operation of the equipment and are available to do any job required in treatment.
9. Prepare the chamber for immediate reuse following a treatment.
10. Do not use oil on any oxygen fitting or piece of chamber equipment.
11. Maintain all gas supply cylinders full.
12. Avoid damage to the doors and seals.
13. Never allow open flame, matches, cigarette lighters, or pipes to be carried into the chamber.
14. Prohibit the use of electrical appliances in the chamber unless the unit is specially designed for use in hyperbaric oxygen environments.

SECTION III: RECOMPRESSION TREATMENT

This section provides information useful in diagnosing and treating decompression sickness, gas embolism, and other emergency medical problems. The first step of any treatment involves diagnosing the sickness. Signs and symptoms relative to each sickness are listed, followed by the action which must be immediately taken once the sickness is confirmed. A flow chart is given to provide a systematic method of treating each sickness. Once the treatment table (Tables 1–6) has been established, treatment is normally concluded by carrying out the decompression procedures specified in that table. If complications develop during or after treatment, the procedures given at the end of this section will apply. *Diagnosis and prescription of treatment are the responsibility of the attending physician(s).* Experienced chamber attendants are generally very familiar with the diving sicknesses and may be called on to offer comment or advice. *The attendant should not, however, assume the responsibility of prescribing treatment without approval and direction of a qualified physician.*

DECOMPRESSION SICKNESS (Pain Only)

Diagnosis (Probable occurrence within 6 hours following dive)

Symptoms: Local pain, usually in joints of arms or legs; itching.

Signs: Diver complaining of joint pain. Pain not promoted by touch or vigorous rubbing. Blotchy skin rash.

Immediate Action:
1. Stop massive bleeding if present
2. Examine patient
3. Enter chamber; begin pressurization at 25 fpm.

Treatment: See Figure 8

DECOMPRESSION SICKNESS (Serious Symptoms)

Diagnosis (Probable occurrence within 6 hours following dive)

Symptoms: Dizziness; defective vision; paralysis; shortness of breath; extreme fatigue; extreme pain; abdominal pain; ringing in ears.

Signs: Diver staggering; paralyzed extremities; rapid breathing; choking; diver complaining of extreme pain; doubled over with pain; collapse or unconsciousness.

TABLE 1A. AIR TREATMENT

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
100	30	Air	30
80	12	Air	43
60	30	Air	74
50	30	Air	105
40	30	Air	136
30	60	Air	197
20	60	Air	258
10	120	Air	379
0	1	Air	380

1. Use – treatment of pain-only decompression sickness when oxygen cannot be used and pain is relieved at a depth of less than 66 ft.
2. Descent rate – 25 fpm.
3. Ascent rate – 1 min between stops.
4. Time at 100 ft – includes time from the surface.

TABLE 2A. AIR TREATMENT

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
165	30	Air	30
140	12	Air	43
120	12	Air	56
100	12	Air	69
80	12	Air	82
60	30	Air	113
50	30	Air	144
40	30	Air	175
30	120	Air	296
20	120	Air	417
10	240	Air	658
0	1	Air	659

1. Use – treatment of pain-only decompression sickness when oxygen cannot be used and pain is relieved at a depth greater than 66 ft.
2. Descent rate – 25 fpm.
3. Ascent rate – 1 min between stops.
4. Time at 165 ft – includes time from the surface.

TABLE 3. AIR TREATMENT

Depth (feet)	Time	Breathing Media	Total Elapsed Time (hrs:min)
165	30 min	Air	0:30
140	12 min	Air	0:43
120	12 min	Air	0:56
100	12 min	Air	1:09
80	12 min	Air	1:22
60	30 min	Oxygen (or Air)	1:53
50	30 min	Oxygen (or Air)	2:24
40	30 min	Oxygen (or Air)	2:55
30	12 hr	Air	14:56
20	2 hr	Air	16:57
10	2 hr	Air	18:58
0	1 min	Air	18:59

1. Use – treatment of serious symptoms when oxygen cannot be used and symptoms are relieved within 30 min at 165 ft.
2. Descent rate – 25 fpm.
3. Ascent rate – 1 min between stops.
4. Time at 165 ft – includes time from surface.

TABLE 4. AIR TREATMENT

Depth	Time	Breathing Media	Total Elapsed Time (hrs:min)
165	½ to 1½ hr	Air	1:30
140	½ hr	Air	2:01
120	½ hr	Air	2:32
100	½ hr	Air	3:03
80	½ hr	Air	3:34
60	6 hr	Air	9:35
50	6 hr	Air	15:36
40	6 hr	Air	21:37
30	11 hr	Air	32:38
30	1 hr	Oxygen (or Air)	33:38
20	1 hr	Air	34:39
20	1 hr	Oxygen (or Air)	35:39
10	1 hr	Air	36:40
10	1 hr	Oxygen (or Air)	37:40
0	1 min	Oxygen	37:41

1. Use – treatment of serious symptoms or gas embolism when oxygen cannot be used and when symptoms are not relieved within 30 min at 165 ft.
2. Descent rate – 25 fpm.
3. Ascent rate – 1 min between stops.
4. Time at 165 ft – includes time from the surface.

TABLE 5. OXYGEN TREATMENT

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time* (minutes)
60	20	Oxygen	20
60	5	Air	25
60	20	Oxygen	45
60 to 30	30	Oxygen	75
30	5	Air	80
30	20	Oxygen	100
30	5	Air	105
30 to 0	30	Oxygen	135

1. Use – treatment of pain-only decompression sickness when oxygen can be used and symptoms are relieved within 10 min at 60 ft.
2. Descent rate – 25 fpm.
3. Ascent rate – 1 fmp. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
4. Time at 60 ft – begins on arrival at 60 ft.
5. If oxygen breathing must be interrupted, allow 15 min after the reaction has entirely subsided and resume schedule at point of interruption.
6. If oxygen breathing must be interrupted at 60 ft, switch to TABLE 6 upon arrival at 30 ft stop.
7. Tender breathes air throughout. If treatment is a repetitive dive for the tender or the table is lengthened, the tender should breathe oxygen during the last 30 min of ascent to the surface.

*Does not include descent time.

TABLE 5A. OXYGEN TREATMENT

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
165	15*	Air	15
165 to 60	4	Air	19
60	20	Oxygen	29
60	5	Air	44
60	20	Oxygen	64
60 to 30	30	Oxygen	94
30	5	Air	99
30	20	Oxygen	119
30	5	Air	124
30 to 0	30	Oxygen	154

1. Use – treatment of gas embolism when oxygen can be used and symptoms are relieved within 15 min at 165 ft.
2. Descent rate – as fast as possible.
3. Ascent rate – 1 fpm. Do not compensate for slower ascent rates. Compensate for faster ascent rates by halting the ascent.
4. Time at 165 ft – includes time from the surface.
5. If oxygen breathing must be interrupted, allow 15 min after the reaction has entirely subsided and resume schedule at point of interruption.
6. Tender breathes air throughout. If treatment is a repetitive dive for the tender or the table is lengthened, the tender should breathe oxygen during the last 30 min of ascent to the surface.

*Includes descent time.

TABLE 6. OXYGEN TREATMENT

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time* (minutes)
60	20	Oxygen	20
60	5	Air	25
60	20	Oxygen	45
60	5	Air	50
60	20	Oxygen	70
60	5	Air	75
60 to 30	30	Oxygen	105
30	15	Air	120
30	60	Oxygen	180
30	15	Air	195
30	60	Oxygen	255
30 to 0	30	Oxygen	285

1. Use – treatment of decompression sickness when oxygen can be used and symptoms are not relieved within 10 min at 60 ft. Patient breathes oxygen from the surface.

2. Descent rate – 25 fpm

3. Ascent rate – 1 fpm. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.

4. Time at 60 ft – begins on arrival at 60 ft.

5. If oxygen breathing must be interrupted, allow 15 min after the reaction has entirely subsided and resume schedule at point of interruption.

6. Tender breathes air throughout. If treatment is a repetitive dive for the tender or the table is lengthened, the tender should breathe oxygen during the last 30 min of ascent to the surface.

*Does not include descent time.

TABLE 6A. OXYGEN TREATMENT

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
165	30*	Air	30
165 to 60	4	Air	34
60	20	Oxygen	54
60	5	Air	59
60	20	Oxygen	79
60	5	Air	84
60	20	Oxygen	104
60	5	Air	109
60 to 30	30	Oxygen	139
30	15	Air	154
30	60	Oxygen	214
30	15	Air	229
30	60	Oxygen	289
30 to 0	30	Oxygen	319

1. Use – treatment of gas embolism when oxygen can be used and symptoms moderate to a major extent within 30 min at 165 ft.
2. Descent rate – as fast as possible.
3. Ascent rate – 1 fpm. Do not compensate for slower ascent rates. Compensate for faster ascent rates by halting the ascent.
4. Time at 165 ft – includes time from the surface.
5. If oxygen breathing must be interrupted, allow 15 min after the reaction has entirely subsided and resume schedule at point of interruption.
6. Tender breathes air throughout. If treatment is a repetitive dive for the tender or the table is lengthened, the tender should breathe oxygen during the last 30 min of ascent to the surface.

*Includes descent time.

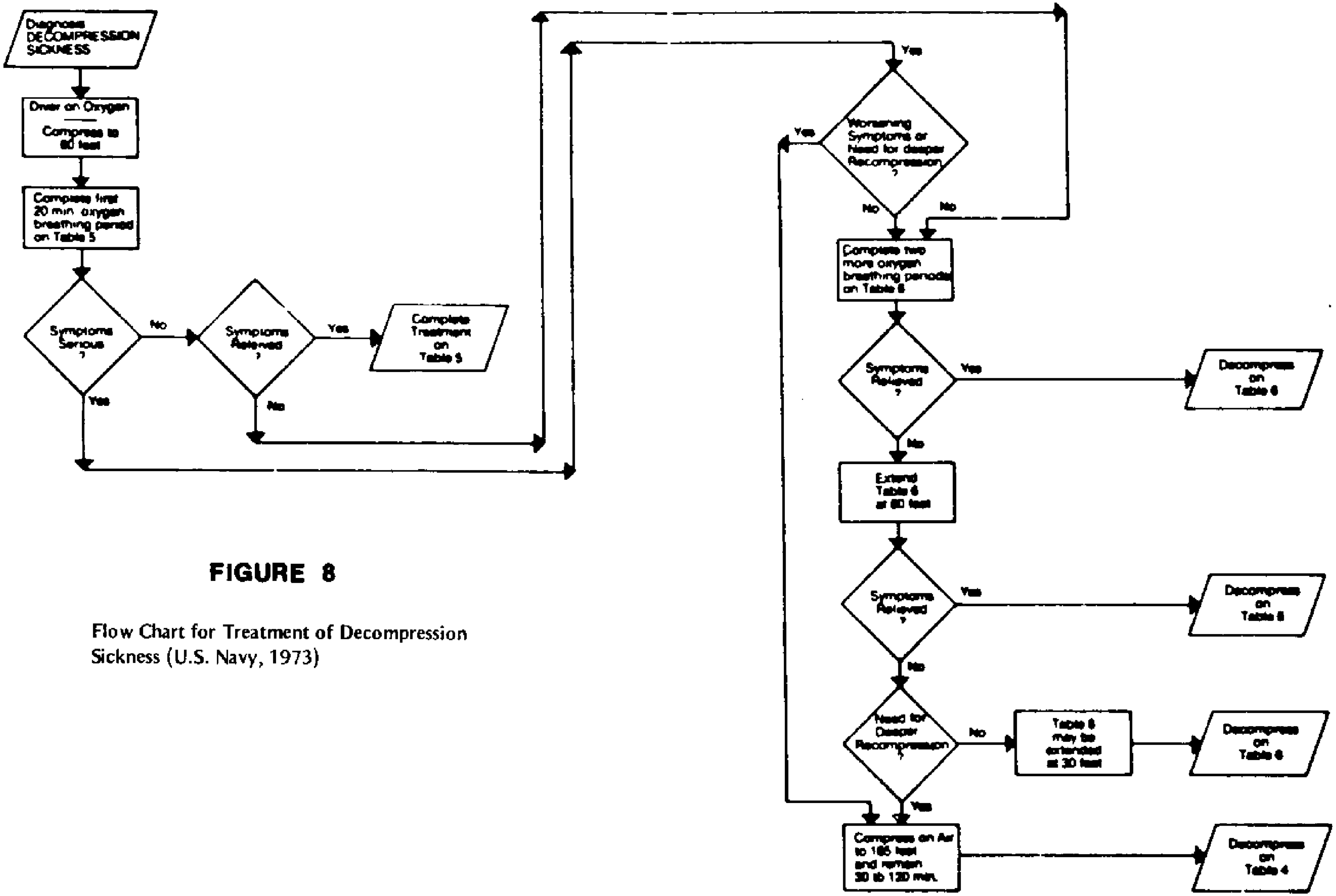


FIGURE 8

Flow Chart for Treatment of Decompression Sickness (U.S. Navy, 1973)

Immediate Action:

1. Restore breathing using mouth-to-mouth resuscitation, bag, or mechanical resuscitator,
2. Stop massive bleeding if present,
3. Begin pressurization at 25 fpm,
4. Examine patient.

Treatment: See Figure 8

GAS EMBOLISM

Diagnosis (Probable occurrence within minutes following dive)

Symptoms: Fatigue; dizziness; blurred vision; paralysis or weakness of extremities; chest discomfort or pain; progressively worsening

Signs: Diver confused, staggering, having difficulty seeing; paralyzed or weakened extremities; blueness; chest pain, rapid shallow breathing, unequal expansion of chest wall (pneumothorax)
Blueness of skin, lips, or fingernails; difficulty breathing; shock (mediastinal emphysema);
Swelling of neck; crackling sensation when skin moved, change in voice, difficulty breathing (subcutaneous emphysema);
Collapse or unconsciousness

Immediate Action:

1. Restore breathing using mouth-to-mouth resuscitation, bag, or mechanical resuscitator.
2. Stop massive bleeding if present.
3. Treatment of pneumothorax by physician (if diagnosis indicates).
4. Pressurize patient to 165 ft as fast as possible.
5. Examine patient.

Treatment: See Figure 9

COMPLICATIONS

There are three major complications which may affect the recompression treatment of a patient.

1. Worsening of the patient's condition during treatment (see below).

2. Recurrence of the patient's original symptoms or development of new symptoms during treatment (see Figure 10).

3. Recurrence of the patient's original symptoms or development of new symptoms following treatment (see Figure 11).

Patient's Condition Worsening

- Stop the ascent.
- Consider the use of 80% helium–20% oxygen if patient is experiencing difficulty breathing.
- Examine for pneumothorax or tehsion pneumothorax.
- Treat as a recurrence during treatment.

GENERAL NOTES ON TREATMENT OF GAS EMBOLISM AND DECOMPRESSION SICKNESS

1. If a patient's condition is not considered fully satisfactory at the conclusion of the normal period at 60 ft (Table 6), or if an additional safeguard is desired for any reason, give an additional cycle of treatment (20 min oxygen, 5 min air) at 60 ft. Observe for evidence of oxygen toxicity.

2. The period at 30 ft may also be extended by one cycle (15 min air, 60 min oxygen).

3. The use of Table 4 has long been regarded as the "treatment of last resort." In general, oxygen treatment tables have a far better success rate than air treatment tables. Some authorities avoid Table 4 entirely when oxygen can be given and, in any case, limit periods on air at 165 ft to 30 min or less. As stated above, Table 6 oxygen treatment can be extended. It can also be repeated. Adjunctive medical treatment should be considered when the response to recompression and oxygen is not prompt and adequate.

4. A fundamental rule is not to continue ascent if a patient's condition has worsened. This situation is handled as a *recurrence during treatment.* Details for dealing with recurrence are given in this handbook and the U.S. Navy Diving Manual.

5. The possibility of *late recurrence* dictates that the patient be retained at or near the chamber for at least 6 hr and in the vicinity for at least 24 hr.

6. Patients who require recompression treatment may also require first aid or other medical or surgical procedures. In most instances, both may be accomplished or the priorities are clear. Adequate fluid intake is important.

Decompression shock is an obvious medical problem. Maintenance of normal blood volume by usual methods is clearly indicated. *Low molecular weight dextran* (Dextran 40, Rheomacrodex) is useful to combat hematologic changes especially in patients with severe or persistent symptoms. (The usual maximum is one liter/day for 5 days.)

Steriods are considered a useful adjunct by some, emphatically so in suspected spinal cord edema. A suggested dose is Decadron, 10 mg I.V., followed by 4 mg I.M. every 6 hr. Tapering is not required for use not longer than 72 hours. The possibility of lowering O_2 tolerance suggests withholding steroids until the 30 ft stage of Table 6.

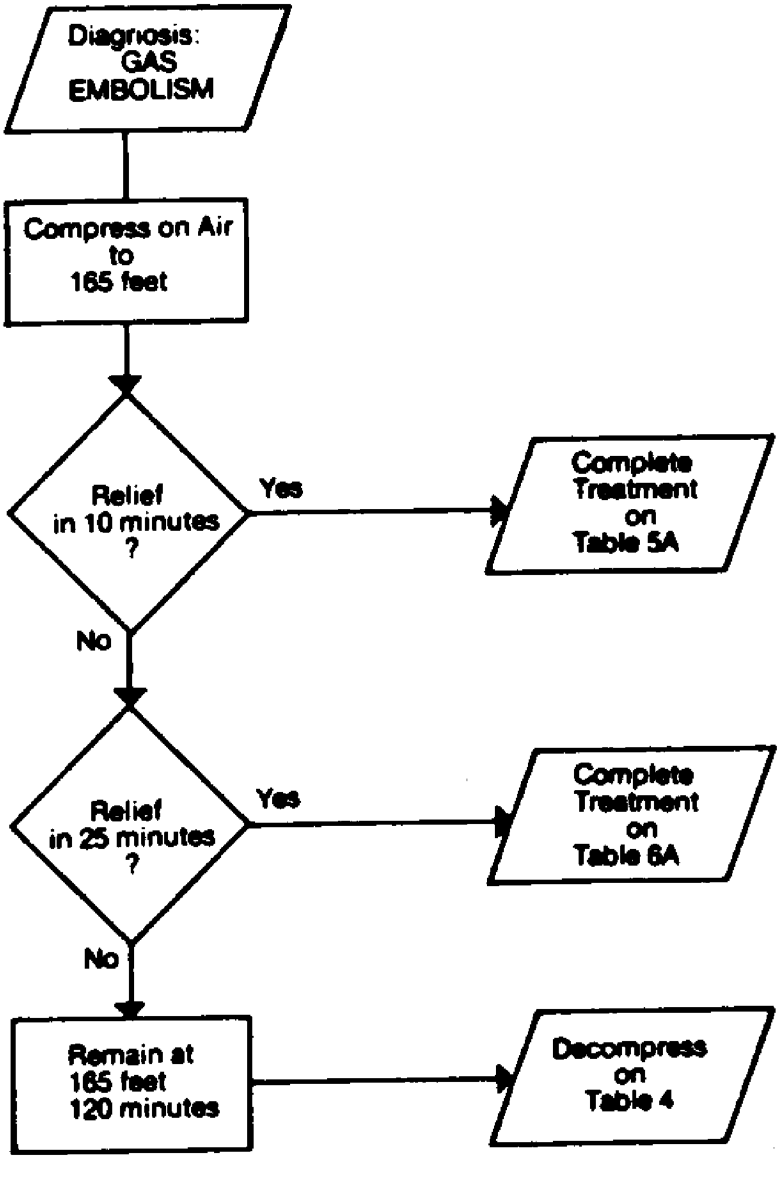


Figure 9 Flow Chart for Treatment of Gas Embolism (U.S. Navy 1973)

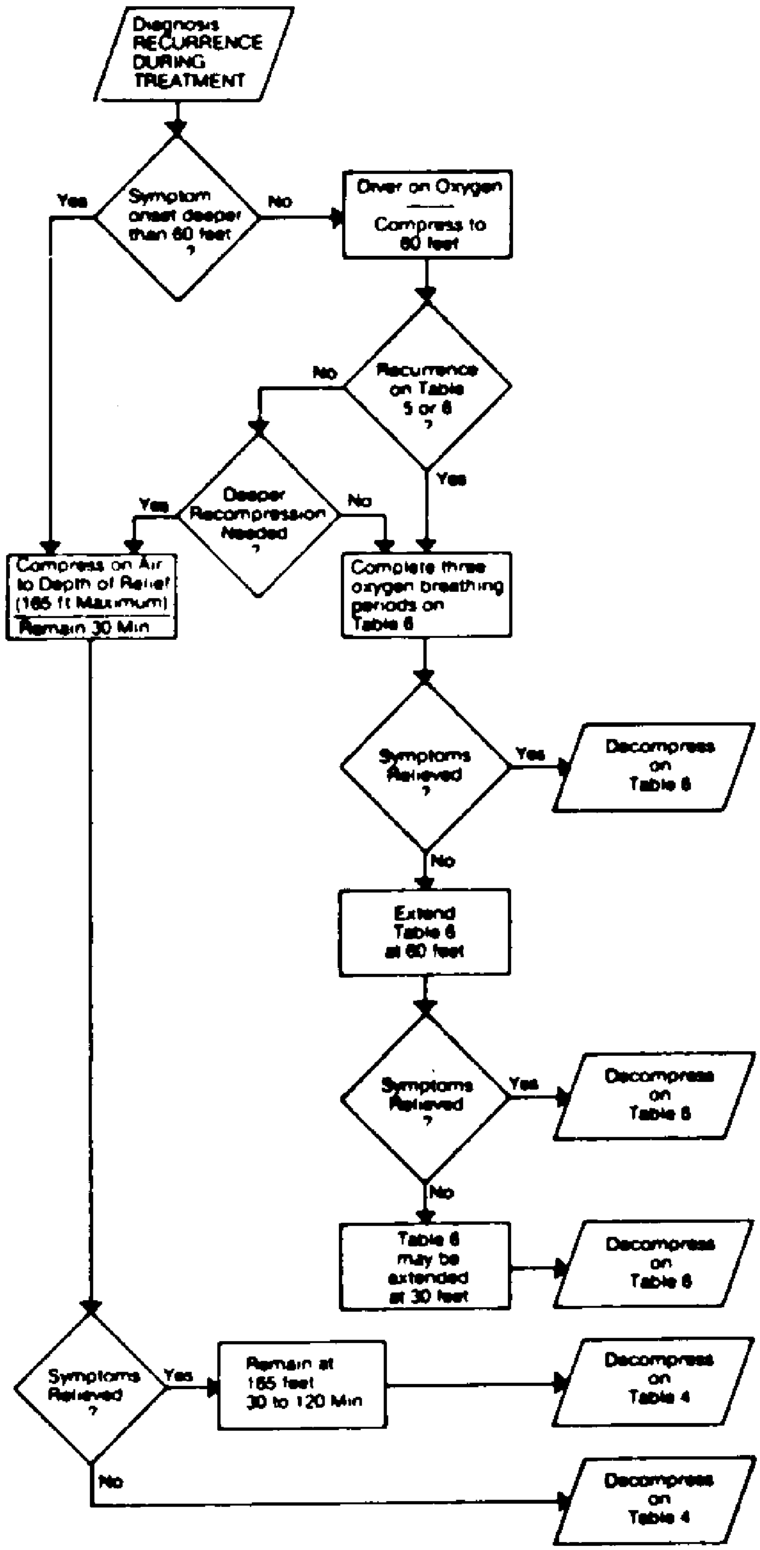


Figure 10 Flow Chart for Recurring Symptoms During Treatment (U.S. Navy, 1973).

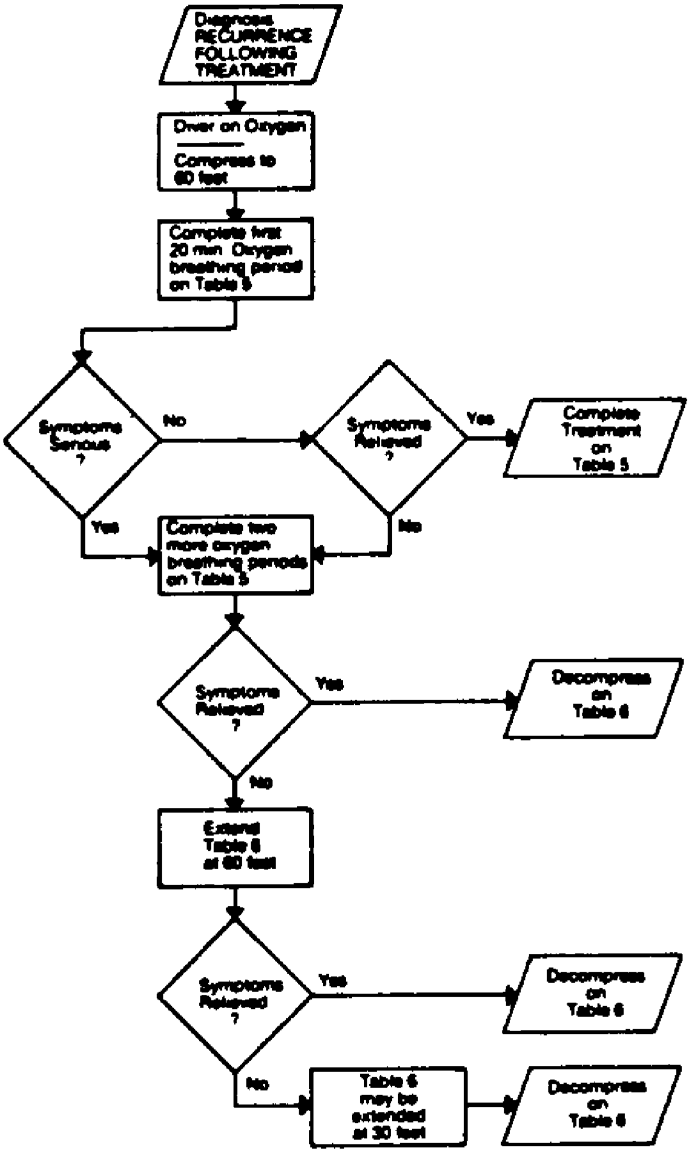


Figure 11 Flow Chart for Recurring Symptoms Following Treatment (U.S. Navy, 1973)

The use of *heparin* is considered controversial. It has been advocated in shock and to combat hematologic changes.

Sedatives and narcotics may obscure the symptomatology and entail risk of respiratory insufficiency. They should be avoided or given in minimal effective dosage. *Aspirin* can be given in usual amounts and is administered routinely by some authorities.

Routine precautions in handling medication at pressure include opening ampules and needling the stopper of vials and I.V. bottles before compression. An inadequately vented I.V. bottle may, for example, implode on descent or explode during ascent.

The above notes are based on comments given by E. H. Lanphier, M.D., in *The New Science of Skin and Scuba Diving*, Association Press, 1974 and the 13th edition of *The Merck Manual.*

CARBON MONOXIDE POISONING

Hyperbaric oxygen is used to eliminate carbon monoxide from the blood. In addition, sufficient oxygen is physically dissolved in the plasma during hyperbaric treatment to supply the body's metabolic needs until elimination is complete.

Diagnosis:

Signs and Symptoms: Headache, nausea, vomiting, dizziness, rapid heart beat, irregular heart beat, cherry-red skin color, visual changes, drowsiness, confusion, lack of coordination, coma, death.

Treatment: Pressurize patient to 3 ata (66 fsw) until carbon monoxide in the blood is reduced to a safe level, usually one hour. Oxygen is administered in 20 min intervals with 5 min of air breathing between oxygen breathing periods.

SMOKE INHALATION

The vast majority of smoke inhalation patients suffer from carbon monoxide poisoning and should be treated for carbon monoxide poisoning until proven otherwise.

CYANIDE POISONING

Certain cyanide intoxications are not immediately and dramatically fatal. Cyanide poisons the blood and causes tissue hypoxia. Chemical treatment will eventually rid the blood of cyanide, however, hyperbaric oxygen is necessary to sustain the patient through the critical period.

Treatment: Pressurization must be initiated immediately. The chamber is pressurized to 3 ata (66 fsw). The appropriate medications are administered. The patient is placed on oxygen; the pressure is slowly reduced to 33 fsw, and subsequent decompression is determined by the patient's clinical condition and the chamber attendant's standard air decompression requirement.

GAS GANGRENE

Human tissues that have compromised blood circulation are prone to develop a gas forming infection called gas gangrene. Formerly, surgical removal of the tissue was the definitive form of therapy. While this is still true, it is now generally recognized that in cases of severe gas gangrene, the presurgery use of hyperbaric oxygen substantially improves the patient's chance for survival.

Treatment: The patient is treated at 3 ata (66 fsw) for 90 min, three times during the first 24 hr. Two 90 min treatments are given the second 24 hr and on the third and fourth days, one treatment. Generally the patient will breath oxygen for 20 min intervals with 5 min periods of air breathing between the oxygen intervals. When the patient is clinically stable, surgical therapy is carried out even if the full course of hyperbaric treatment has not been completed.

EMERGENCY MEDICAL KIT

Each hyperbaric chamber facility must maintain an an emergency medical kit which is available for use in or out of the chamber. The primary kit, small enough to carry into the chamber, should contain routine diagnostic equipment and other equipment needed immediately in an emergency. Because many sterile items must be considered contaminated after exposure to increased atmospheric pressure, it is desirable to maintain a secondary supply of equipment and medicines that will be sent into the chamber only if specifically required. The primary kit should include:

- Flashlight
- Stethoscope
- Otoscope--Ophthalmoscope
- Sphygmomanometer (aneroid type, never mercury)
- Reflex hammer
- Tuning fork
- Pin and brush for sensory test
- Tongue depressors

Emergency equipment and medications:

- Tongue depressors taped and padded as a bite

pad for use in case of convulsions (or equivalent)
- Oropharyngeal airway
- Resuscitation bag respirator
- Laryngoscope
- Sterile scalpel and blade assortment
- Sterile hemostats (two each)
- Syringe, 5 cc (two each) with needles (disposable)
- Bandage scissors
- Epinephrine 1:1,000 aqueous for injection
- Sterile gauze pads
- Cotton balls
- Benzalkonium chloride

Miscellaneous

- Adhesive tape
- Tourniquet

The secondary medical kit should contain:

Emergency equipment:

- Suture material, sterile
- Suture needles, assorted, sterile
- Sterile syringes (disposable, plastic)
  - 5 cc, 2 each
  - 10 cc, 2 each
  - 30 cc, 2 each
- Sterile needles, 16, 18, 20, and 22 gauge (preferably disposable)
- Three-way stopcocks, sterile, 2 each
- Sterile thoracentesis needle, 16 gauge, 4 in long
- Selection of endotracheal tubes (plastic) with low pressure inflatable cuffs

Emergency medications:

- Intravenous fluids:
  - 5% dextrose in saline
  - 5% dextrose in water
  - Ringer's injection, lactated
  - Low molecular weight dextran (Rheomacrodex Dextran-40)
- Lidocaine (1% and 4%)
- Corticosteroid: dexamethasone for intravenous or intramuscular injection
- Amobarbital sodium, injectable
- Phenobarbital, injectable
- Diazepam, injectable
- Diphenylythydantain sodium, injectable
- Chloropromazine, injectable
- Codeine tablets
- Aspirin
- An injectable antihistamine
- Sterile water for injection
- Surgical soap

Miscellaneous

- Nasogastric tube
- Asepto syringe
- Sterile bladder catheterization tray (preferably disposable
- Intravenous infusion kits, sterile, disposable (two each)
- Gauze roller bandage, 1 in and 2 in, sterile
- Band-aids
- Sterile gloves, surgical
- Sterile towels
- Splints
- AMBU-type resuscitator
- Eye patch

SECTION IV: CHAMBER SYSTEM INSTALLATION AND MAINTENANCE

The manufacturer should deliver the chamber with instructions for permanently mounting the chamber and making it operational. After the chamber is installed, an air system must be provided to meet the requirements of the chamber. Finally, since it relates directly to the size of the chamber and the design of the air system, the main exhaust valves must be calibrated to facilitate adequate ventilation of the chamber or a flow meter installed. Details on installation and maintenance of chambers and air supply systems are beyond the scope of this handbook; consult appropriate construction codes, U. S. Navy publications, and manufacturer's instruction books.

AIR SUPPLY REQUIREMENTS

A hyperbaric chamber treatment facility must have a primary and a secondary air supply system which satisfy the following requirements:

Primary—sufficient air to pressurize the chamber to 165 fsw and ventilate through a complete treatment.

Secondary—sufficient air to pressurize the chamber once to 165 fsw and ventilate for 1 hour.

Either system may consist of air banks or a suitable compressor or both. The required total capacity is calculated as follows:

1. Primary System Capacity (for chamber not equipped with an overboard oxygen discharge system; assuming two patients and one tender in the chamber).

$$C_p = 12V + 58{,}757$$

where,

C_p	=	total capacity of primary system (standard cubic feet)
V	=	chamber volume (cubic feet)
12	=	atmospheres equivalent for 165 ft times 2 pressurizations (absolute)
58,757	=	total air required to ventilate during a Table 4 treatment (scf)

Table 7, reproduced from the U.S. Navy Recompression Chamber Operator's Handbook, gives data concerning the ventilation rates and total air requirements for two patients and one attendant undergoing recompression treatment. As indicated, the maximum air flow rate that the system need deliver is 140.7 scfm (O_2 stop at 60 ft).

2. Primary System Capacity (for chamber equipped with an overboard oxygen discharge system; assuming one patient breathing oxygen and one attendant breathing air in the chamber.

$$C_p = 12V + 33{,}825$$

where,

33,825	=	total air required to ventilate during a Table 4 treatment (scf)

Table 8 gives data concerning the ventilation rates and total air requirements for one patient and one attendant undergoing recompression treatment in a chamber equipped with an overboard oxygen discharge system. As indicated, the maximum air flow rate that the system need deliver is 35.9 scfm (165 ft stop). Table 9 gives data for air requirement in a chamber without the overboard discharge system.

3. Secondary System Capacity (for chamber not equipped with an overboard oxygen discharge system; assuming two patients and one attendant in the chamber).

$$C_s = 6V + 8{,}442$$

where,

C_p	=	total capacity of secondary system (scf)
V	=	chamber volume (cf)
6	=	atmospheres equivalent of 165 ft (a)
8,442	=	maximum ventilation rate of 140.7 scfm for 1 hr.

4. Secondary Supply System (for chamber equipped with an overboard oxygen discharge system; assuming one patient breathing oxygen and one attendant breathing air in the chamber).

$$C_s = 6V + 2{,}154$$

where,

2,154	=	maximum ventilation rate of 35.9 scfm for 1 hr.

The following formula may be used to compute *approximate* internal volume for most cylindrical chambers:

$$V_c = \text{chamber volume, cf} = 0.00046\, D^2L$$
$$V_i = \text{inner compartment volume, cf} = 0.70\, V_c$$
$$V_o = \text{outer compartment volume, cf} = 0.30\, V_c$$

where,

D	=	inside diameter of shell, inches
L	=	overall length of chamber, inches

OXYGEN BREATHING MASK

The University's hyperbaric chamber is equipped with both standard and overboard discharge type oxygen breathing masks. The standard type oxygen mask consists of an oral-nasal mask, demand regulator for oxygen supply, and appropriate hoses and fittings. Oxygen breathing mask with an overboard discharge system consists of the same basic components as the standard mask with the addition of a mask mounted vacuum regulator and appropriate hoses and fittings to exhaust the exhaled breath (Fig. 12).

The cylinder pressure oxygen is reduced to approximately 75 psig by a pressure regulator. This low pressure oxygen flows through a lightweight, flexible hose to a demand regulator located on the mask. A control knob on the demand regulator allows adjustment of flow in order to minimize breathing resistance or permit constant flow if desired. Oxygen delivery pressure may also be adjusted by the outside attendants to enhance flow characteristics.

In the overboard discharge units, the diver's exhalation is removed through a regulator mounted on the left side of the mask. The regulator exhaust is connected by hose to the outside of the chamber. For a pressure differential in excess of 60 fsw, a second vacuum regulator must be connected between the hose and the chamber wall to limit the differential pressure at the outlet of the mask mounted regulator. An interlock valve is an integral part of the system. This safety device shuts off the vacuum should a supply pressure loss occur. *Do not pressurize* the unit to

TABLE 7. Ventilation Air Requirement for Recompression Treatment in Chamber Without Overboard Oxygen Discharge.

Depth of Stop (FSW)	Vent Rate[1] (SCFM)		Ventilation Air Required at Stop (SCF) Treatment Table[3]							
	Air Stop	O_2 Stop	1A	2A	3(O_2)	4(O_2)	5	6	5A	6A
165	47.9			1437	1437	5749			719	1437
140	41.9			503	503	1256				
120	37.0			444	444	1111			138	139
100	32.2		966	386	386	965				
80	27.3		328	328	328	821				
60	22.5	140.7	675	676	4221	8104	5741	8780	5741	8780
50	20.1	125.6	603	603	3768	7234				
40	17.7	110.5	530	530	3314	6363	3540	3541	3540	3540
30	15.3	95.4	916	1831	10984	15790	2060	11900	2060	11900
20	12.8	80.2	770	1540	1541	5585				
10	10.4	65.0	1250	2501	1250	4532	2180	2180	2180	2180
Pressurization[2]	570		756	1247	1247	1247	453	453	1247	1247
Total for Treatment			6794	12026	29423	58757	13974	26854	15625	29223

1 For two patients and one attendant all breathing oxygen at appropriate stops.

2 Chamber volume approximately 160 cf.

3 From "U.S. Navy Recompression Chamber Operator's Handbook."

TABLE 8. Ventilation Air Requirements for Recompression Treatment in Chamber <u>With</u> Overboard Oxygen Discharge System.

Depth of Stop (FSW)	Vent Rate[1] (SCFM)	Ventilation Air Required at Stop (SCF) Treatment Table							
		1A	2A	$3(O_2)$	$4(O_2)$	5	6	5A	6A
165	36.0		1080	1080	3240			539	1077
140	31.0		372	372	930				
120	27.8		334	334	834			106[3]	106[3]
100	24.0	720	288	288	720				
80	20.5	246	246	246	615				
60	16.9	507	507	507	6084	761	1268	761	1268
50	15.1	453	453	453	5436				
40	13.3	399	399	399	4788	426[3]	426[3]	426[3]	426[3]
30	11.5	690	1380	8280	8280	345	1725	345	1725
20	9.6	576	1152	1152	1152				
10	7.8	936	1872	936	936	261[3]	261[3]	261[3]	261[3]
Pressurization[2]		544	810	810	810	380	380	810	810
Total for Treatment		5071	8893	14857	33825	2173	4060	3248	5673

[1] For one patient breathing oxygen at appropriate stops and the attendant breathing air throughout treatment.

[2] Inner compartment volume 135 cf.

[3] Based on median depth between stops on continuous decompression.

TABLE 9. Ventilation Air Requirements for Recompression Treatment in Chamber <u>Without</u> Overboard Oxygen Discharge System.

Depth of Stop (FSW)	Vent Rate[1] (SCFM)		Ventilation Air Required at Stop (SCF) Treatment Table							
	Air Stop	O_2 Stop	1A	2A	$3(O_2)$	$4(O_2)$	5	6	5A	6A
165	36.0			1080	1080	3240			539	1077
140	31.0			372	372	930				
120	27.8			334	334	834			106[3]	106[3]
100	24.0		720	288	288	720				
80	20.5		246	246	246	615				
60	16.9	35.2	507	507	1056	6084	1493	2366	1493	2366
50	15.1	31.4	453	453	942	5436				
40	13.3	27.7	399	399	831	4788	885[3]	885[3]	885[3]	885[3]
30	11.5	23.9	690	1380	8280	9024	593	3213	593	3213
20	9.6	20.0	576	1152	1152	1776				
10	7.8	16.3	936	1872	936	1446	555[3]	555[3]	555[3]	555[3]
Pressurization[2]			544	810	810	810	810	810	810	810
Total for Treatment			5071	8893	16327	35703	4336	7829	4981	9012

[1] For one patient breathing oxygen at appropriate stops and the attendant breathing air throughout treatment.

[2] Inner compartment volume 135 cf.

[3] Based on median depth between stops on continuous decompression.

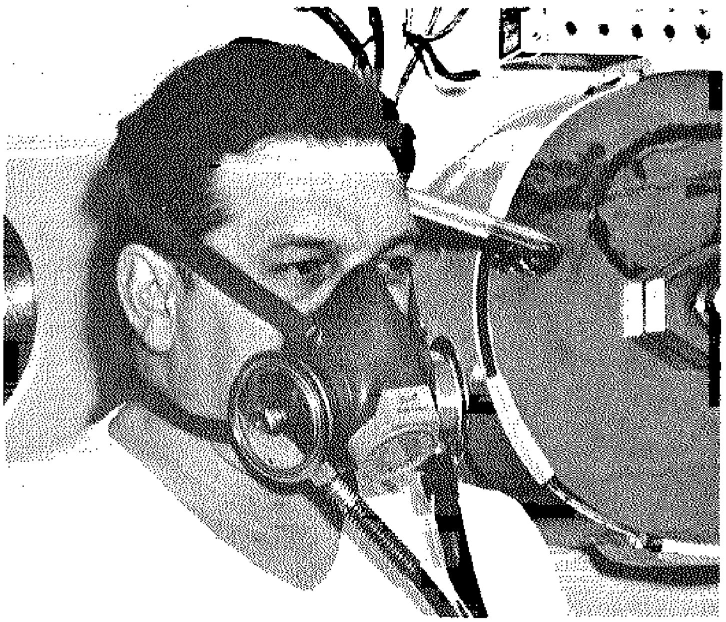


FIGURE 12 Oxygen Mask with Overboard Discharge System

a depth greater than 60 ft unless it is fitted with an auxiliary vacuum regulator or the discharge hose has been disconnected for the external exhaust port.

These units should be inspected for unrestricted operation by the attendant prior to each use. The hose fittings are inserted into properly labeled connectors on the wall of the chamber. After testing, the internal and external valves are closed until oxygen is required.

The mask must be cleaned with an antiseptic solution (antibacterial soap and warm water, alcohol, sterilizing agent, etc.) after each use and stored in a sealed plastic bag. Routine inspection and preventive maintenance is required annually or when malfunction is evident. Generally inspection and repair service are provided by the manufacturer or his local representative. For further information, consult Appendix E of this handbook or the appropriate manufacturer's instruction manual.

OXYGEN MONITORING EQUIPMENT

An oxygen analyzer is useful for monitoring oxygen concentrations in chambers where oxygen is used for therapy, research, or surface decompression. Based on current U.S. Navy recommendations, the oxygen level in hyperbaric chambers should not exceed 25 percent. Higher concentrations constitute a specific fire hazard.

Several oxygen analyzers are available. Some units are placed outside the chamber with a remote sensor located inside the chamber; an appropriate chamber penetration is required. Small, portable galvanic cell type units may be placed directly in the chamber. In choosing portable units for hyperbaric use, be certain to consult with the manufacturer to be certain that the unit is compatible with hyperbaric environments. Since many units readout in response to partial pressure of oxygen relative to one atmosphere pressure, mathematical conversions must be made to denote the true reading at depth. Manufacturer's instruction manuals should be consulted for detailed information on specific oxygen analyzers. Special instructions for use of the oxygen analyzer used in the University's chamber are given in Appendix D.

CORROSION PROTECTION

Corrosion products are best removed by hand or by using a slender pointed tool, being careful not to gouge or otherwise damage the base metal. The corroded area and a small area around it should then be cleaned to remove any remaining paint and/or corrosion products. The area should then be painted with one primer coat and one exterior coat using fire retardant paint. Painting should be kept to an absolute minimum.

FIRE EXTINGUISHING EQUIPMENT AND AGENTS

The U.S. Navy's *Design Manual: Hyperbaric Facilities* (NAVFAC DM-39) states that "although research has been performed on nonaqueous extinguishing agents, studies have not yet reached the point where any extinguishing agent can be recommended with confidence as being superior to a water spray with adequate drainage." The manual further states that "tests have shown that a hand-aimed stream of water is one of the most effective ways to put out a small fire in its initial stages" and that sand and water buckets are "in a class of items which can do no harm and may do some good."

Therefore, containers of water and/or a small hand-held water spray fire extinguisher are used in the University's chamber. Each type of extinguisher should be tested in the chamber under pressure equivalent to 60 fsw prior to initial installation and periodically inspected thereafter.

FIRE RETARDANT CLOTHING

The hyperbaric chamber facility should be provided with special fire retardant clothing, mattress cover, sheets, and blankets. These items may be constructed of special fire retardant fabric or treated with a fire retardant solution so that they will not support combustion at 165 ft in air and 60 ft in a 25% oxygen—75% nitrogen atmosphere.

PRESSURE TEST

In accordance with recommendations made by the U.S. Navy (1973b), a periodic pressure test must be conducted on recompression chambers when they are initially installed, moved and reinstalled, and at five-year intervals at a given location. The test is to be conducted as follows:

1. Pressurize inner compartment to 100 fsw. Using soapy water or an equivalent solution, leak-test all shell penetration fittings, viewports, hatch seals, hatch dogs, valve connections, pipe joints, and shell weldments.

2. Mark leaks. Depressurize compartment and

adjust, repair, or replace components as necessary to eliminate leaks.

a. Viewport leaks: Remove viewport gasket (replace if necessary), wipe clean and lubricate with appropriate lubricant. When reinstalling viewport, tighten retaining ring bolts until the gasket just compresses *evenly* about the viewport. Do not compress the gasket.

b. Weldment leaks: Repair in accordance with applicable requirements for unfired pressure vessels. Consult the chamber manufacturer or a local representative for specific instructions. Following weldment repairs, the chamber must be hydrostatically tested per manufacturer's specifications for recertification. Special instructions for hydrostatic testing are also available from the U.S. Navy Experimental Diving Unit.

3. Repeat steps 1 and 2 until all leaks have been eliminated.

4. Pressurize compartment to chamber's maximum design pressure (not hydrostatic pressure) and hold for five minutes (The pressure should be stabilized at the specified depth relative to ambient temperature prior to starting test time.).

5. Depressurize compartment to 165 fsw. Hold for one hour. If pressure drops below 145 fsw, locate and mark leaks. Depressurize chamber and repair leaks in accordance with step 2 above and repeat this process until final pressure is at least 145 fsw (The pressure should be stabilized at the specified depth relative to ambient temperature prior to starting test time.).

6. Repeat steps 1 through 5 leaving the inner door open and outer door closed. Leak test those portions of the chamber not previously tested.

SECTION V: ADDITIONAL USES OF HYPERBARIC CHAMBERS

In addition to being used for recompression treatment of divers suffering from decompression sickness or gas embolism and other clinical applications, hyperbaric chambers are also routinely used for:

- Surface Decompression
- Omitted Decompression
- Diver Candidate Pressure and Oxygen Tolerance Test
- Pressurizing Personnel for Training and Demonstration

SURFACE DECOMPRESSION

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

Surface decompression offers many advantages which enhance the diver's safety. Shorter exposure time in the water keeps him from chilling to a dangerous level. Inside the recompression chamber, the diver can be maintained at a constant pressure, unaffected by surface conditions of the sea. Observed constantly by the chamber operator, and monitored intermittently by medical personnel, any signs of decompression sickness can be readily detected and immediately treated.

If an oxygen breathing system is installed in the recompression chamber, surface decompression should be conducted in accordance with the Surface Decompression Table Using Oxygen. If air is the only breathing medium available, the Surface Decompression Table Using Air must be used. Both tables, and the specific instruction for their use, are in Change 1 (0994-001-9011) to the *U.S. Navy Diving Manual*, NAVSHIPS 0994-001-9010 and the *Research Diver's Manual* (University of Michigan Sea Grant Program).

There is no surface decompression table for use following an exceptional exposure dive. Additionally, repetitive diving tables for dives following surface decompression have not been calculated.

Prior to making a dive that will employ surface decompression procedures, the chamber must undergo a predive checkout. Upon surfacing the diver, his tenders have only 3.5 min to remove his breathing gear, assist him into the chamber, and begin recompression.

OMITTED DECOMPRESSION

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

1. Use of Surface Decompression Tables. The surface Table Using Oxygen or the Surface Table Using Air may be used to make up omitted decompression only if the emergency surface interval occurs at such a time that water stops are not required or have already been completed.

2. Surface Decompression Tables Not Applicable. When the conditions which permit the use of the surface decompression tables are not fulfilled, the diver's decompression has been compromised. Special care must be taken to detect signs of decompression sickness, regardless of what action is initiated. The diver must be returned to pressure as soon as possible.

a. If the chamber is equipped for oxygen breathing, take the patient to 60 fpm, having him breathe oxygen from the surface. If no symptoms of decompression sickness appear after 10 min, decompress on Table 5. If symptoms appear and are not relieved after 10 min, decompress on Table 6.

b. If the chamber is not equipped for oxygen breathing, take the patient to 100 ft at 25 fpm and keep him at that depth for 30 min. If no symptoms of decompression sickness appear during that period, decompress on Table 1A.

Consider any decompression sickness developed during or after these procedures as a recurrence.

U.S. NAVY DIVER CANDIDATE PRESSURE AND OXYGEN TOLERANCE TESTS

U.S. Navy and some government agency diving candidates are required to pass a pressure and/or oxygen tolerance test before they are eligible for diver training or annual diver recertification. The following test procedures were developed specifically for diver candidate pressure and oxygen tolerance tests. Although the specific decompression is not in accordance with the standard Air Decompression Table, it has proven to be safe and effective over years of experience in U.S. Navy facilities.

1. The candidate must undergo an appropriate diving medical examination and be cleared for diving.
2. Chamber procedures and equalization methods are explained to the candidate(s) as previously discussed.
3. The candidate(s) and attendant enter the chamber and are pressurized to 112 ft at a rate which can be tolerated by the candidate.
4. The chamber is ventilated for one minute at 112 ft to cool the interior.
5. Ascend to 60 ft at 60 fpm.
6. The attendant places an oxygen mask on the candidate's face, and the candidate breathes 100% oxygen for 30 min. During this time the candidate remains at rest and the chamber is ventilated at 12.5 acfm (or 6 acfm if chamber is equipped with an overboard oxygen discharge). The attendant must constantly monitor the candidate for signs of oxygen toxicity.
7. After 30 min the mask is removed and the chamber is depressurized to the surface at a rate of 60 fpm.

During pressurization the candidate must demonstrate the ability to equalize pressure in his ears effectively and otherwise withstand the effects of pressure. Due consideration must be given to the presence of an upper respiratory infection which may temporarily impair the ability to equalize pressure.

During the oxygen tolerance test, if the candidate convulses or exhibits definite preconvulsive signs (i.e., twitching of facial muscles or limbs), he fails the test; remove the mask. The test is not to be repeated. If during the test the candidate complains of symptoms such as nausea, tingling sensation, dizziness, etc., the mask should be removed and the test may be terminated. The test may be repeated at a later date at the discretion of the attending physician.

PRESSURIZING PERSONNEL FOR TRAINING AND DEMONSTRATION

All university employees and students to be pressurized in the hyperbaric chamber must have satisfactorily completed a medical examination given by an approved physician and pronounced physically qualified for such activity. A record of the medical examination, signed by the physician, shall be filed with the university diving coordinator and at the chamber facility.

Since many trainees will not be affiliated with the university, a person who holds an approved skin and scuba diver certificate of training and is active in underwater diving or is an approved diver trainee from non-university programs may be exempted from the medical examination requirement at the discretion of the chamber supervisor and/or the attending physician. Exempties must, however, sign a statement attesting to the fact that they are not aware of any personal physical abnormalities that are contraindications to diving. All persons, regardless of affiliation, shall be required to execute a Waiver, Release and Indemnity Agreement and Acknowledgment of Risk statement prior to entering the chamber.

The chamber attendants must interview each individual undergoing a pressure test, chamber orientation, or an oxygen tolerance test to insure that they conform to the requirements previously stated. The chamber attendants should ask the following questions of each person entering the chamber:

1. Have you had a good night's sleep?
2. Have you done any heavy drinking in the last 12 hours?
3. Do you have a cold or have you recently had a cold?
4. Have you been hospitalized or suffered a serious illness in the past year?
5. Do you have any physical problems which have or would possibly have disqualified you from diving?

If the chamber attendant detects any unsatisfactory answer or observes any physical abnormality, he should reject the individual from pressurization until the person is designated as qualified by a physician. All personnel must sign appropriate medical information and release forms prior to entering the chamber. Inform everyone that smoking is prohibited in the laboratory area.

Trainees shall be instructed to stay clear of the chamber door and control area while the chamber is in operation. Unauthorized personnel are not allowed to handle control valves or watches.

Prior to admitting personnel to the chamber, the chamber attendant must ensure that shoes have been removed and that no individual has materials such as cigarettes, pipes, lighters, pens, etc. in his pockets. All watches except for diving watches should be removed. Although all normal clothing is combustible, cotton appears to de desirable over synthetic and wool materials because of its nonstatic property. If the attendant detects high static electricity levels on clothing, he may request that the individual change into more suitable garments. Ideally, fire-resistant clothing should be issued to all chamber occupants.

As the personnel enter the chamber, instruct them to be seated in a noncramped position. Ideally, no more than four persons should be pressurized in the university chamber at a time. If possible, a trained attendant should accompany them in the chamber. Describe the pressurization sequence emphasizing the equalization procedure and signal for stopping pressurization in the event they are unable to equalize (raise clenched fist). Inform them to expect a high noise level (issue ear protectors, if necessary) and significant temperature increase due to the adiabatic heat of compression during descent. Some may wish to remove a sweater or outer shirt to avoid excessive perspiring. When the chamber has reached maximum depth, observe the occupants for signs of anxiety, claustrophobia and nitrogen narcosis. Have them note the changes in voice (slight "Donald Duck"-like quality), difficulty whistling, and increased resistance to forceful inhalation through the nose due to the increased density of the air. If the chamber is ventilated on a periodic basis, the occupants should be forwarned of air bursts. Prior to depressurization of the chamber, inform the occupants to breathe normally and not to hold their breath during depressurization. Warn them that the air temperature will decrease significantly and that a water vapor fog may form in the chamber. This is normal and the occupants should not be alarmed. Request that occupants not handle the chamber door assembly or fire extinguishing equipment while under pressure.

Following decompression, the personnel who have been subjected to pressure are requested to remain in the building for one hour and in the vicinity for 12 hours. They should not fly for at least 12 hours, or more if so instructed by the chamber supervisor or attending physician. If they experience any unusual symptoms or illness during the next 24 hours, they are requested to consult with the facility's hyperbaric physician. An information card should be issued to all participants and they should carry the card for 24 hours.

REFERENCES

Kindwall, E. 1971. *Hyperbaric Medical Procedures,* Milwaukee, WI: St. Luke's Hospital.

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U.S. Navy, 1970a. *U.S. Navy Diving Manual,* Washington, D.C.: U.S. Government Printing Office (NAVSHIPS 0994-001-9010).

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U.S. Navy, 1973b. *U.S. Navy Recompression Chamber Operator's Handbook,* Washington, D.C.: (NAVSHIPS 0994-014-5010).

APPENDIX A

STANDARD AIR DECOMPRESSION TABLES

From

U.S. Navy Diving Manual*

*For the purpose of standardization, the table numbers in Appendix A are the same as those given in U.S. Navy Change 1 (0994-001-9011) of the U.S. Navy Diving Manual (NAVSHIPS 0994-001-9010).

Table	
1–9	Decompression procedures
1–10	U.S. Navy standard air decompression table
1–11	No-decompression limits and repetitive dive group designation table for no-decompression air dives
1–12	Surface interval credit table for air decompression dives
1–13	Repetitive dive timetable for air dives
1–14	U.S. Navy standard air decompression table for exceptional exposures
1–15	Surface decompression table using oxygen
1–16	Surface decompression table using air

(FORMERLY TABLE 1–4, 1963 DIVING MANUAL)

TABLE 1–9.—*Decompression procedures*

GENERAL INSTRUCTIONS FOR AIR DIVING

Need for Decompression

A quantity of nitrogen is taken up by the body during every dive. The amount absorbed depends upon the depth of the dive and the exposure (bottom) time. If the quantity of nitrogen dissolved in the body tissues exceeds a certain critical amount, the ascent must be delayed to allow the body tissue to remove the excess nitrogen. Decompression sickness results from failure to delay the ascent and to allow this process of gradual desaturation. A specified time at a specific depth for purposes of desaturation is called a decompression stop.

No-Decompression Schedules

Dives that are not long or deep enough to require decompression stops are no-decompression dives. Dives to 33 feet or less do not require decompression stops. As the depth increases, the allowable bottom time for no-decompression dives decreases. Five minutes at 190 feet is the deepest no-decompression schedule. These dives are all listed in the *No-Decompression Limits and Repetitive Group Designation Table for No-Decompression Dives* (No-Decompression Table (table 1-11)), and only require compliance with the 60-feet-per-minute rate of ascent.

Schedules That Require Decompression Stops

All dives beyond the limits of the *No-Decompression Table* require decompression stops. These dives are listed in the *Navy Standard Air Decompression Table* (table 1–10). Comply exactly with instructions except as modified by surface decompression procedures.

Variations in Rate of Ascent

Ascend from all dives at the rate of 60 feet per minute.

In the event you are unable to maintain the 60-feet-per-minute rate of ascent:

- **(*a*) If the delay was at a depth greater than 50 feet: increase the bottom time by the difference between the time used in ascent and the time that should have been used at a rate of 60 feet per minute. Decompress according to the requirements of the new total bottom time.**
- **(*b*) If the delay was at a depth less than 50 feet: increase the first stop by the difference between the time used in ascent and the time that should have been used at the rate of 60 feet per minute.**

In the event you exceed the 60 feet per minute rate:

(c) If no decompression stops are required, but the bottom time places you within 10 minutes of a schedule that does require decompression; stop at 10 feet for the time that you should have taken in ascent at 60 feet per minute.

(d) If decompression is required; stop 10 feet below the first listed decompression depth for the remaining time that you should have taken in ascent at 60 feet per minute.

Repetitive Dive Procedure

A dive performed within 12 hours of surfacing from a previous dive is a repetitive dive. The period between dives is the surface interval. Excess nitrogen requires 12 hours to be effectively lost from the body. These tables are designed to protect the diver from the effects of this residual nitrogen. Allow a minimum surface interval of 10 minutes between all dives. For any interval under 10 minutes, add the bottom time of the previous dives to that of the repetitive dive and choose the decompression schedule for the total bottom time and the deepest dive. Specific instructions are given for the use of each table in the following order:

(1) The *No-Decompression Table* or the *Navy Standard Air Decompression Table* gives the repetitive group designation for all schedules which may precede a repetitive dive.

(2) The *Surface Interval Credit Table* gives credit for desaturation occurring during surface interval.

(3) The *Repetitive Dive Timetable* gives the number of minutes of residual nitrogen time to add to the actual bottom time of the repetitive dive to obtain decompression for the residual nitrogen.

(4) The *No-Decompression Table* or the *Navy Standard Air Decompression Table* gives the decompression required for the repetitive dive.

U.S. NAVY STANDARD AIR DECOMPRESSION TABLE

Instructions for Use

Time of decompression stops in the table is in minutes.

Enter the table at the exact or the next greater depth than the maximum depth attained during the dive. Select the listed bottom time that is exactly equal to or is next greater than the bottom time of the dive. Maintain the diver's chest as close as possible to each decompression depth for the number of minutes listed. The rate of ascent *between* stops is not critical for stops of 50 feet or less. Commence timing each stop on arrival at the decompression depth and resume ascent when the specified time has lapsed.

For example—a dive to 82 feet for 36 minutes. To determine the proper decompression procedure: The next greater depth listed in this table is 90 feet. The next greater bottom time listed opposite 90 feet is 40. Stop 7 minutes at 10 feet in accordance with the 90/40 schedule.

For example—a dive to 110 feet for 30 minutes. It is known that the depth did not exceed 110 feet. To determine the proper decompression schedule: The exact depth of 110 feet is listed. The exact bottom time of 30 minutes is listed opposite 110 feet. Decompress according to the 110/30 schedule unless the dive was particularly cold or arduous. In that case, go to the schedule for the next deeper and longer dive, i.e., 120/40.

TABLE 1–10.– *U.S. Navy Standard Air Decompression Table*

(FORMERLY TABLE 1–5, 1963 DIVING MANUAL)

Depth (feet)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)					Total ascent (min:sec)	Repetitive group
			50	40	30	20	10		
40	200						0	0:40	(*)
	210	0:30					2	2:40	N
	230	0:30					7	7:40	N
	250	0:30					11	11:40	O
	270	0:30					15	15:40	O
	300	0:30					19	19:40	Z
50	100						0	0:50	(*)
	110	0:40					3	3:50	L
	120	0:40					5	5:50	M
	140	0:40					10	10:50	M
	160	0:40					21	21:50	N
	180	0:40					29	29:50	O
	200	0:40					35	35:50	O
	220	0:40					40	40:50	Z
	240	0:40					47	47:50	Z

*See table 1–11 for repetitive groups in no-decompression dives.

TABLE 1-10.—*U.S. Navy Standard Air Decompression Table*—Continued

Depth (feet)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)					Total ascent (min:sec)	Repetitive group
			50	40	30	20	10		
60	60						0	1:00	(*)
	70	0:50					2	3:00	K
	80	0:50					7	8:00	L
	100	0:50					14	15:00	M
	120	0:50					26	27:00	N
	140	0:50					39	40:00	O
	160	0:50					48	49:00	Z
	180	0:50					56	57:00	Z
	200	0:40				1	69	71:00	Z
70	50						0	1:10	(*)
	60	1:00					8	9:10	K
	70	1:00					14	15:10	L
	80	1:00					18	19:10	M
	90	1:00					23	24:10	N
	100	1:00					33	34:10	N
	110	0:50				2	41	44:10	O
	120	0:50				4	47	52:10	O
	130	0:50				6	52	59:10	O
	140	0:50				8	56	65:10	Z
	150	0:50				9	61	71:10	Z
	160	0:50				13	72	86:10	Z
	170	0:50				19	79	99:10	Z
80	40						0	1:20	(*)
	50	1:10					10	11:20	K
	60	1:10					17	18:20	L
	70	1:10					23	24:20	M
	80	1:00				2	31	34:20	N
	90	1:00				7	39	47:20	N
	100	1:00				11	46	58:20	O
	110	1:00				13	53	67:20	O
	120	1:00				17	56	74:20	Z
	130	1:00				19	63	83:20	Z
	140	1:00				26	69	96:20	Z
	150	1:00				32	77	110:20	Z
90	30						0	1:30	(*)
	40	1:20					7	8:30	J
	50	1:20					18	19:30	L
	60	1:20					25	26:30	M
	70	1:10				7	30	38:30	N
	80	1:10				13	40	54:30	N
	90	1:10				18	48	67:30	O
	100	1:10				21	54	76:30	Z
	110	1:10				24	61	86:30	Z
	120	1:10				32	68	101:30	Z
	130	1:00			5	36	74	116:30	Z
100	25						0	1:40	(*)
	30	1:30					3	4:40	I
	40	1:30					15	16:40	K
	50	1:20				2	24	27:40	L
	60	1:20				9	28	38:40	N

*See table 1-11 for repetitive groups in no-decompression dives.

Table 1-10.—*U.S. Navy Standard Air Decompression Table*—Continued

Depth (feet)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)					Total ascent (min:sec)	Repetitive group
			50	40	30	20	10		
100—Continued	70	1:20				17	39	57:40	O
	80	1:20				23	48	72:40	O
	90	1:10			3	23	57	84:40	Z
	100	1:10			7	23	66	97:40	Z
	110	1:10			10	34	72	117:40	Z
	120	1:10			12	41	78	132:40	Z
110	20						0	1:50	(*)
	25	1:40					3	4:50	H
	30	1:40					7	8:50	J
	40	1:30				2	21	24:50	L
	50	1:30				8	26	35:50	M
	60	1:30				18	36	55:50	N
	70	1:20			1	23	48	73:50	O
	80	1:20			7	23	57	88:50	Z
	90	1:20			12	30	64	107:50	Z
	100	1:20			15	37	72	125:50	Z
120	15						0	2:00	(*)
	20	1:50					2	4:00	H
	25	1:50					6	8:00	I
	30	1:50					14	16:00	J
	40	1:40				5	25	32:00	L
	50	1:40				15	31	48:00	N
	60	1:30			2	22	45	71:00	O
	70	1:30			9	23	55	89:00	O
	80	1:30			15	27	63	107:00	Z
	90	1:30			19	37	74	132:00	Z
	100	1:30			23	45	80	150:00	Z
130	10						0	2:10	(*)
	15	2:00					1	3:10	F
	20	2:00					4	6:10	H
	25	2:00					10	12:10	J
	30	1:50				3	18	23:10	M
	40	1:50				10	25	37:10	N
	50	1:40			3	21	37	63:10	O
	60	1:40			9	23	52	86:10	Z
	70	1:40			16	24	61	103:10	Z
	80	1:30		3	19	35	72	131:10	Z
	90	1:30		8	19	45	80	154:10	Z
140	10						0	2:20	(*)
	15	2:10					2	4:20	G
	20	2:10					6	8:20	I
	25	2:00				2	14	18:20	J
	30	2:00				5	21	28:20	K
	40	1:50			2	16	26	46:20	N
	50	1:50			6	24	44	76:20	O
	60	1:50			16	23	56	97:20	Z
	70	1:40		4	19	32	68	125:20	Z
	80	1:40		10	23	41	79	155:20	Z

*See table 1-11 for repetitive groups in no-decompression dives.

TABLE 1-10.—*U.S. Navy Standard Air Decompression Table*—Continued

Depth (feet)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)					Total ascent (min:sec)	Repetitive group
			50	40	30	20	10		
150	5						0	2:30	C
	10	2:20					1	3:30	E
	15	2:20					3	5:30	G
	20	2:10				2	7	11:30	H
	25	2:10				4	17	23:30	K
	30	2:10				8	24	34:30	L
	40	2:00			5	19	33	59:30	N
	50	2:00			12	23	51	88:30	O
	60	1:50		3	19	26	62	112:30	Z
	70	1:50		11	19	39	75	146:30	Z
	80	1:40	1	17	19	50	84	173:30	Z
160	5						0	2:40	D
	10	2:30					1	3:40	F
	15	2:20				1	4	7:40	H
	20	2:20				3	11	16:40	J
	25	2:20				7	20	29:40	K
	30	2:10			2	11	25	40:40	M
	40	2:10			7	23	39	71:40	N
	50	2:00		2	16	23	55	98:40	Z
	60	2:00		9	19	33	69	132:40	Z
	70	1:50	1	17	22	44	80	166:40	Z
170	5						0	2:50	D
	10	2:40					2	4:50	F
	15	2:30				2	5	9:50	H
	20	2:30				4	15	21:50	J
	25	2:20			2	7	23	34:50	L
	30	2:20			4	13	26	45:50	M
	40	2:10		1	10	23	45	81:50	O
	50	2:10		5	18	23	61	109:50	Z
	60	2:00	2	15	22	37	74	152:50	Z
	70	2:00	8	17	19	51	86	183:50	Z
180	5						0	3:00	D
	10	2:50					3	6:00	F
	15	2:40				3	6	12:00	I
	20	2:30			1	5	17	26:00	K
	25	2:30			3	10	24	40:00	L
	30	2:30			6	17	27	53:00	N
	40	2:20		3	14	23	50	93:00	O
	50	2:10	2	9	19	30	65	128:00	Z
	60	2:10	5	16	19	44	81	168:00	Z
190	5						0	3:10	D
	10	2:50				1	3	7:10	G
	15	2:50				4	7	14:10	I
	20	2:40			2	6	20	31:10	K
	25	2:40			5	11	25	44:10	M
	30	2:30		1	8	19	32	63:10	N
	40	2:30		8	14	23	55	103:10	O
	50	2:20	4	13	22	33	72	147:10	Z
	60	2:20	10	17	19	50	84	183:10	Z

*See table 1-11 for repetitive groups in no-decompression dives.

TABLE 1-11.—*No-decompression limits and repetitive group designation table for no-decompression air dives*

(FORMERLY TABLE 1-6, 1963 DIVING MANUAL)

Depth (feet)	No-decompression limits (min)	Repetitive groups (air dives)														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10	----------	60	120	210	300	----	----	----	----	----	----	----	----	----	----	----
15	----------	35	70	110	160	225	350	----	----	----	----	----	----	----	----	----
20	----------	25	50	75	100	135	180	240	325	----	----	----	----	----	----	----
25	----------	20	35	55	75	100	125	160	195	245	315	----	----	----	----	----
30	----------	15	30	45	60	75	95	120	145	170	205	250	310	----	----	----
35	310	5	15	25	40	50	60	80	100	120	140	160	190	220	270	310
40	200	5	15	25	30	40	50	70	80	100	110	130	150	170	200	----
50	100	----	10	15	25	30	40	50	60	70	80	90	100	----	----	----
60	60	----	10	15	20	25	30	40	50	55	60	----	----	----	----	----
70	50	----	5	10	15	20	30	35	40	45	50	----	----	----	----	----
80	40	----	5	10	15	20	25	30	35	40	----	----	----	----	----	----
90	30	----	5	10	12	15	20	25	30	----	----	----	----	----	----	----
100	25	----	5	7	10	15	20	22	25	----	----	----	----	----	----	----
110	20	----	----	5	10	13	15	20	----	----	----	----	----	----	----	----
120	15	----	----	5	10	12	15	----	----	----	----	----	----	----	----	----
130	10	----	----	5	8	10	----	----	----	----	----	----	----	----	----	----
140	10	----	----	5	7	10	----	----	----	----	----	----	----	----	----	----
150	5	----	----	5	----	----	----	----	----	----	----	----	----	----	----	----
160	5	----	----	----	5	----	----	----	----	----	----	----	----	----	----	----
170	5	----	----	----	5	----	----	----	----	----	----	----	----	----	----	----
180	5	----	----	----	5	----	----	----	----	----	----	----	----	----	----	----
190	5	----	----	----	5	----	----	----	----	----	----	----	----	----	----	----

Instructions for Use

I. No-decompression limits:

This column shows at various depths greater than 30 feet the allowable diving times (in minutes) which permit surfacing directly at 60 feet a minute with no decompression stops. Longer exposure times require the use of the Standard Air Decompression Table (table 1-10).

II. Repetitive group designation table:

The tabulated exposure times (or bottom times) are in minutes. The times at the various depths in each vertical column are the maximum exposures during which a diver will remain within the group listed at the head of the column.

To find the repetitive group designation at surfacing for dives involving exposures up to and including the no-decompression limits: Enter the table on the ***exact or next greater depth*** than that to which exposed and select the listed exposure time ***exact or next greater*** than the actual exposure time. The repetitive group designation is indicated by the letter at the head of the vertical column where the selected exposure time is listed.

For example: A dive was to 32 feet for 45 minutes. Enter the table along the 35-foot-depth line since it is next greater than 32 feet. The table shows that since group D is left after 40 minutes' exposure and group E after 50 minutes, group E (at the head of the column where the 50-minute exposure is listed) is the proper selection.

Exposure times for depths less than 40 feet are listed only up to approximately 5 hours since this is considered to be beyond field requirements for this table.

TABLE 1-12.—*Surface Interval Credit Table for air decompression dives*

(FORMERLY TABLE 1-7, 1963 DIVING MANUAL)

[Repetitive group at the end of the surface interval (air dive)]

Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
0:10 0:22	0:23 0:34	0:35 0:48	0:49 1:02	1:03 1:18	1:19 1:36	1:37 1:55	1:56 2:17	2:18 2:42	2:43 3:10	3:11 3:45	3:46 4:29	4:30 5:27	5:28 6:56	6:57 10:05	10:00 12:00*
O	0:10 0:23	0:24 0:36	0:37 0:51	0:52 1:07	1:08 1:24	1:25 1:43	1:44 2:04	2:05 2:29	2:30 2:59	3:00 3:33	3:34 4:17	4:18 5:16	5:17 6:44	6:45 9:54	9:55 12:00*
	N	0:10 0:24	0:25 0:39	0:40 0:54	0:55 1:11	1:12 1:30	1:31 1:53	1:54 2:18	2:19 2:47	2:48 3:22	3:23 4:04	4:05 5:03	5:04 6:32	6:33 9:43	9:44 12:00*
		M	0:10 0:25	0:26 0:42	0:43 0:59	1:00 1:18	1:19 1:39	1:40 2:05	2:06 2:34	2:35 3:08	3:09 3:52	3:53 4:49	4:50 6:18	6:19 9:28	9:29 12:00*
			L	0:10 0:26	0:27 0:45	0:46 1:04	1:05 1:25	1:26 1:49	1:50 2:19	2:20 2:53	2:54 3:36	3:37 4:35	4:36 6:02	6:03 9:12	9:13 12:00*
				K	0:10 0:28	0:29 0:49	0:50 1:11	1:12 1:35	1:36 2:03	2:04 2:38	2:39 3:21	3:22 4:19	4:20 5:48	5:49 8:58	8:59 12:00*
					J	0:10 0:31	0:32 0:54	0:55 1:19	1:20 1:47	1:48 2:20	2:21 3:04	3:05 4:02	4:03 5:40	5:41 8:40	8:41 12:00*
						I	0:10 0:33	0:34 0:59	1:00 1:29	1:30 2:02	2:03 2:44	2:45 3:43	3:44 5:12	5:13 8:21	8:22 12:00*
							H	0:10 0:36	0:37 1:06	1:07 1:41	1:42 2:23	2:24 3:20	3:21 4:49	4:50 7:59	8:00 12:00*
								G	0:10 0:40	0:41 1:15	1:16 1:59	2:00 2:58	2:59 4:25	4:26 7:35	7:36 12:00*
									F	0:10 0:45	0:46 1:29	1:30 2:28	2:29 3:57	3:58 7:05	7:06 12:00*
										E	0:10 0:54	0:55 1:57	1:58 3:22	3:23 6:32	6:33 12:00*
											D	0:10 1:09	1:10 2:38	2:39 5:48	5:49 12:00*
												C	0:10 1:39	1:40 3:30	2:50 12:00*
													B	0:10 2:10	2:11 12:00*
														A	0:10 12:00*

Repetitive group at the beginning of the surface interval from previous dive

Instructions for Use

Surface interval time in the table is in *hours* and *minutes* (7:59 means 7 hours and 59 minutes). The surface interval must be at least 10 minutes.

Find the *repetitive group designation letter* (from the previous dive schedule) on the diagonal slope. Enter the table horizontally to select the surface interval time that is exactly between the actual surface interval times shown. The repetitive group designation for the *end* of the surface interval is at the head of the vertical column where the selected surface interval time is listed. For example, a previous dive was to 110 feet for 30 minutes. The diver remains on the surface 1 hour and 30 minutes and wishes to find the new repetitive group designation: The repetitive group from the last column of the 110/30 schedule in the Standard Air Decompression Tables is "J." Enter the surface interval credit table along the horizontal line labeled "J." The 1-hour-and-30-minute surface interval lies between the times 1:20 and 1:47. Therefore, the diver has lost sufficient inert gas to place him in group "G" (at the head of the vertical column selected).

*NOTE.—Dives following surface intervals of *more* than 12 hours are not considered repetitive dives. *Actual* bottom times in the Standard Air Decompression Tables may be used in computing decompression for such dives.

TABLE 1-13.—*Repetitive dive timetable for air dives*

(FORMERLY TABLE 1-8, 1963 DIVING MANUAL)

Repetitive groups	Repetitive dive depth (ft) (air dives)															
	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
A	7	6	5	4	4	3	3	3	3	3	2	2	2	2	2	2
B	17	13	11	9	8	7	7	6	6	6	5	5	4	4	4	4
C	25	21	17	15	13	11	10	10	9	8	7	7	6	6	6	6
D	37	29	24	20	18	16	14	13	12	11	10	9	9	8	8	8
E	49	38	30	26	23	20	18	16	15	13	12	12	11	10	10	10
F	61	47	36	31	28	24	22	20	18	16	15	14	13	13	12	11
G	73	56	44	37	32	29	26	24	21	19	18	17	16	15	14	13
H	87	66	52	43	38	33	30	27	25	22	20	19	18	17	16	15
I	101	76	61	50	43	38	34	31	28	25	23	22	20	19	18	17
J	116	87	70	57	48	43	38	34	32	28	26	24	23	22	20	19
K	138	99	79	64	54	47	43	38	35	31	29	27	26	24	22	21
L	161	111	88	72	61	53	48	42	39	35	32	30	28	26	25	24
M	187	124	97	80	68	58	52	47	43	38	35	32	31	29	27	26
N	213	142	107	87	73	64	57	51	46	40	38	35	33	31	29	28
O	241	160	117	96	80	70	62	55	50	44	40	38	36	34	31	30
Z	257	169	122	100	84	73	64	57	52	46	42	40	37	35	32	31

Instructions for Use

The bottom times listed in this table are called "residual nitrogen times" and are the times a diver is to consider he has *already* spent on bottom when he *starts* a repetitive dive to a specific depth. They are in minutes.

Enter the table horizontally with the repetitive group designation from the Surface Interval Credit Table. The time in each vertical column is the number of minutes that would be required (at the depth listed at the head of the column) to saturate to the particular group.

For example: The final group designation from the Surface Interval Credit Table, on the basis of a previous dive and surface interval, is "H." To plan a dive to 110 feet, determine the residual nitrogen time for this depth required by the repetitive group designation: Enter this table along the horizontal line labeled "H." The table shows that one must *start* a dive to 110 feet as though he had already been on the bottom for 27 minutes. This information can then be applied to the Standard Air Decompression Table or No-Decompression Table in a number of ways:

(1) Assuming a diver is going to finish a job and take whatever decompression is required, he must add 27 minutes to his actual bottom time and be prepared to take decompression according to the 110-foot schedules for the sum or equivalent single dive time.

(2) Assuming one wishes to make a quick inspection dive for the minimum decompression, he will decompress according to the 110/30 schedule for a dive of 3 minutes or less (27+3=30). For a dive of over 3 minutes but less than 13, he will decompress according to the 110/40 schedule (27+13=40).

(3) Assuming that one does not want to exceed the 110/50 schedule and the amount of decompression it requires, he will have to start ascent before 23 minutes of actual bottom time (50−27=23).

(4) Assuming that a diver has air for approximately 45 minutes bottom time and decompression stops, the possible dives can be computed: A dive of 13 minutes will require 23 minutes of decompression (110/40 schedule), for a total submerged time of 36 minutes. A dive of 13 to 23 minutes will require 34 minutes of decompression (110/50 schedule), for a total submerged time of 47 to 57 minutes. Therefore, to be safe, the diver will have to start ascent before 13 minutes or a standby air source will have to be provided.

TABLE 1-14.—*U.S. Navy Standard Air Decompression Table for exceptional exposures*

(FORMERLY TABLE 1-9, 1963 DIVING MANUAL)

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)													Total ascent time (min:sec)
			130	120	110	100	90	80	70	60	50	40	30	20	10	
40	360	0:30													23	23:40
	480	0:30													41	41:40
	720	0:30													69	69:40
60	240	0:40												2	79	82:00
	360	0:40												20	119	140:00
	480	0:40												44	148	193:00
	720	0:40												78	187	266:00
80	180	1:00												35	85	121:20
	240	0:50											6	52	120	179:20
	360	0:50											29	90	160	280:20
	480	0:50											59	107	187	354:20
	720	0:40										17	108	142	187	455:20
100	180	1:00										1	29	53	118	202:40
	240	1:00										14	42	84	142	283:40
	360	0:50									2	42	73	111	187	416:40
	480	0:50									21	61	91	142	187	503:40
	720	0:50									55	106	122	142	187	613:40
120	120	1:20										10	19	47	98	176:00
	180	1:10									5	27	37	76	137	284:00
	240	1:10									23	35	60	97	179	396:00
	360	1:00								18	45	64	93	142	187	551:00
	480	0:50							3	41	64	93	122	142	187	654:00
	720	0:50							32	74	100	114	122	142	187	773:00
140	90	1:30									2	14	18	42	88	166:20
	120	1:30									12	14	36	56	120	240:20
	180	1:20								10	26	32	54	94	168	386:20
	240	1:10							8	28	34	50	78	124	187	511:20
	360	1:00						9	32	42	64	84	122	142	187	684:20
	480	1:00						31	44	59	100	114	122	142	187	801:20
	720	0:50					16	56	88	97	100	114	122	142	187	924:20
170	90	1:50								12	12	14	34	52	120	246:50
	120	1:30						2	10	12	18	32	42	82	156	356:50
	180	1:20					4	10	22	28	34	50	78	120	187	535:50
	240	1:20					18	24	30	42	50	70	116	142	187	681:50
	360	1:10				22	34	40	52	60	98	114	122	142	187	873:50
	480	1:00			14	40	42	56	91	97	100	114	122	142	187	1007:50

Table 1-14.—*U.S. Navy Standard Air Decompression Table for exceptional exposures*—Continued

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)													Total ascent time (min:sec)
			130	120	110	100	90	80	70	60	50	40	30	20	10	
200	5	3:10													1	4:20
	10	3:00												1	4	8:20
	15	2:50											1	4	10	18:20
	20	2:50											3	7	27	40:20
	25	2:50											7	14	25	49:20
	30	2:40										2	9	22	37	73:20
	40	2:30									2	8	17	23	59	112:20
	50	2:30									6	16	22	39	75	161:20
	60	2:20								2	13	17	24	51	89	199:20
	90	1:50					1	10	10	12	12	30	38	74	134	324:20
	120	1:40				6	10	10	10	24	28	40	64	98	180	473:20
	180	1:20		1	10	10	18	24	24	42	48	70	106	142	187	685:20
	240	1:20		6	20	24	24	36	42	54	68	114	122	142	187	842:20
	360	1:10	12	22	36	40	44	56	82	98	100	114	122	142	187	1058:20
210	5	3:20													1	4:30
	10	3:10												2	4	9:30
	15	3:00											1	5	13	22:30
	20	3:00											4	10	23	40:30
	25	2:50										2	7	17	27	56:30
	30	2:50										4	9	24	41	81:30
	40	2:40									4	9	19	26	63	124:30
	50	2:30								1	9	17	19	45	80	174:30
220	5	3:30													2	5:40
	10	3:20												2	5	10:40
	15	3:10											2	5	16	26:40
	20	3:00										1	3	11	24	42:40
	25	3:00										3	8	19	33	66:40
	30	2:50									1	7	10	23	47	91:40
	40	2:50									6	12	22	29	68	140:40
	50	2:40								3	12	17	18	51	86	190:40
230	5	3:40													2	5:50
	10	3:20											1	2	6	12:50
	15	3:20											3	6	18	30:50
	20	3:10										2	5	12	26	48:50
	25	3:10										4	8	22	37	74:50
	30	3:00									2	8	12	23	51	99:50
	40	2:50								1	7	15	22	34	74	156:50
	50	2:50								5	14	16	24	51	89	202:50
240	5	3:50													2	6:00
	10	3:30											1	3	6	14:00
	15	3:30											4	6	21	35:00
	20	3:20										3	6	15	25	53:00
	25	3:10									1	4	9	24	40	82:00
	30	3:10									4	8	15	22	56	109:00
	40	3:00								3	7	17	22	39	75	167:00
	50	2:50							1	8	15	16	29	51	94	218:00

TABLE 1-14.—*U.S. Navy Standard Air Decompression Table for exceptional exposures*—Continued

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)													Total ascent time (min:sec)
			130	120	110	100	90	80	70	60	50	40	30	20	10	
250	5	3:50												1	2	7:10
	10	3:40											1	4	7	16:10
	15	3:30										1	4	7	22	38:10
	20	3:30										4	7	17	27	59:10
	25	3:20									2	7	10	24	45	92:10
	30	3:20									6	7	17	23	59	116:10
	40	3:10								5	9	17	19	45	79	178:10
	60	2:40					4	10	10	10	12	22	36	64	126	298:10
	90	2:10		8	10	10	10	10	10	28	28	44	68	98	186	514:10
260	5	4:00												1	2	7:20
	10	3:50											2	4	9	19:20
	15	3:40										2	4	10	22	42:20
	20	3:30									1	4	7	20	31	67:20
	25	3:30									3	8	11	23	50	99:20
	30	3:20								2	6	8	19	26	61	126:20
	40	3:10							1	6	11	16	19	49	84	190:20
270	5	4:10												1	3	8:30
	10	4:00											2	5	11	22:30
	15	3:50										3	4	11	24	46:30
	20	3:40									2	3	9	21	35	74:30
	25	3:30								2	3	8	13	23	53	106:30
	30	3:30								3	6	12	22	27	64	138:30
	40	3:20							5	6	11	17	22	51	88	204:30
280	5	4:20												2	2	8:40
	10	4:00										1	2	5	13	25:40
	15	3:50									1	3	4	11	26	49:40
	20	3:50									3	4	8	23	39	81:40
	25	3:40								2	5	7	16	23	56	113:40
	30	3:30							1	3	7	13	22	30	70	150:40
	40	3:20						1	6	6	13	17	27	51	93	218:40
290	5	4:30												2	3	9:50
	10	4:10										1	3	5	16	29:50
	15	4:00									1	3	6	12	26	52:50
	20	4:00									3	7	9	23	43	89:50
	25	3:50								3	5	8	17	23	60	120:50
	30	3:40							1	5	6	16	22	36	72	162:50
	40	3:30						3	5	7	15	16	32	51	95	228:50
300	5	4:40												3	3	11:00
	10	4:20										1	3	6	17	32:00
	15	4:10									2	3	6	15	26	57:00
	20	4:00								2	3	7	10	23	47	97:00
	25	3:50							1	3	6	8	19	26	61	129:00
	30	3:50							2	5	7	17	22	39	75	172:00
	40	3:40						4	6	9	15	17	34	51	90	231:00
	60	3:00		4	10	10	10	10	10	14	28	32	50	90	187	460:00

TABLE 1-14.—*U.S. Navy Standard Air Decompression Table for exceptional exposures*—Continued

Extreme exposures—250 and 300 ft

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Decompression stops (feet)																				Total ascent time (min:sec)
			200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	
250	120	1:50							5	10	10	10	10	16	24	24	36	48	64	94	142	187	684:10
	180	1:30					4	8	8	10	22	24	24	32	42	44	60	84	114	122	142	187	931:10
	240	1:30					9	14	21	22	22	40	40	42	56	76	98	100	114	122	142	187	1109:10
300	90	2:20					3	8	8	10	10	10	10	16	24	24	34	48	64	90	142	187	693:00
	120	2:00			4	8	8	8	8	10	14	24	24	24	34	42	58	66	102	122	142	187	890:00
	180	1:40	6	8	8	8	14	20	21	21	28	40	40	48	56	82	98	100	114	122	142	187	1168:00

TABLE 1–15.–*Surface decompression table using oxygen*

(FORMERLY TABLE 1–17, 1963 DIVING MANUAL)

1	2	3	4				5	6	7	8
Depth (ft, gage)	Bottom time (min)[1]	Time to first stop or surface[2]	Time (min) breathing air at water stops (ft)[3]				Surface interval[4]	Time at 40-foot chamber stop (min) on oxygen[5]	Surface[6]	Total decom-pression time (min:sec)[7]
			60	50	40	30				
70	52	2:48	0	0	0	0	SURFACE INTERVAL NOT TO EXCEED 5 MINUTES	0	2-MINUTE ASCENT FROM 40 FEET IN CHAMBER TO SURFACE WHILE BREATHING OXYGEN	2:48
	90	2:48	0	0	0	0		15		23:48
	[8]120	2:48	0	0	0	0		23		31:48
	150	2:28	0	0	0	0		31		39:48
	180	2:48	0	0	0	0		39		47:48
80	40	3:12	0	0	0	0		0		3:12
	70	3:12	0	0	0	0		14		23:12
	85	3:12	0	0	0	0		20		29:12
	100	3:12	0	0	0	0		26		35:12
	[8]115	3:12	0	0	0	0		31		40:12
	130	3:12	0	0	0	0		37		46:12
	150	3:12	0	0	0	0		44		53:12
90	32	3:36	0	0	0	0		0		3:36
	60	3:36	0	0	0	0		14		23:36
	70	3:36	0	0	0	0		20		29:36
	80	3:36	0	0	0	0		25		34:36
	[8]90	3:36	0	0	0	0		30		39:36
	100	3:36	0	0	0	0		34		43:36
	110	3:36	0	0	0	0		39		48:36
	120	3:36	0	0	0	0		43		52:36
	130	3:36	0	0	0	0		48		57:36
100	26	4:00	0	0	0	0		0		4:00
	50	4:00	0	0	0	0		14		24:00
	60	4:00	0	0	0	0		20		30:00
	70	4:00	0	0	0	0		26		36:00
	[8]80	4:00	0	0	0	0		32		42:00
	90	4:00	0	0	0	0		38		48:00
	100	4:00	0	0	0	0		44		54:00
	110	4:00	0	0	0	0		49		59:00
	120	4:00	0	0	0	0		53		63:00

See footnotes at end of table.

TABLE 1-15.–*Surface decompression table using oxygen*–Continued

1 Depth (ft, gage)	2 Bottom time (min)[1]	3 Time to first stop or surface[2]	4 Time (min) breathing air at water stops (ft)[3]				5 Surface interval[4]	6 Time at 40-foot chamber stop (min) on oxygen[5]	7 Surface[6]	8 Total decompression time (min:sec)[7]
			60	50	40	30				
110	22	4:24	0	0	0	0	SURFACE INTERVAL NOT TO EXCEED 5 MINUTES	0	2-MINUTE ASCENT FROM 40 FEET IN CHAMBER TO SURFACE WHILE BREATHING OXYGEN	4:24
	40	4:24	0	0	0	0		12		22:24
	50	4:24	0	0	0	0		19		29:24
	60	4:24	0	0	0	0		26		36:24
	[8]70	4:24	0	0	0	0		33		43:24
	80	3:12	0	0	0	1		40		51:12
	90	3:12	0	0	0	2		46		58:12
	100	3:12	0	0	0	5		51		66:12
	110	3:12	0	0	0	12		54		76:12
120	18	4:48	0	0	0	0		0		4:48
	30	4:48	0	0	0	0		9		19:48
	40	4:48	0	0	0	0		16		26:48
	50	4:48	0	0	0	0		24		34:48
	[8]60	3:36	0	0	0	2		32		44:36
	70	3:36	0	0	0	4		39		53:36
	80	3:36	0	0	0	5		46		61:36
	90	3:12	0	0	3	7		51		72:12
	100	3:12	0	0	6	15		54		86:12
130	15	5:12	0	0	0	0		0		5:12
	30	5:12	0	0	0	0		12		23:12
	40	5:12	0	0	0	0		21		32:12
	50	4:00	0	0	0	3		29		43:00
	[8]60	4:00	0	0	0	5		37		53:00
	70	4:00	0	0	0	7		45		63:00
	80	3:36	0	0	0	7		51		75:36
	90	3:36	0	0	10	12		56		89:36
140	13	5:36	0	0	0	0		0		5:36
	25	5:36	0	0	0	0		11		22:36
	30	5:36	0	0	0	0		15		26:36
	35	5:36	0	0	0	0		20		31:36
	40	4:24	0	0	0	2		24		37:24
	45	4:24	0	0	0	4		29		44:24
	50	4:24	0	0	0	6		33		50:24
	[8]55	4:24	0	0	0	7		38		56:24
	60	4:24	0	0	0	8		43		62:24
	65	4:00	0	0	3	7		48		70:00
	70	3:36	0	2	7	7		51		79:36

TABLE 1–15.–*Surface decompression table using oxygen*–Continued

1	2	3	4				5	6	7	8
Depth (ft, gage)	Bottom time (min)[1]	Time to first stop or surface[2]	Time (min) breathing air at water stops (ft)[3]				Surface interval[4]	Time at 40-foot chamber stop (min) on oxygen[5]	Surface[6]	Total decompression time (min:sec)[7]
			60	50	40	30				
150	11	6:00	0	0	0	0	SURFACE INTERVAL NOT TO EXCEED 5 MINUTES	0	2-MINUTE ASCENT FROM 40 FEET IN CHAMBER TO SURFACE WHILE BREATHING OXYGEN	6:00
	25	6:00	0	0	0	0		13		25:00
	30	6:00	0	0	0	0		18		30:00
	35	4:48	0	0	0	4		23		38:48
	40	4:24	0	0	3	6		27		48:24
	45	4:24	0	0	5	7		33		57:24
	[8]50	4:00	0	2	5	8		38		66:00
	55	3:36	2	5	9	4		44		77:36
160	9	6:24	0	0	0	0		0		6:24
	20	6:24	0	0	0	0		11		23:24
	25	6:24	0	0	0	0		16		28:24
	30	5:12	0	0	0	2		21		35:12
	35	4:48	0	0	4	6		26		48:48
	40	4:24	0	3	5	8		32		61:24
	[8]45	4:00	3	4	8	6		38		73:00
170	7	6:48	0	0	0	0		0		6:48
	20	6:48	0	0	0	0		13		25:48
	25	6:48	0	0	0	0		19		31:48
	30	5:12	0	0	3	5		23		44:12
	35	4:48	0	4	4	7		29		57:48
	[8]40	4:24	4	4	8	6		36		72:24

[1]Time interval in minutes from leaving the surface to leaving the bottom.

[2]Time of ascent in minutes and seconds to the first stop or to the surface at a rate of 25 feet per minute.

[3]Water stops: Time spent at tabulated stops using air. If no water stops are required, use a 25-foot-per-minute rate of ascent to the surface. When water stops are required, use a 25-foot-per-minute rate of ascent to the first stop. Take an additional minute between stops. Use 1 minute for the ascent from 30 feet to the surface.

[4]Surface interval: The surface interval shall not exceed 5 minutes and is composed of the following elements:

a. Time of ascent from the 30-foot water stop to the surface (1 minute).
b. Time on the surface for landing the diver on deck and undressing (not to exceed 3 minutes and 30 seconds).
c. Time of descent in the recompression chamber from the surface to 40 feet (about 30 seconds).

[5]See Table 1–32, paragraph (10).

[6]Surfacing: Oxygen breathing during this 2-minute period shall follow without interruption the period of oxygen breathing tabulated in col. 6.

[7]Total decompression time in minutes and seconds. This time includes:

a. Time of ascent from the bottom to the first stop at 25 feet per minute, col. 3.
b. Sum of tabulated water stops, col. 4.
c. One minute between water stops.
d. The surface interval, col. 5.
e. Time at 40 feet in the recompression chamber, col. 6.
f. Time of ascent, an additional 2 minutes, from 40 feet to the surface, col. 7.

The total decompression time may be shortened only by decreasing the time required to undress the diver on deck.

[8]These are the optimum exposure times for each depth and represent for the average diver the best balance of safety, length of work period, and amount of useful work. Exposure beyond these limits of time is permitted only under special conditions.

TABLE 1-16.–*Surface decompression table using air*

(FORMERLY TABLE 1–18, 1963 DIVING MANUAL)

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Time at water stops (min)				Chamber stops (air) (min)		Total ascent time (min:sec)
			30	20	10		20	10	
40	230	:30			3	TIME ON SURFACE NOT TO EXCEED 3 MINUTES AND 30 SECONDS		7	14:30
	250	:30			3			11	18:30
	270	:30			3			15	22:30
	300	:30			3			19	26:30
50	120	:40			3			5	12:40
	140	:40			3			10	17:40
	160	:40			3			21	28:40
	180	:40			3			29	36:40
	200	:40			3			35	42:40
	220	:40			3			40	47:40
	240	:40			3			47	54:40
60	80	:50			3			7	14:50
	100	:50			3			14	21:50
	120	:50			3			26	33:50
	140	:50			3			39	46:50
	160	:50			3			48	55:50
	180	:50			3			56	63:50
	200	:40		3			3	69	80:10
70	60	1:00			3			8	16:00
	70	1:00			3			14	22:00
	80	1:00			3			18	26:00
	90	1:00			3			23	31:00
	100	1:00			3			33	41:00
	110	:50		3			3	41	52:20
	120	:50		3			4	47	59:20
	130	:50		3			6	52	66:20
	140	:50		3			8	56	72:20
	150	:50		3			9	61	78:20
	160	:50		3			13	72	93:20
	170	:50		3			19	79	106:20
80	50	1:10			3			10	18:10
	60	1:10			3			17	25:10
	70	1:10			3			23	31:10
	80	1:00		3			3	31	42:30
	90	1:00		3			7	39	54:30
	100	1:00		3			11	46	65:30
	110	1:00		3			13	53	74:30
	120	1:00		3			17	56	81:30
	130	1:00		3			19	63	90:30
	140	1:00		26			26	69	126:30
	150	1:00		32			32	77	146:30

TABLE 1–16.—*Surface decompression table using air*—Continued

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Time at water stops (min)					TIME ON SURFACE NOT TO EXCEED 3 MINUTES AND 30 SECONDS	Chamber stops (air) (min)		Total ascent time (min:sec)
			50	40	30	20	10		20	10	
90	40	1:20					3			7	15:20
	50	1:20					3			18	26:20
	60	1:20					3			25	33:20
	70	1:10				3			7	30	45:40
	80	1:10				13			13	40	71:40
	90	1:10				18			18	48	89:40
	100	1:10				21			21	54	101:40
	110	1:10				24			24	61	114:40
	120	1:10				32			32	68	137:40
	130	1:00			5	36			36	74	156:40
100	40	1:30					3			15	23:30
	50	1:20				3			3	24	35:50
	60	1:20				3			9	28	45:50
	70	1:20				3			17	39	64:50
	80	1:20				23			23	48	99:50
	90	1:10			3	23			23	57	111:50
	100	1:10			7	23			23	66	124:50
	110	1:10			10	34			34	72	155:50
	120	1:10			12	41			41	78	177:50
110	30	1:40					3			7	15:40
	40	1:30				3			3	21	33:00
	50	1:30				3			8	26	43:00
	60	1:30				18			18	36	78:00
	70	1:20			1	23			23	48	101:00
	80	1:20			7	23			23	57	116:00
	90	1:20			12	30			30	64	142:00
	100	1:20			15	37			37	72	167:00
120	25	1:50					3			6	14:50
	30	1:50					3			14	22:50
	40	1:40				3			5	25	39:10
	50	1:40				15			15	31	67:10
	60	1:30			2	22			22	45	97:10
	70	1:30			9	23			23	55	116:10
	80	1:30			15	27			27	63	138:10
	90	1:30			19	37			37	74	173:10
	100	1:30			23	45			45	80	189:10
130	25	2:00					3			10	19:00
	30	1:50				3			3	18	30:20
	40	1:50				10			10	25	51:20
	50	1:40			3	21			21	37	88:20
	60	1:40			9	23			23	52	113:20
	70	1:40			16	24			24	61	131:20
	80	1:30		3	19	35			35	72	170:20
	90	1:30		8	19	45			45	80	203:20

TABLE 1-16.–*Surface decompression table using air*–Continued

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Time at water stops (min)						Chamber stops (air) (min)		Total ascent time (min:sec)
			50	40	30	20	10		20	10	
140	20	2:10					3	TIME ON SURFACE NOT TO EXCEED 3 MINUTES AND 30 SECONDS		6	15:10
	25	2:00				3			3	14	26:30
	30	2:00				5			5	21	37:30
	40	1:50			2	16			16	26	66:30
	50	1:50			6	24			24	44	104:30
	60	1:50			16	23			23	56	124:30
	70	1:40		4	19	32			32	68	161:30
	80	1:40		10	23	41			41	79	200:30
150	20	2:10				3			3	7	19:40
	25	2:10				4			4	17	31:40
	30	2:10				8			8	24	46:40
	40	2:00			5	19			19	33	82:40
	50	2:00			12	23			23	51	115:40
	60	1:50		3	19	26			26	62	142:40
	70	1:50		11	19	39			39	75	189:40
	80	1:40	1	17	19	50			50	84	227:40
160	20	2:20				3			3	11	23:50
	25	2:20				7			7	20	40:50
	30	2:10			2	11			11	25	55:50
	40	2:10			7	23			23	39	98:50
	50	2:00		2	16	23			23	55	125:50
	60	2:00		9	19	33			33	69	169:50
	70	1:50	1	17	22	44			44	80	214:50
170	15	2:30				3			3	5	18:00
	20	2:30				4			4	15	30:00
	25	2:20			2	7			7	23	46:00
	30	2:20			4	13			13	26	63:00
	40	2:10		1	10	23			23	45	109:00
	50	2:10		5	18	23			23	61	137:00
	60	2:00	2	15	22	37			37	74	194:00
	70	2:00	8	17	19	51			51	86	239:00
180	15	2:40				3			3	6	19:10
	20	2:30			1	5			5	17	35:10
	25	2:30			3	10			10	24	54:10
	30	2:30			6	17			17	27	74:10
	40	2:20		3	14	23			23	50	120:10
	50	2:10	2	9	19	30			30	65	162:10
	60	2:10	5	16	19	44			44	81	216:10

TABLE 1-16.—*Surface decompression table using air*—Continued

Depth (ft)	Bottom time (min)	Time to first stop (min:sec)	Time at water stops (min)					TIME ON SURFACE NOT TO EXCEED 3 MINUTES AND 30 SECONDS	Chamber stops (air) (min)		Total ascent time (min:sec)
			50	40	30	20	10		20	10	
190	15	2:50				4			4	7	22:20
	20	2:40			2	6			6	20	41:20
	25	2:40			5	11			11	25	59:20
	30	2:30		1	8	19			19	32	86:20
	40	2:30		8	14	23			23	55	130:20
	50	2:20	4	13	22	33			33	72	184:20
	60	2:20	10	17	19	50			50	84	237:20

NOTE.—The ascent rates in this table are 60 feet per minute to the first stop, between stops and to the surface in the water and in the chamber. The descent rate in the chamber is also 60 feet per minute. The total ascent time may be shortened only by shortening the surface interval.

APPENDIX B

AIR SUPPLY SYSTEM (G.G. BROWN BUILDING) AND AIR PURITY SPECIFICATIONS

PRIMARY AIR SYSTEM (G. G. Brown Building, Fig. 13)

Normally, one compressor is "ON" at all times; it automatically engages to pump air when the pressure in the air receiver drops. Prior to pressurization, an attendant should assure that a compressor is "ON" and drain moisture accumulations from the air receiver-moisture separator tank. The moisture is drained by opening a valve on a pipe extending from the lower portion of the tank (east side). Allow air and moisture to discharge into floor drain for at least 5 min or until no more moisture is evident in the discharge. A 12-inch crescent wrench may be used for opening the discharge valve.

If the compressor is not operating, or it is necessary to activate the other compressor, use the following procedure:

1. Check compressor cylinder lubricator oil level (sight glass). The level must never drop below 1/3 full. Add Stanoil Industrial Oil No. 31 if necessary.

2. Check compressor crankcase oil level; it must be near the center of the sight glass.

3. Turn the power and drive motor for the appropriate compressor at the main power panel on the southeast wall of the room. It may be necessary to depress the restart button.

4. Turn selector switch on the compressor control panel to either "ON" position.

5. Check crankcase oil pressure gauge. It must read between 25 and 30 psig: if below 20 psig, TURN COMPRESSOR OFF.

6. Check intercooler pressure; it should read between 22 and 30 psig when the compressure *is pumping air.*

7. Observe air pressure gauge until it reaches approximately 100 psi and the compressor disengages.

8. Drain air receiver as indicated.

To Stop A Compressor:

1. Turn selector switch on the compressor control panel to the "OFF" position.

2. Turn off drive motor at the main power panel.

Additional instructions for compressor operation are posted on the compressors. If a compressor malfunction is suspected, contact the proper authorities. Telephone numbers for compressor repair and maintenance service are posted in 1038 G. G. Brown.

EMERGENCY AIR SYSTEM OPERATION (1038 G. G. Brown Building)

The emergency air system consists of banks of high-pressure air, a regulator, and appropriate lines and fittings to connect the system to chamber piping. Normally, three banks of 6--300 cf of high-pressure cylinders will be available in the chamber room. These banks should be gauged on a regular schedule and maintained "FULL" between treatments. They are charged with a high-pressure compressor; instructions for compressor operation are posted on or near the compressor.

Prior to starting treatment, attach a regulator to one air bank. A regulator labeled "EMERGENCY AIR REGULATOR FOR CHAMBER" is located in equipment locker no. 4. Attach regulator to bank manifold and ensure that regulator is deactivated by turning pressure selector in counter-clockwise direction until it turns without resistance. Turn on one cylinder valve slowly and ensure that regulator is functioning by turning pressure selector in a clockwise direction until a small amount of air discharges. Deactivate regulator and ensure that all cylinders are full. Attach emergency air supply line to the regulator outlet. With the primary air supply valve closed, insert the quick-connect coupling into the chamber supply line fitting (labeled) on west wall of room. Activate emergency air flow briefly. Set regulator at approximately 200 psig. Close manifold valve on air bank and drain the regulator and supply line. The air bank with regulator and supply line attached may be disconnected and stowed near by in readiness during treatment.

In the event of an electrical power failure or malfunction of the primary air compressor system, initiate the following emergency procedures to supply air to the chamber:

1. Immediately close all chamber inlet and exhaust valves.

2. *Close* the primary air supply valve located on the west wall of the room. Failure to close this valve will result in loss of emergency air.

3. Connect emergency air supply line.

4. Open air bank manifold valve.

5. Continue normal ventilation procedures; adjust emergency supply regulator as needed.

6. If electrical power is still functioning, go to the compressor room, turn off the malfunctioning compressor, and turn on the standby compressor. It may only be necessary to restart the compressor that stopped.

7. If a malfunction is suspected, request emergency compressor service. Appropriate numbers are posted in the chamber room.

AIR PURITY SPECIFICATIONS

Breathing air for chamber pressurization and ventilation must be free from carbon monoxide, carbon dioxide, *oil vapor*, and other impurities. The air should be analyzed periodically to ensure purity for breathing in accordance with the following specifications:

Oxygen	Atmospheric
Maximum carbon monoxide .	0.001% (10 ppm)
Maximum carbon dioxide . .	0.050% (500 ppm)
Maximum total volatile hydrocarbons . . .	0.001% (10 ppm)
Maximum total oxides . . .	0.000005% (.05 ppm)
Dust and droplets of water and oil	Lack of any residue after passage of 5000 cc of air through a white membrane sieve filter
Odor	Absent

For details on air testing and air system maintenance, consult U.S. Navy (1970a), Somers (1972), and the compressor manufacturer's maintenance manuals.

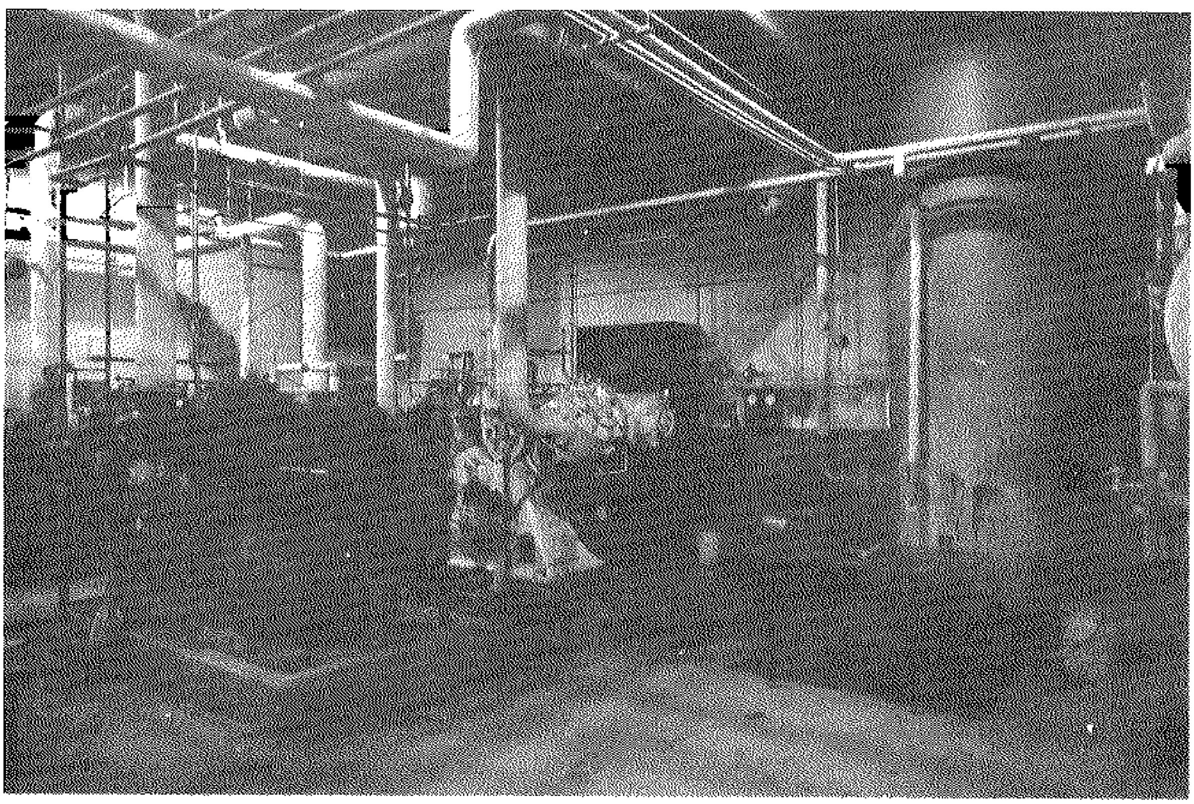

FIGURE 13 Primary Air Supply System

APPENDIX C

VALVE CALIBRATION

The standard procedure for determining volume ventilation is to open the chamber exhaust valve a given number of turns (or fraction of a turn), which provides a given number of cubic feet of ventilation per minute at a specific chamber pressure. Constant chamber pressure during the ventilation period is then maintained with the air supply or control valve. To calibrate the exhaust valve, use the following procedure:

1. Mark the valve handle to facilitate relatively accurate determination of the number of turns and fractions of turns.

2. Compute the rates of ventilation at various depths that are commonly needed in treatment. If the air supply is ample, determination of ventilation rates for 30, 60, 100, and 165 ft may be sufficient, because the valve opening specified for a given flow at one depth will provide at least that much at a greater depth. It will be convenient to know the valve settings for rates like 30, 60, or 120 cfm because these give a simple relationship between volume and time. Be certain to use settings for ventilation rates required at 30 and 60 foot stops that are compatible with the chamber and normal number of occupants.

3. Determine the necessary valve settings for the selected flows and depths by using the chamber itself as a measuring vessel and a stopwatch for timing.

a. Calculate the time required to change the chamber pressure by 10 ft if the exhaust valve setting were allowing air to escape at the desired rate close to the given depth. Use the formula:

$$T = \frac{V \times 20}{R \times (P + 33)/33}$$

where,

T = time in seconds for chamber pressure to change 10 ft.

V = internal volume of compartment being used for test (cf).

R = rate of ventilation desired in cfpm as measured at chamber pressure.

P = chamber pressure (gauge) in feet of sea water

b. Pressurize the empty compartment to 5 ft beyond the given depth. Open the exhaust valve a certain amount and determine the time required for a change of 10 ft. For example, if checking for a depth of 165 ft, pressurize to 170 ft and clock the time required for decompression to 160 ft. Repeat the procedure while varying the valve opening until you determine what setting will provide a rate closest to the calculated time. Calculate times for other rates and depths and determine settings in the same way. Make a chart or table of valve settings.

This procedure is difficult with 1/4-turn ball valves used on many civilian chambers. A reference template may be required on the valve.

APPENDIX D

OXYGEN MONITORING EQUIPMENT

BioMarine Industries' Model 0A202, Portable Oxygen Analyzer

A BioMarine Industries' Model 0A202 Portable Oxygen Analyzer is provided for university chambers where oxygen is used for therapy, research, or surface decompression procedures. Oxygen level in hyperbaric chambers should not exceed 25%.

In the analyzer, oxygen is sensed directly by a galvanic cell containing a gold cathode and a lead anode in a basic electrolyte. The entire cell is encapsulated in inert plastic. The sensor face is a fluorocarbon polymer. Oxygen diffusing through the cell face initiates redox reactions which generate a minute current proportional to the oxygen partial pressure. A temperature-compensated circuit converts the current to a proportional voltage which is displayed directly on the meter face as oxygen percentage. This figure must be converted to actual oxygen percentage based on the depth of the chamber; conversion procedures and tables are included. The unit may be single-point calibrated with gas mixtures of any known concentration within the range of the meter. Normally the unit is calibrated with atmospheric air.

The following are specifications for the Model 0A202:

Scale: 0–100%

Response: 90% in less than 20 sec.

Calibration Linearity: ± 1% of scale at constant temperature.

Accuracy: ± 1% of full scale.

Temperature Compensation Error: ± 5% in range 32°–104° F

Pressure: 500 psi miximum

Decompression Rate: 50 psi/min maximum

This unit is shown in Figure 14.

OPERATION

To operate the instrument, check on the calibration and then use the instrument either for direct, remote, or sample analysis.

1. **Calibration:** If the instrument is being used to analyze oxygen levels below 50%, calibration can be performed in fresh air. To calibrate, expose the instrument, or the extension sensor if connected, to air, and the scale reading should be 21%, then rotate the calibration screw with a small screwdriver until the meter reads 21%.

If the instrument is being used to analyze oxygen levels above 50%, calibration should be performed using gas mixtures with a known high oxygen concentration or with pure 100% oxygen. The instrument face sensor, or remote sensor if it is connected, should be exposed to the gas. This can be done by placing the instrument or remote sensor in a box or bag filled with the gas mixture, and, after a period of a minute, adjusting the calibration screw until the meter reading is set at the known value of oxygen in the gas.

NOTE: For instruments which operate with the face sensor and the remote sensor, calibration must be performed with the sensor being used for analysis.

2. **Analysis:** After calibration is completed, the instrument can be used in the following ways.

a. Direct Exposure: When the instrument, or the remote sensor if connected, is placed in the atmosphere to be analyzed, the meter will show the percent of oxygen concentration in the atmosphere within one minute after exposure.

b. Sample Analysis: For certain applications, the face sensor, or the remote sensor if attached, is exposed to a sample of the gas being analyzed by using adapters which direct the gas flow over the sensor face. (See BIOMARINE BULLETIN No. 0A71. Application of adapters to 200 Series instruments.)

APPLICATION NOTES

1. **High Humidity Atmospheres:** If the instrument, or remote sensor if attached, is in operation in a high humidity atmosphere, it is advisable to ensure that moisture does not condense and pool on the sensor face. This can be achieved by placing the sensor on its side so that any moisture will run off the face after condensation.

2. **Effects of Altitude:** As altitude above sea level increases, the amount of oxygen available decreases for a fixed percentage setting on the instrument. This effect should be taken into account when prescribing oxygen percentages at altitude.

This effect is generally not significant except for altitudes several thousand feet above sea level.

3. **Hyperbaric Atmosphere:** If the instrument, or the remote sensor if attached, is in operation in a hyperbaric atmosphere, the true oxygen percentage may be calculated as follows:

$$\%\ \text{oxygen} = \frac{\text{meter reading}}{1 + (\text{depth in fsw})/33}$$

The following chart provides the necessary figures for normal chamber operations:

Depth (fsw)	Meter reading for true oxygen 21%	25%	30%
10	27	32.6	39
20	33.7	40	48
30	39.9	47.5	57
40	46.5	55	66
50	52.8	62.5	75
60	59.2	70	84
66	63	75	90

Specific instructions and precautions:

a. Do not exceed a pressurization or depression rate of 50 psi/min. In normal practice, pressurize and depressurize at the same rate as a human subject.

b. Pressurize instrument to treatment depth in normal air environment and adjust calibration (if necessary) for appropriate reading given on above chart prior to introduction of excess oxygen into the chamber atmosphere.

c. If the initial pressurization depth is to exceed 66 fsw, do not place the instrument in the chamber. Wait until the chamber is decompressed to 66 fsw or less and lock the instrument in through the medical or man-lock. Oxygen partial pressures beyond the *equivalent* of 100% at one atmosphere or 760 mm Hg may damage the meter.

MAINTENANCE

The instrument should be maintenance free under most operating conditions, however, a certain amount of preventative maintenance will ensure the continued operation of the instrument and minimize the requirement for repair or replacement.

In the event of apparent failure, it is suggested that you contact your local BMI representative. If this is not convenient, contact BioMarine Industries, 303 W. Lancaster Avenue, Devon, Pennsylvania.

1. **Preventive Maintenance:** It is advisable to perform the following operations on a routine basis.

a. Check and adjust the calibration of the instrument or its remote sensor once a week if used under normal conditions, and every 72 hrs if used in extreme temperature and humidity atmospheres.

b. Clean the face of the sensor with a soft damp cloth every month under normal conditions, or after every use where high concentrations of contaminants were present.

2. **Sensor Replacement:** When the face sensor, or the remote sensor if connected, can no longer be calibrated by adjustment of the calibration screw, even after the sensor has been cleaned with a damp cloth, it can be assumed that the useful life of the sensor has terminated and it should be replaced.

To replace the face sensor, refer to Figure 15. Remove the two screws (A) on the back cover plate (B) and lift out the chassis (C). Unscrew the face ring (D) of the sensor, detach the two sensor wire connectors (E) and remove the failed sensor. Connect the red stripe and black stripe wires to replacement sensor. (see Fig. 16). Replace the sensor face ring and the back cover plate and secure the two screws in the back of the instrument. After calibration, the unit is ready for use.

To replace remote sensor, simply remove from remote sensor plug and discard. Plug in replacement remote sensor. After calibration, the unit is ready for use.

NOTE: Under no circumstances should an attempt be made to disassemble the sensor body. This would render the BMI warranty void.

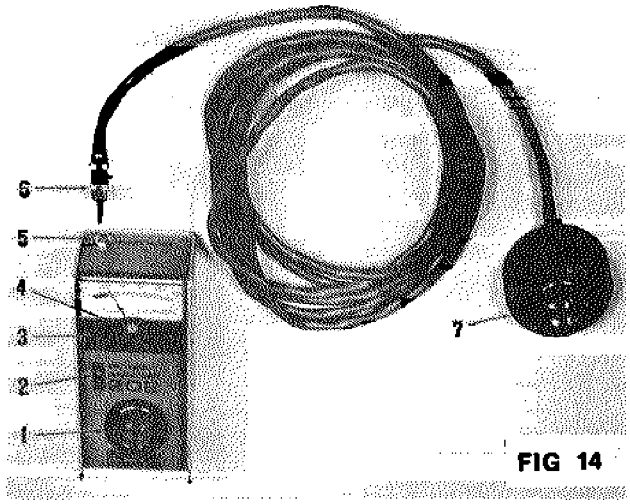

Figure 14   Portable Oxygen Analyzer

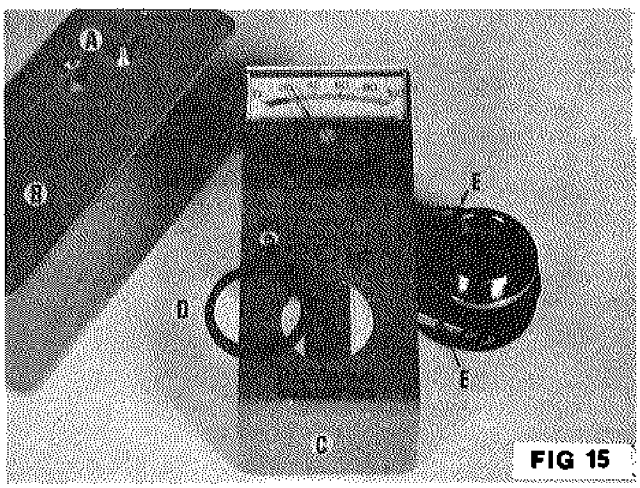

Figure 15   Sensor Replacement

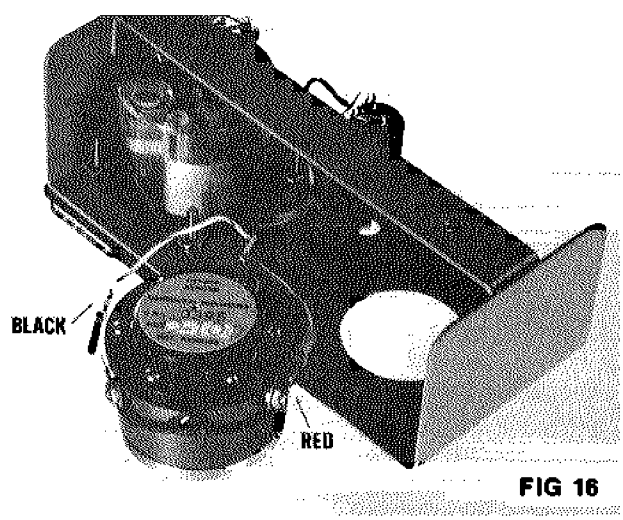

Figure 16   Sensor Replacement

APPENDIX E

SCOTT DIVER'S INHALATOR WITH OVERBORAD DISCHARGE

This appendix delineates operation and maintenance instructions and replaceable parts information for the Scott Aviation P/N 801238–00 Diver's Inhalator with Overboard Discharge (Pressure Vacuum System). The system consists of a mask fitted with a demand regulator for oxygen supply, a vacuum regulator, and necessary hoses and fittings. The systems differ only in the lengths of the supply and vacuum hoses.

The assembly, mask, and regulators are intended for use in administering breathing oxygen in a hyperbaric chamber during decompression. The mask provides for a face seal to prevent oxygen leakage past the seal to face interface. It can be held to the face by hand or affixed by head straps.

The demand regulator is capable of providing adequate flow by reducing the oxygen supply pressure to a breathable pressure. It is also capable of providing a constant flow by adjusting the control knob into the constant flow position.

The exhalation regulator allows the exhaled gases to be carried to an outside atmosphere by way of a vacuum source system.

OPERATION

a. Connect the supply hose and the vacuum hose to the proper chamber connections.

b. Ascertain the presence of the blow-out disc in the housing on the rear of the vacuum regulator assembly.

c. Turn the supply and vacuum sources on.

d. Don the mask assembly, chin first.

e: Place the lower headband below the ears, connecting the right and left straps at the rear of the head. Place the upper headband above the ears, connecting the right and left straps at the rear of the head. Adjust the headbands for the most comfortable, snuggest fit.

f. Adjust the knob on the demand regulator assembly for either demand operation or constant flow operation. Turning the knob to its fullest inward limit (clockwise) will provide constant flow, and turning the knob to its fullest outward position (counterclockwise) will provide demand operation.

g. After use, remove the mask, turn the vacuum and supply sources off and disconnect the supply and vacuum hoses from the chamber connections.

DISASSEMBLY (See Fig. 17)

Use the following procedure to disassemble the system. Disassemble only to the extent shown. Disassembly beyond the extent shown may result in permanent damage to the system.

a. Unthread supply hose (1 or 2) at the demand regulator assembly.

b. Open clamp (5) to allow removal of exhaust hose (3 or 4) from the vacuum regulator; then remove clamp (5).

c. Remove gasket (6) from end of hose (1 or 2).

d. Remove sleeves (7) then screens (7A) from hose (3 or 4).

e. Slide grommets (8) off hose assemblies.

f. Remove the demand regulator assembly by removing nut (9) and washer (10).

g. Remove cover assembly (11) by spreading and removing clamp (12).

h. Lift diaphragm assembly (13) out of case assembly (17).

i. Remove clamp (14) and spring (15); then remove stem assembly (16) from case assembly (17).

j. Remove the vacuum regulator by removing nut (18) and washer (19).

k. Remove cover (20) by spreading and removing clamp (21).

l. Lift diaphragm and stem guide assembly (22) out of case assembly (26).

m. Slide spring (23) off valve assembly (24) then remove valve assembly from case assembly (26).

n. If the regulator is fitted with either a rubber plug or a blow-out disc assembly, obtain teflon plug (25) and follow the procedure outlines on modification instruction sheet, P/N 89026-00 enclosed with the plug. NOTE: Do not remove plug from regulators where it has already been installed.

o. Unsnap headbands (27) from facepiece assembly (28).

INSPECTION

Use the following procedure to inspect the system following each use:

a. Inspect hoses, mask facepiece assembly, headbands and diaphragms for rips, tears, and punctures.

b. Inspect threaded fittings for burrs and crossthreading.

c. Inspect for missing or damaged hardware, such as screws, washers, nuts, grommets and clamps.

d. Inspect the mask assembly for fasteners pulling out or identification plate rivet pulling out.

e. Inspect all metal parts for burrs, nicks, dents, cracks and corrosion.

REPAIR AND REPLACEMENT

Repair of parts, other than removing burrs and chasing threads, is not recommended. Parts requiring repair should be replaced and the replaced component returned to Scott Aviation or a qualified overhaul facility.

a. Replace all rubber parts at least once every five years.

b. Replace screens (7A) whenever removed.

CLEANING

a. Periodic external cleaning of the unit should be performed monthly or as required during use.

b. Wash the entire unit, except the regulator assemblies, with a solution of detergent or soap and warm water.

CAUTION: TAKE CARE THAT WATER DOES NOT ENTER THE REGULATOR ASSEMBLY OPENINGS DURING CLEANING PROCEDURE.

c. Wipe the outside of the regulator assemblies with a clean cloth (slightly dampened in clear water) and wipe dry with a lint-free cloth.

WARNING: USE PRECAUTIONS WHEN HANDLING ETHYL ALCOHOL SINCE THIS CHEMICAL IS FLAMMABLE.

d. Clean and disinfect the mask facepiece assembly and headbands by washing with a solution of detergent or soap and warm water. Sponge the components with a 70% solution of ethyl alcohol or a 2% solution of creosol and allow to completely air dry for a minimum of two hours.

WARNING: USE PRECAUTIONS WHEN HANDLING TRICHLOROETHYLENE SINCE THIS CHEMICAL MAY BE HARMFUL TO THE OPERATOR.

e. Metal parts which have been contaminated can be cleaned using a vapor degreasing method with stabilized trichloroethylene conforming to MIL–T–27602.

REASSEMBLY (see Fig. 17)

WARNING: DO NOT ALLOW OIL, GREASE OR FLAMMABLE SOLVENTS TO COME IN CONTACT WITH PARTS THAT WILL BE EXPOSED TO PRESSURIZED OXYGEN. SUCH MATERIALS AS WELL AS DUST, LINT AND FINE METAL FILINGS ARE ALL POTENTIAL COMBUSTIBLES WHICH MIGHT, WHEN EXPOSED TO OXYGEN UNDER PRESSURE, IGNITE AND RESULT IN AN EXPLOSION.

a. Snap headbands (27) onto fasteners in facepiece assembly (28).

b. Install teflon plug (25) in case assembly (26), if the regulator has not been previously modified. Use the procedure outlined on modification instruction sheet, P/N 89026-00, which is enclosed with the plug.

c. Place spring (23) on valve assembly (24) and mount in the outlet port of case assembly (26).

d. Install diaphragm and stem guide assembly (22) in case assembly (26) with lip of stem guide under stem of valve assembly (24) and lip of diaphragm in groove provided in case assembly (26).

NOTE: Insure that diaphragm is free of crimps, bulges or wrinkles.

e. Place cover (20) over diaphragm and secure with clamp (21).

f. Install the vacuum regulator assembly on the right side (as worn) of facepiece assembly (28) using washer (19) and nut (18).

g. Install stem assembly (16) in case assembly (17) inlet port; slide spring (15) over stem assembly (16), then install clamp (14). Secure the clamp to the stem assembly using a small amount of Eccoceram CS bonding material (manufactured by Emerson and Cuming Inc., Canton, Massachusetts).

h. Install diaphragm assembly (13) in case assembly (17), with lip of diaphragm in groove provided in the case assembly.

NOTE: Insure that diaphragm is free of crimps, bulges or wrinkles.

i. Place cover assembly (11) over diaphragm and secure with clamp (12).

j. Install the demand regulator assembly on the left side (as worn) of facepiece assembly (28) using washer (10) and nut (9).

k. Slide grommets (8) onto hoses (1 and 3 or 2 and 4); then install sleeves (7) in both ends of hose (3 or 4) after wrapping screens (7A) around sleeves (7), close to the small end of the sleeves.

l. Insert gasket (6) in hose (1 or 2) and slide clamp (5) over regulator end of hose (3 or 4).

m. Thread hose (1 or 2) fitting onto the demand regulator and secure hose (3 and 4) to the vacuum regulator with clamp (5).

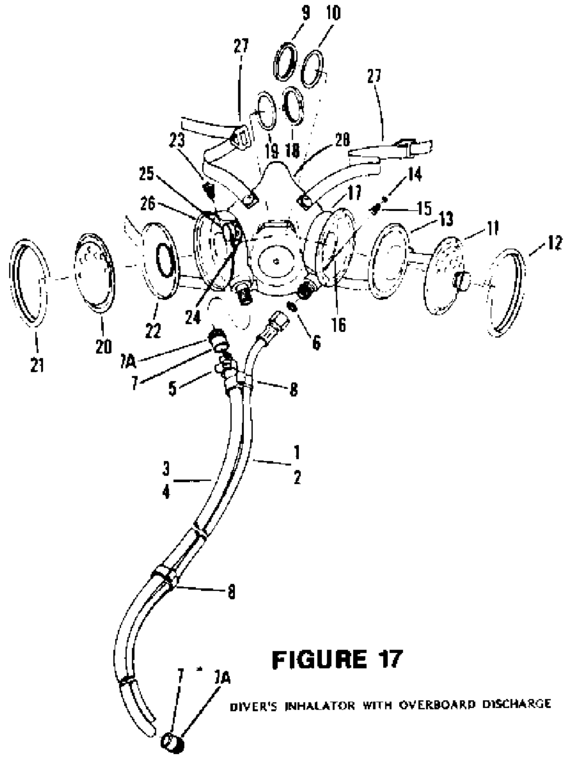

FIGURE 17

DIVER'S INHALATOR WITH OVERBOARD DISCHARGE

TROUBLESHOOTING

The following chart presents the most common troubles occurring with the unit together with their probable causes and remedies.

TROUBLE	PROBABLE CAUSE	REMEDY
Leakage at chamber supply or vacuum connection	Loose connection Cross threading in fitting	Tighten fittings Replace fittings
Leakage at connections to regulator assemblies	Loose fitting at demand regulator Loose or damaged hose clamp at vacuum regulator	Tighten fitting Tighten or replace clamp
Leakage at mating of regulator assemblies and mask	Loose nut Cross threading of nut or regulator case	Replace nut Replace nut or regulator case
No oxygen flow to mask assembly	Open connection at chamber or demand regulator connectors Damaged supply hose Crimped supply hose	Reconnect fittings Replac. hose Straighten hose
No evacuation of user' exhalation	Open connection at vacuum regulator or chamber connectors Damaged vacuum hose Crimped vacuum hose	Reconnect fittings Replace hose Straighten hose

APPENDIX F

FORMS

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HYPERBARIC UNIT

RECOMPRESSION TRAINING RECORD

NAME OF STUDENT *(Last, first, middle initial)*	DIVE	TABLE USED	DATE

CHAMBER OPERATOR	TIME KEEPER	INSIDE ATTENDANT	PHYSICIAN

TIME

PRESSURIZATION START	TOTAL BOTTOM	TOTAL DECOMPRESSION	TOTAL DIVE	EXIT CHAMBER

	DIVE		
	HRS	MIN	SEC
LEAVE SURFACE	0	00	00
REACH FT.			
LEAVE FT.			
REACH FT.			
LEAVE FT.			
REACH FT.			
LEAVE FT.			
REACH 30 FT.			
LEAVE 30 FT.			
REACH 20 FT.			
LEAVE 20 FT.			
REACH 10 FT.			
LEAVE 10 FT.			
REACH SURFACE			

	OXYGEN TOLERANCE TEST		
	HRS	MIN	SEC
ON OXYGEN			
OFF OXYGEN			
PASS	FAIL		

OXYGEN CYLINDER PRESSURE	
START PSIG	
FINISH PSIG	

TIME AT STOP	MAXIMUM DEPTH
40	FT.
30	
20	
10	

REMARKS

OTHER STUDENTS IN CHAMBER

HAMBER OPERATOR *(Signature)*	CHAMBER SUPERVISOR *(Signature)*

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UNDERWATER TECHNOLOGY LABORATORY

HYPERBARIC UNIT

TREATMENT RECORD

NAME OF PATIENT *(Last, first, middle initial)*	DIVE	DATE

CHAMBER OPERATOR	TIME KEEPER	INSIDE ATTENDANT	PHYSICIAN

TIME

PRESSURIZATION START	TOTAL BOTTOM	TOTAL DECOMPRESSION	TOTAL DIVE	EXIT CHAMBER

OXYGEN THERAPY	HRS	MIN	SEC	NOTES
LEAVE SURFACE				
REACH FT				
ON OXYGEN				
LEAVE FT				
REACH 10 FT				
LEAVE 10 FT				
REACH SURFACE				
OFF OXYGEN				

SYMPTOMS, MEDICATIONS, AND COMMENTS:

CYLINDER PRESSURES

	START	FINISH
OXYGEN I		
OXYGEN II		
AIR I		
AIR II		
AIR III		

TIMES FOR ADDITIONAL PERSONNEL PRESSURIZED

NAME	ENTER CHAMBER	BOTTOM TIME	DECOMPRESSION	LEAVE CHAMBER

CHAMBER OPERATOR *(Signature)*	ATTENDING PHYSICIAN *(Signature)*

TREATMENT SCHEDULES FOR AIR EMBOLIMS AND DECOMPRESSION SICKNESS

(INSTRUCTIONS FOR USE IN HYPERBARIC CHAMBER ATTENDANT'S HANDBOOK)

TABLE 5	HRS	MIN	SEC
LEAVE SURFACE	0	00	00
REACH 60 FT			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
LEAVE 60 FT			
ASCENT 30/O_2			
REACH 30 FT			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
ASCENT 30/O_2			
REACH SURFACE			

TABLE 6	HRS	MIN	SEC
LEAVE SURFACE	0	00	00
REACH 60 FT			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
LEAVE 60 FT			
ASCENT 30/O_2			
REACH 30 FT			
COMPLETE 15/AIR			
COMPLETE 60/O_2			
COMPLETE 15/AIR			
COMPLETE 60/O_2			
LEAVE 30 FT			
ASCENT 30/O_2			
REACH SURFACE			

TABLE 5	HRS	MIN	SEC
LEAVE SURFACE	0	00	00
REACH 165 FT			
COMPLETE 15/AIR			
LEAVE 165 FT			
ASCENT 4/AIR			
REACH 60 FT			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
LEAVE 60 FT			
ASCENT 30/O_2			
REACH 30 FT			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
LEAVE 30 FT			
ASCENT 30/O_2			
REACH SURFACE			

NOTES

TABLE 6A	HRS	MIN	SEC
LEAVE SURFACE	0	00	00
REACH 165 FT			
COMPLETE 30/AIR			
LEAVE 165 FT			
ASCENT 4/AIR			
REACH 60 FT			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
COMPLETE 20/O_2			
COMPLETE 5/AIR			
LEAVE 60 FT			
ASCENT 30/O_2			
REACH 30 FT			
COMPLETE 15/AIR			
COMPLETE 60/O_2			
COMPLETE 15/AIR			
COMPLETE 60/O_2			
LEAVE 30 FT			
ASCENT 30/O_2			
REACH SURFACE			

TABLE 4	HRS	MIN	SEC
LEAVE SURFACE	0	00	00
REACH 60 FT			
LEAVE 60 FT			
REACH 100 FT			
LEAVE 100 FT			
REACH 165 FT			
LEAVE 165 FT			
REACH 140 FT			
LEAVE 140 FT			
REACH 120 FT			
LEAVE 120 FT			
REACH 100 FT			
LEAVE 100 FT			
REACH 80 FT			
LEAVE 80 FT			
REACH 60 FT			
LEAVE 60 FT			
REACH 50 FT			
LEAVE 50 FT			
REACH 40 FT			
LEAVE 40 FT			
REACH 30 FT			
LEAVE 30 FT			
REACH 20 FT			
LEAVE 20 FT			
REACH 10 FT			
LEAVE 10 FT			
REACH SURFACE			

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UNDERWATER TECHNOLOGY LABORATORY

CONSENT FOR PRESSURIZATION IN HYPERBARIC CHAMBER

ACKNOWLEDGEMENT OF RISK

This hyperbaric chamber is used with certain precautions to prevent injury to participants. Pressure changes on the body can cause serious injury if any of these conditions are present or were present in the past:

Upper respiratory infection (presently or in the last week)
Bronchospasm (wheezing or asthma)
Repeated pneumonias, pleurisy or pneumothorax (collapsed lung)
Calcium scars in the lung
Emphysema or severe fibrosis of the lung
Cavities, air pockets, or bullae in the lung
Previous chest surgery or radiation
Diabetes or epilepsy

If any of the above are present, consultation with the University's hyperbaric physician will be necessary before pressurization.

As in diving, any inability to equalize pressure in the ears, or severe sinus difficulty will cause severe pain and possible future hearing impairment. On depressurization one must breathe normally as breathholding can cause air embolization and possible pneumothorax (ruptured lung).

I, the Undersigned, do hereby certify that I have successfully completed a nationally recognized training course in skin and scuba diving and/or that I have received a special orientation to pressurization in a hyperbaric chamber. I do acknowledge that I am fully aware of the nature of pressurization in a hyperbaric chamber with specific reference to the fact that pressure changes on the body can cause serious injury if various respiratory abnormalities, or conditions which result in unconsciouness are present or were present in the past. I hereby certify that, to my knowledge, I have no medical problems that are inconsistent with high level physical exertion and the specific requirements related to diving or chamber activity. I further acknowledge that I am aware of the potential risk involved with diving and/or pressurization in a hyperbaric chamber and that I openly accept these risks.

WITNESS: ____________________ ____________________
Signature of Participant

DATE: ____________________ ____________________
Signature of Parent or Guardian
where applicable

THE UNIVERSITY OF MICHIGAN

SEA GRANT PROGRAM

UNDERWATER TECHNOLOGY LABORATORY

WAIVER, RELEASE AND INDEMNITY AGREEMENT

For and in consideration of permission to participate in hyperbaric chamber and Underwater Technology Laboratory activities and related instructional courses given by Sea Grant Program, University of Michigan, City of Ann Arbor, County of Washtenaw, and State of Michigan, the Undersigned hereby voluntarily releases, discharges, waives and relinquishes any and all actions or causes of action for personal injury, property damage or wrongful death occurring to him/herself arising as a result of engaging or receiving instructions in said activity or any activities incidental thereto wherever or however the same may occur and for whatever period said activities or instructions may continue, and the Undersigned does for him/herself, his/her heirs, executors, administrators and assigns hereby release, waive, discharge, and relinquish any action or causes of action, aforesaid, which may hereafter arise for him/herself and for his/her estate, and agrees that under no circumstances wil he/she or his/her heirs, executors, administrators and assigns prosecute, present any claim for personal injury, property damage or wrongful death against the University of Michigan or any of its officers, agents, servants, or employees for any of said causes of action, whether the same shall arise by the negligence of any of said persons, or otherwise. IT IS THE INTENTION OF THE UNDERSIGNED BY THIS INSTRUMENT, TO EXEMPT AND RELIEVE THE UNIVERSITY OF MICHIGAN FROM LIABILITY FOR PERSONAL INJURY, PROPERTY DAMAGE OR WRONGFUL DEATH CAUSED BY NEGLIGENCE OR OTHERWISE.

The Undersigned, for him/herself, his/her heirs, executors, administrators or assigns agrees that in the event any claim for personal injury, property damage or wrongful death shall be prosecuted against the University of Michigan he/she shall indemnify and save harmless the same University of Michigan from any and all claims or causes of action by whomever or wherever made or presented for personal injuries, property damage or wrongful death.

The Undersigned acknowledges that he/she has read the foregoing two paragraphs, has been fully and completely advised of the potential dangers incidental to engaging in the diving and instruction activity and is fully aware of the legal consequences of signing the within instrument.

WITNESS: ______________________ ______________________
Signature of Participant

DATED: ______________________ ______________________
Signature of Parent or Guardian where applicable

THE UNIVERSITY OF MICHIGAN

UNDERWATER TECHNOLOGY LABORATORY

HYPERBARIC CHAMBER

PARENTAL OR GUARDIAN'S RELEASE AND INDEMNITY AGREEMENT

The Undersigned, being the parent, guardian, or person having the care and custody of ______________________________ (minor's name) does hereby consent that his son/daughter/ward may participate in the hyperbaric chamber activities and instruction and in consideration of The University of Michigan of Ann Arbor, Michigan, permitting our ______________ to so participate, does hereby covenant and agree not to sue The University of Michigan of Ann Arbor, Michigan, for any claim which may arise out of the aforementioned activity, and does further agree to indemnify and hold harmless the said University of Michigan of Ann Arbor, Michigan from any claim which our son/daughter/ward may claim from the aforementioned activity.

____
Signature of Parent or Guardian

____
Signature of Participant

THE UNIVERSITY OF MICHIGAN
UNDERWATER TECHNOLOGY LABORATORY

TO: Hyperbaric Chamber Visitor

SUBJECT: Pressurization in Hyperbaric Chamber

Welcome to the Underwater Technology Laboratory. Those individuals who will be undergoing chamber orientation and pressurization must read and sign the medical information form and release forms prior to entering the chamber. Smoking in the laboratory is prohibited. The chamber attendant will ask the following:

Have you had:
a. a good night's sleep?
b. any heavy drinking (past 12 hours)?
c. a recent cold?
d. hospitalization or serious illness (past year)?

When you have been approved for entering the chamber, please stay clear of the chamber door and control area while the chamber is in operation. Unauthorized persons are not allowed to handle control valves or watches. However, remain in the area so as to be available when your name is called for your pressurization.

Prior to entering the chamber, it is mandatory that you remove your shoes and all objects such as cigarettes, lighters, matches, pens, paper, etc. from your pockets as a safety precaution. It is also necessary to remove your watch (except diving watches). Loosen belts and restrictive clothing.

When entering the chamber, please be seated so as not to be in cramped position. There will be a qualified attendant operating the chamber and controlling pressure. When the air is turned on by the attendant, it will be noisy and the pressure increase will be felt. Start equalizing pressure in your ears immediately by yawning, swallowing, or holding your nose and trying to force air out. Should you experience trouble equalizing or pain in your ears, raise your hand and the attendant will stop pressurization. When pressure equalizes in your ears and pain is no longer felt, inform the attendant (OK sign or telephone) and he will continue pressurization. During pressurization there will also be a noticeable increase in chamber temperature; remove outer shirt if necessary to avoid excessive perspiring. During your stay at depth periodic bursts of air will be used to ventilate the chamber. The attendant will inform you when he is ready to depressurize the chamber. Breathe normally during depressurization; <u>do not hold your breath</u>. The chamber air temperature will cool significantly and a water vapor fog will form in the chamber. Do not be alarmed; the attendant will clear the fog when you reach decompression depth. Do not handle the chamber door assembly when under pressure, especially during decompression.

<u>Post Dive Procedures</u>: After completion of the pressurization, you are to remain in the building for one hour and should remain in the Ann Arbor area for 12 hours. Do not fly for at least 12 hours or more if so instructed. If you should feel any unusual symptoms such as pain in joints, respiratory distress, mental confusion, etc., contact Dr. Martin Nemiroff of the University Medical Center by telephoning 764-9522 or 764-9530 or at home, 761-7928. Thank you for observing our safety procedures and regulations. Please carry the "MEDICAL EMERGENCY IDENTIFICATION CARD" on your person for 24 hours after pressurization. We hope that this has been a pleasant and educational experience and wish you the best in the field of diving.

The University of Michigan – Underwater Technology Laboratory
Hyperbaric Chamber Personnel Identification

Name______________________________

Date of Pressurization______________________________

Time Under Pressure____________________ Depth__________ft.

Time Decompression Completed______________________________

Chamber Attendant______________________________

EMERGENCY CONTACT NUMBERS:

The University of Michigan Medical Center
Martin J. Nemiroff, M.D.
Hospital: (313) 764-9522, 764-9530 Home: (313) 761-7928
Michigan State Police Operations Office, Lansing, Michigan
(517) 332-2521, Ext. 201

Note: Bearer, please destroy this card 24 hrs after pressurization.

MEDICAL EMERGENCY IDENTIFICATION CARD

The person bearing this card may be suffering from **air embolism** or **decompression sickness** as a result of recent pressurization in a hyperbaric chamber. **Symptoms** indicating these conditions include: **severe pain in arms and legs; weakness or inability to use arms and legs; dizziness; impairment of speech, hearing, or vision; headache; convulsions; unconsciousness; and/or respiratory arrest.** Determine if the victim has been exposed to increased pressure within the past 24 hours (see date and time on reverse of card). If so,

- **Administer artificial respiration immediately if victim is not breathing and give first aid for shock.**
- **Contact nearest physician and indicate that the victim is possibly suffering from delayed symptoms of a diving accident. Indicate to the physician the name of the physician given on the reverse side of card.**
- **Follow physician's instructions.**
- **Physician may contact Michigan State Police Operations Office in Lansing, Michigan for recompression instructions and may consult with physician listed on reverse side of this card.**

APPENDIX G

HYPERBARIC CHAMBER ATTENDANT

COURSE OUTLINE

A. Objectives

1. To provide the student with a knowledge of the characteristics of a hyperbaric chamber.

2. To acquaint the student with basic operational and maintenance procedures.

3. To provide the student with practical experience in the operation of a hyperbaric chamber.

4. To provide the student with necessary knowledge for assisting medical personnel in treating diving accidents and other illnesses requiring hyperbaric oxygenation.

5. To acquaint the student with the basic principles and use of treatment and decompression tables.

B. Outline of Instruction

1. Application of hyperbaric chambers in treatment of diving accidents and other illnesses

2. Role of the chamber attendant

3. Hyperbaric chambers
   - a. Types of chambers
   - b. UofM chamber
     - (1) Valving
     - (2) Gauges
   - c. Lighting
   - d. Communications
   - e. Precautions in the use of the chamber
     - (1) Lighting
     - (2) Doors
     - (3) Oxygen
     - (4) Fire prevention
     - (5) Other

4. Air supply for chambers
   - a. Compressors
   - b. Storage units
   - c. Pressure and volume requirements
   - d. Emergency

5. Chamber operation
   - a. Pre-dive checklist
   - b. Oxygen system
   - c. Regulator settings
   - d. Chamber ventilation
     - (1) Flow meter
     - (2) Valve calibration
   - e. Entering and leaving the chamber while pressurized.
   - f. Use of medical lock.
   - g. Post-dive maintenance checklist
   - h. Cleaning and painting
   - i. Special safety precautions
   - j. Pressure testing
   - k. Fire prevention and extinguishing equipment

6. Handling oxygen
   - a. Cylinders
   - b. Mask
   - c. Overboard discharge system
   - d. Oxygen analyzer

7. Tending the patient
   - a. Basic requirements
   - b. Medical evaluations
   - c. Assisting the physician
   - d. Medical kit

8. Record and timekeeping

9. Standard decompression tables (review)

10. Treatment tables (selection and reading)

11. Review of case histories

12. Other applications of chamber and role of attendant.
    - a. Research
    - b. Education
    - c. Procedures for handling group demonstrations

13. Practical exercises
    - a. Preparation for pressurization
    - b. Personnel evaluation
    - c. Pressurization
    - d. Ventilation
    - e. Record and timekeeping
    - f. Maintaining proper rate of ascent
    - g. Use of man lock and medical lock
    - h. Reading tables
    - i. Training dives
    - j. Simulated treatment