SS521-AG-PRO-010

0910-LP-708-8001 **REVISION 4**

U.S. Navy Diving Manual

Volume 1:	Diving Principles and Policies
Volume 2:	Air Diving Operations
Volume 3:	Mixed Gas Surface Supplied Diving Operations
Volume 4:	Closed Circuit and Semiclosed Circuit Diving Operations
Volume 5:	Diving Medicine and Recompression Chamber Operations

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NAVSEA TECHNICAL MANUAL CERTIFICATION SHEET

1 of 1

Certification Applies to: New Manual ☐ Revision ☐ Change ☒

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CHANGES AND REVISIONS:

Purpose: The requirements contained within this manual have been completely modified and revised. The contents of this manual require a thorough review prior to use.

Equipment Alteration Numbers Incorporated:

TMDER/ACN Numbers Incorporated:

Continue on reverse side or add pages as needed.

CERTIFICATION STATEMENT

This is to certify that responsible NAVSEA activities have reviewed the above identified document for acquisition compliance, technical coverage, and printing quality. This form is for internal NAVSEA management use only, and does not imply contractual approval or acceptance of the technical manual by the Government, nor relieve the contractor of any responsibility for delivering the technical manual in accordance with the contract requirement.

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Foreword

Department of the Navy
Naval Sea Systems Command
01 March 2001

Change A of the U.S. Navy Diving Manual Revision 4 provides the latest procedures and equipment currently available to military divers. It specifically incorporates new surface supplied mixed gas procedures designed to significantly reduce the risk of oxygen toxicity. Other significant changes include a new requirement for mandatory use of an octopus when using SCUBA, as well as, details with regard to the requirements for emergency gas for both surface supplied diving and recompression chamber primary and secondary air.

This change will be promulgated on a CD-ROM disk as well as in hard copy. Additional changes to the manual will be distributed annually. Interim changes will be promulgated by naval message and posted on the NAVSEA 00C web site (www.navsea.navy.mil/sea00c) to ensure that the most accurate and timely updates are provided to military divers.

Comments about or recommendations concerning the U.S. Navy Diving Manual may be forwarded to Supervisor of Diving, Naval Sea Systems Command, 2531 Jefferson Davis Hwy, Arlington, VA 22242-5160 or call commercial 703-607-2766, DSN 327-2766.

B. MARSH
Director of Ocean Engineering
Supervisor of Salvage and Diving

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Safety Summary

STANDARD NAVY SYNTAX

Since this manual will form the technical basis of many subsequent instructions or directives, it utilizes the standard Navy syntax as pertains to permissive, advisory, and mandatory language. This is done to facilitate the use of the information provided herein as a reference for issuing Fleet Directives. The concept of word usage and intended meaning that has been adhered to in preparing this manual is as follows:

“Shall” has been used only when application of a procedure is mandatory.

“Should” has been used only when application of a procedure is recommended.

“May” and “need not” have been used only when application of a procedure is discretionary.

“Will” has been used only to indicate futurity; never to indicate any degree of requirement for application of a procedure.

The usage of other words has been checked against other standard nautical and naval terminology references.

GENERAL SAFETY

This Safety Summary contains all specific WARNINGS and CAUTIONS appearing elsewhere in this manual and are referenced by page number. Should situations arise that are not covered by the general and specific safety precautions, the Commanding Officer or other authority will issue orders, as deemed necessary, to cover the situation.

SAFETY GUIDELINES

Extensive guidance for safety can be found in the OPNAV 5100 series instruction manual, Navy Safety Precautions.

SAFETY PRECAUTIONS

The WARNINGS, CAUTIONS, and NOTES contained in this manual are defined as follows:

WARNING	**Identifies an operating or maintenance procedure, practice, condition, or statement, which, if not strictly observed, could result in injury to or death of personnel.**
CAUTION	**Identifies an operating or maintenance procedure, practice, condition, or statement, which, if not strictly observed, could result in damage to or destruction of equipment or loss of mission effectiveness, or long-term health hazard to personnel.**
NOTE	**An essential operating or maintenance procedure, condition, or statement, which must be highlighted.**

WARNING Hyperventilation is dangerous and can lead to unconsciousness and death. (Page 3-20)

WARNING Never do a forceful Valsalva maneuver during descent or ascent. During descent, this action can result in alternobaric vertigo or a round or oval window rupture. During ascent, this action can result in a pulmonary overinflation syndrome. (Page 3-23)

WARNING Do not use a malfunctioning compressor to pump diver’s breathing air or charge diver's air storage flasks as this may result in contamination of the diver's air supply. (Page 4-11)

WARNING Welding or cutting torches may cause an explosion on penetration of gas-filled compartments, resulting in serious injury or death. (Page 6-22)

WARNING Scuba equipment is not authorized for use in enclosed space diving. (Page 6-25)

WARNING Skip-breathing may lead to hypercapnia and shall not be practiced. (Page 7-30)

WARNING During ascent, the diver without the mouthpiece must exhale to offset the effect of decreasing pressure on the lungs which could cause an air embolism. (Page 7-36)

WARNING During enclosed space diving, all divers shall be outfitted with MK 21 MOD 1 with EGS or MK 20 MOD 0 that includes a diver-to-diver and diver-to-topside communications system and an EGS for the diver inside the space. (Page 8-30)

WARNING For submarine ballast tanks, the divers shall not remove their diving equipment until the atmosphere has been flushed twice with air from a compressed air source meeting the requirements of Chapter 4, or the submarine L.P. blower, and tests confirm that the atmosphere is safe for breathing. Tests of the air in the enclosed space shall be conducted hourly. Testing shall be done in accordance with NSTM 074, Volume 3, Gas Free Engineering (S9086-CH-STM-030/CH-074) for forces afloat, and NAVSEA S-6470-AA-SAF-010 for shore-based facilities. If the divers smell any unusual odors they shall immediately don their EGS. (Page 8-30)

WARNING If the diving equipment should fail, the diver shall immediately switch to the EGS and abort the dive. (Page 8-31)

WARNING If job conditions call for using a steel cable or a chain as a descent line, the Diving Officer must approve such use. (Page 8-33)

WARNING Altitudes above 10,000 feet impose a serious stress on the body and significant medical problems may develop while the acclimatization process takes place. Ascents to these altitudes must be slow to allow acclimatization to occur and prophylactic drugs may be required. These exposures should always be planned in consultation with a Diving Medical Officer. Commands conducting diving operations above 10,000 feet may obtain the appropriate decompression procedures from NAVSEA 00C. (Page 9-41)

WARNING Mixing contaminated or non-oil free air with 100% oxygen can result in a catastrophic fire and explosion. (Page 10-10)

WARNING No repetitive dives are authorized after an emergency procedure requiring a shift to the EBS. (Page 17-24)

WARNING Hypoxia and hypercapnia may give the diver little or no warning prior to onset of unconsciousness. (Page 17-40)

WARNING The MK 25 does not have a carbon dioxide-monitoring capability. Failure to adhere to canister duration operations planning could lead to unconsciousness and/or death. (Page 18-20)

WARNING CPR should not be initiated on a severely hypothermic diver unless it can be determined that the heart has stopped or is in ventricular fibrillation. CPR should not be initiated in a patient that is breathing. (Page 19-15)

WARNING This procedure is to be performed with an unmanned chamber to avoid exposing occupants to unnecessary risks. (Page 22-17)

CAUTION This checklist is an overview intended for use with the detailed Operating Procedures (OPs) from the appropriate equipment O&M technical manual. (Page 6-48)

CAUTION Avoid overinflation and be aware of the possibility of blowup when breaking loose from mud. It is better to call for aid from the standby diver than to risk blowup. (Page 8-29)

CAUTION Never attempt to interpolate between decompression schedules. (Page 9-6)

CAUTION In very cold water, the wet suit is only a marginally effective thermal protective measure, and its use exposes the diver to hypothermia and restricts available bottom time. The use of alternative thermal protective equipment should be considered in these circumstances. (Page 11-5)

CAUTION Prior to the use of variable volume dry suits and hot water suits in cold and ice-covered waters, divers must be trained in their use and be thoroughly familiar with the operation of these suits. (Page 11-6)

CAUTION The MK 16 UBA provides no visual warning of excess CO_2 problems. The diver should be aware of CO_2 toxicity symptoms. (Page 17-4)

CAUTION Do not institute active rewarming with severe cases of hypothermia. (Page 19-15)

CAUTION If the tender is outside of no-decompression limits, he should not be brought directly to the surface. Either take the decompression stops appropriate to the tender or lock in a new tender and decompress the patient leaving the original tender to complete decompression. (Page 20-3)

CAUTION Acrylic view-ports should not be lubricated or come in contact with any lubricant. Acrylic view-ports should not come in contact with any volatile detergent or leak detector (non-ionic detergent is to be used for leak test). When reinstalling view-port, take up retaining ring bolts until the gasket just compresses evenly about the view-port. Do not overcompress the gasket. (Page 22-22)

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Table 2-2. Components of Dry Atmospheric Air.

	Concentration	
Component	**Percent by Volume**	**Parts per Million (ppm)**
Nitrogen	78.084	
Oxygen	20.946	
Carbon Dioxide	0.033	
Argon	0.0934	
Neon		18.18
Helium		5.24
Krypton		1.14
Xenon		0.08
Hydrogen		0.5
Methane		2.0
Nitrous Oxide		0.5

treatment facilities. Sometimes 100 percent oxygen is used in shallow diving operations and certain phases of mixed-gas diving operations. However, breathing pure oxygen under pressure may induce the serious problems of oxygen toxicity.

2-10.3 **Nitrogen.** Like oxygen, nitrogen (N_2) is diatomic, colorless, odorless, and tasteless, and is a component of all living organisms. Unlike oxygen, it will not support life or aid combustion and it does not combine easily with other elements. Nitrogen in the air is inert in the free state. For diving, nitrogen may be used to dilute oxygen. Nitrogen is not the only gas that can be used for this purpose and under some conditions it has severe disadvantages as compared to other gases. Nitrogen narcosis, a disorder resulting from the anesthetic properties of nitrogen breathed under pressure, can result in a loss of orientation and judgment by the diver. For this reason, compressed air, with its high nitrogen content, is not used below a specified depth in diving operations.

2-10.4 **Helium.** Helium (He) is a colorless, odorless, and tasteless gas, but it is monatomic (exists as a single atom in its free state). It is totally inert. Helium is a rare element, found in air only as a trace element of about 5 parts per million (ppm). Helium coexists with natural gas in certain wells in the southwestern United States, Canada, and Russia. These wells provide the world’s supply. When used in diving to dilute oxygen in the breathing mixture, helium does not cause the same problems associated with nitrogen narcosis, but it does have unique disadvantages. Among these is the distortion of speech which takes place in a helium atmosphere. The “Donald Duck” effect is caused by the acoustic properties of helium and it impairs voice communications in deep diving. Another negative characteristic of helium is its high thermal conductivity which can cause rapid loss of body and respiratory heat.

2-10.5 **Hydrogen.** Hydrogen (H_2) is diatomic, colorless, odorless, and tasteless, and is so active that it is rarely found in a free state on earth. It is, however, the most abundant element in the visible universe. The sun and stars are almost pure hydrogen. Pure hydrogen is violently explosive when mixed with air in proportions that include a presence of more than 5.3 percent oxygen. Hydrogen has been used in diving (replacing nitrogen for the same reasons as helium) but the hazards have limited this to little more than experimentation.

2-10.6 **Neon.** Neon (Ne) is inert, monatomic, colorless, odorless, and tasteless, and is found in minute quantities in the atmosphere. It is a heavy gas and does not exhibit the narcotic properties of nitrogen when used as a breathing medium. Because it does not cause the speech distortion problem associated with helium and has superior thermal insulating properties, it has been the subject of some experimental diving research.

2-10.7 **Carbon Dioxide.** Carbon dioxide (CO_2) is colorless, odorless, and tasteless when found in small percentages in the air. In greater concentrations it has an acid taste and odor. Carbon dioxide is a natural by-product of animal and human respiration, and is formed by the oxidation of carbon in food to produce energy. For divers, the two major concerns with carbon dioxide are control of the quantity in the breathing supply and removal of the exhaust after breathing. Carbon dioxide can cause unconsciousness when breathed at increased partial pressure. In high concentrations the gas can be extremely toxic. In the case of closed and semi-closed breathing apparatus, the removal of excess carbon dioxide generated by breathing is essential to safety.

2-10.8 **Carbon Monoxide.** Carbon monoxide (CO) is a colorless, odorless, tasteless, and poisonous gas whose presence is difficult to detect. Carbon monoxide is formed as a product of incomplete fuel combustion, and is most commonly found in the exhaust of internal combustion engines. A diver's air supply can be contaminated by carbon monoxide when the compressor intake is placed too close to the compressor's engine exhaust. The exhaust gases are sucked in with the air and sent on to the diver, with potentially disastrous results. Carbon monoxide seriously interferes with the blood's ability to carry the oxygen required for the body to function normally. The affinity of carbon monoxide for hemoglobin is approximately 210 times that of oxygen. Carbon monoxide dissociates from hemoglobin at a much slower rate than oxygen.

2-10.9 **Kinetic Theory of Gases.** On the surface of the earth the constancy of the atmosphere's pressure and composition tend to be accepted without concern. To the diver, however, the nature of the high pressure or hyperbaric, gaseous environment assumes great importance. The basic explanation of the behavior of gases under all variations of temperature and pressure is known as the kinetic theory of gases.

The kinetic theory of gases states: "The kinetic energy of any gas at a given temperature is the same as the kinetic energy of any other gas at the same temperature." Consequently, the measurable pressures of all gases resulting from kinetic activity are affected by the same factors.

16 oxygen bottle containing 360 standard liters (3.96 scf) of usable gas will last 225 minutes at an oxygen consumption rate of 1.6 liters per minute at any depth, provided no gas leaks from the rig.

Minute ventilation, or respiratory minute volume (RMV), is measured at BTPS (body temperature 37°C/98.6°F, ambient barometric pressure, saturated with water vapor at body temperature) and varies depending on a person's activity level, as shown in Figure 3-6. Surface RMV can be approximated by multiplying the oxygen consumption rate by 25. Although this 25:1 ratio decreases with increasing gas density and high inhaled oxygen concentrations, it is a good rule-of-thumb approximation for computing how long the breathing gas will last.

Unlike oxygen consumption, the amount of gas exhaled by the lungs is depth dependent. At the surface, a diver swimming at 0.5 knot exhales 20 l/min of gas. A scuba cylinder containing 71.2 standard cubic feet (scf) of air (approximately 2,000 standard liters) lasts approximately 100 minutes. At 33 fsw, the diver still exhales 20 l/min at BTPS, but the gas is twice as dense; thus, the exhalation would be approximately 40 standard l/min and the cylinder would last only half as long, or 50 minutes. At three atmospheres, the same cylinder would last only one-third as long as at the surface.

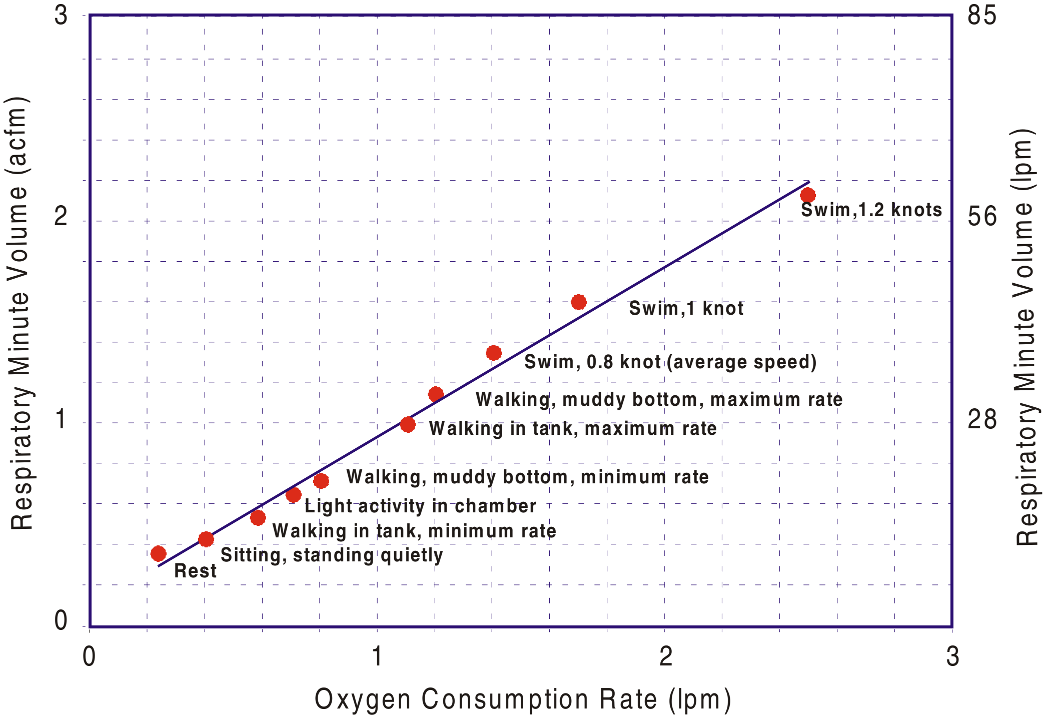
Carbon dioxide production depends only on the level of exertion and can be assumed to be independent of depth. Carbon dioxide production and RQ are used to compute ventilation rates for chambers and free-flow diving helmets. These factors may also be used to determine whether the oxygen supply or the duration of the CO_2 absorbent will limit a diver's time in a closed or semi-closed system.

3-5 RESPIRATORY PROBLEMS IN DIVING

Physiological problems often occur when divers are exposed to the pressures of depth. However, some of the difficulties related to respiratory processes can occur at any time because of an inadequate supply of oxygen or inadequate removal of carbon dioxide from the tissue cells. Depth may modify these problems for the diver, but the basic difficulties remain the same. Fortunately, the diver has normal physiological reserves to adapt to environmental changes and is only marginally aware of small changes. The extra work of breathing reduces the diver's ability to do heavy work at depth, but moderate work can be done with adequate equipment at the maximum depths currently achieved in diving.

3-5.1 **Oxygen Deficiency (Hypoxia).** Oxygen deficiency, or *hypoxia*, is an abnormal deficiency of oxygen in the arterial blood that causes the tissue cells to be unable to receive sufficient oxygen to maintain normal function. Severe hypoxia will stop the normal function of any tissue cell in the body and will eventually kill it, but the cells of the brain tissue are by far the most susceptible to its effects.

The partial pressure of oxygen determines whether the amount of oxygen in a breathing medium is adequate. For example, air contains about 21 percent oxygen and thus provides an oxygen partial pressure of about 0.21 ata at the surface. This



Work	VO_2 (lpm)	RMV (acfm)	RMV (lpm)	Work Level
Rest	0.24	0.35	10	—
Sitting, standing quietly	0.40	0.42	12	Light
Walking in tank, minimum rate	0.58	0.53	15	Light
Light activity in chamber	0.70	0.64	18	Light
Walking, muddy bottom, minimum rate	0.80	0.71	20	Moderate
Walking in tank, maximum rate	1.10	0.99	28	Moderate
Walking, muddy bottom, maximum rate	1.20	1.14	32	Moderate
Swim, 0.8 knot (average speed)	1.40	1.34	38	Moderate
Swim, 1 knot	1.70	1.59	45	Heavy
Swim, 1.2 knot	2.50	2.12	60	Severe

Figure 3-6. Oxygen Consumption and RMV at Different Work Rates.

Proposed changes/updates to OP/EPs for standardized diving equipment shall be submitted as a formal change proposal to the respective O&M Manual in accordance with directions contained therein.

4-2.6.2 **Non-standardized OP/EPs.** Diving and diving support equipment such as ships, small boats, and unique shore facility surface supplied diving and recompression chamber systems shall be operated in accordance with a single set of standard OP/EPs that are developed at the command level and approved for use after validation by NAVSEA Code 00C3 or NAVFAC Code 00CE. Proposed changes/updates to OPs/EPs for non-standardized diving equipment shall be submitted to the applicable approval authority. The following addresses are provided to assist in submitting proposed OP/EP changes and updates.

Submit proposed OP/EP changes and updates for afloat, portable diving and recompression chamber systems, and class-certified equipment to:

COMNAVSEASYSCOM (Code 00C3)
2531 Jefferson Davis Highway
Arlington, VA 22242-5160

Submit proposed OP/EP changes and updates for fixed, shore-based facilities to:

NAVFACENGSERCEN EAST COAST DET (Code 07FH)
Washington Navy Yard, Bldg. 218
1435 10th Street SE, Suite 3000
Washington, DC 20374-5063

4-2.6.3 **OP/EP Approval Process.** Submission of OPs/EPs for approval (if required) must precede the requested on-site survey date by 90 calendar days to allow complete review and resolution of questions. Follow these procedures when submitting OPs/EPs for approval:

- The command shall validate in the forwarding letter that the OPs/EPs are complete and accurate.
- The command must verify that drawings are accurate. Accurate drawings are used as a guide for evaluating OPs/EPs. Fully verified system schematics/drawings with components, gas consoles, manifolds, and valves clearly labeled shall be forwarded with the OPs/EPs.
- Approved OPs/EPs shall have the revision date listed on each page and not have any changes without written NAVSEA/NAVFAC approval.
- The command shall retain system documentation pertaining to DLSS approval, i.e., PSOBs, supporting manufacturing documentation, and OPs/EPs.

4-2.6.4 **Format.** The format for OPs/EPs is as follows:

- System: (Name or description, consistent with drawings)
- Step, Component, Description, Procedure, Location, Check, Note (read in seven columns)

4-2.6.5 **Example.**

- System: High Pressure Air
- Step/Component/Description/Procedure/Location /Initials /Note

  1. ALP-15/Reducer outlet/Open/Salvage Hold/Initials/Note
  2. ALP-GA-7/Reducer outlet/Record Pressure/Salvage Hold/Initials/Note 1

The operator executing the procedure shall initial the Check column. Hazards and items of particular concern shall be identified in the Note column.

Once NAVSEA or NAVFAC has approved the system OP/EPs, they shall not be changed without specific written approval from NAVSEA or NAVFAC.

4-3 DIVER'S BREATHING GAS PURITY STANDARDS

4-3.1 **Diver's Breathing Air.** Diver's air compressed from ANU or certified diving system sources shall meet the U.S. Military Diver's Breathing Air Standards contained in Table 4-1.

Table 4-1. *U.S. Military Diver's Compressed Air Breathing Purity Requirements for ANU Approved or Certified Sources.*

Constituent	Specification
Oxygen (percent by volume)	20-22%
Carbon dioxide (by volume)	1,000 ppm (max)
Carbon monoxide (by volume)	20 ppm (max)
Total hydrocarbons (as CH_4 by volume)	25 ppm (max)
Odor and taste	Not objectionable
Oil, mist, particulates	5 mg/m3 (max)

Diver's breathing air may be procured from commercial sources if a source of military diver's air is not readily available. Diver's air procured from commercial sources shall be certified in writing by the vendor as meeting the purity standards of FED SPEC BB-A-1034 Grade A Source I (pressurized container) or Source II (compressor) air. Specifications for this standard are outlined in Table 4-2.

4-3.2 **Diver's Breathing Oxygen.** Oxygen used for breathing at 100-percent concentrations and for mixing of diver's breathing gases shall meet Military Specification the date of the dive. The minimum data items in the Recompression Chamber Log include:

- Date of dive
- Purpose of the dive
- Identification of diver(s)/patients(s)
- Identification of tender(s)
- Time left surface
- Time reached treatment depth
- Time left treatment depth
- Time reached stop
- Time left stop
- Depth/time of relief
- Change in symptoms
- Recompression chamber air temperature (if available)
- Oxygen and Carbon Dioxide % (if available)
- Medicine given
- Fluid administered
- Fluid void
- Signatures of Diving Officer, Master Diver, or Diving Supervisor

5-6 DIVER'S PERSONAL DIVE LOG

Although specific Navy Divers Personal Logbooks are no longer required, each Navy trained diver is still required to maintain a record of his dives in accordance with the OPNAVINST 3150.27 series. The best way for each diver to accomplish this is to keep a copy of each Diving Log Form in a binder or folder. The Diving Log Form was formerly called DD Form 2544, 3150, or 9940, but is now generated by the Diver Reporting System (DRS) software. The record may also be kept on a personal floppy disk. These forms, when signed by the Diving Supervisor and Diving Officer, are an acceptable record of dives that may be required to justify special payments made to you as a diver and may help substantiate claims made for diving-related illness or injury. If an individual desires a hard copy of the dives, the diver’s command can generate a report using the DRS or by submitting a written request to the Naval Safety Center.

5-7 DIVING MISHAP/CASUALTY REPORTING

Specific instructions for diving mishap, casualty, and hyperbaric treatment are provided in Section A-6, OPNAVINST 5100.19 Series. The Judge Advocate General (JAG) Manual provides instructions for investigation and reporting procedures required in instances when the mishap may have occurred as a result of procedural or personnel error. Diving equipment status reporting instructions related to diving accidents/incidents are specified in this chapter.

5-8 EQUIPMENT FAILURE OR DEFICIENCY REPORTING

The Failure Analysis Report (FAR) system provides the means for reporting, tracking and resolving material failures or deficiencies in diving life-support equipment (DLSE). The FAR was developed to provide a rapid response to DLSE failures or deficiencies. It is sent directly to the configuration manager, engineers, and technicians who are qualified to resolve the deficiency. FAR Form 10560/4 (stock number 0116-LF-105-6020) covers all DLSE not already addressed by other FARs or reporting systems. For example, the MK 21 MOD 1, MK 20 MOD 0 mask, and all open-circuit scuba are reportable on this FAR form; the UBAs MK 16 and MK 25 are reportable on a FAR or a Failure Analysis or Inadequacy Report (FAIR) in accordance with their respective technical manuals. When an equipment failure or deficiency is discovered, the Diving Supervisor or other responsible person shall ensure that the FAR is properly prepared and distributed. Refer to paragraph 5-10 for additional reporting requirements for an equipment failure suspected as the cause of a diving accident.

The one-page FAR form (Figure 5-3) consists of an original and three copies. The completed original is maintained in the Command FAR Log; the copies are mailed to CSS (Code 2510), NAVSEA (Code 00C3) and NEDU (Code 03).

An electronic version of the FAR form is also available on-line at http://www.supsalv.org. Click on Diving or OOC3 Diving. When the next screen appears, click on Failure Analysis Reporting. Follow the instructions and submit the form.

5-9 U.S. NAVY DIVE REPORTING SYSTEM (DRS)

The Dive Reporting System (DRS) is a computer-based method of recording and reporting dives required by the OPNAVINST 3150.27 (series), and replaces reporting on DD Form 2544. The computer software provides all diving commands with a computerized record of dives.

The DRS makes it easy for commands to submit diving data to the Naval Safety Center. The computer software allows users to enter dive data, transfer data to the Naval Safety Center, and to generate individual diver and command reports. The DRS was designed for all branches of the U.S. Armed Services and can be obtained through:

Commander, Naval Safety Center
Attention: Code 37
375 A Street
Norfolk, VA 23511-4399

5-10 ACCIDENT/INCIDENT EQUIPMENT INVESTIGATION REQUIREMENTS

An *accident* is an unexpected event that culminates in loss of or serious damage to equipment or injury to personnel. An *incident* is an unexpected event that degrades safety and increases the probability of an accident.

The number of diving accidents/incidents involving U.S. Navy divers is small when compared to the total number of dives conducted each year. The mishaps that do occur, however, must receive a thorough review to identify the cause and determine corrective measures to prevent further diving mishaps.

This section expands on the OPNAVINST 5100.19 (series) that require expeditious reporting and investigation of diving related mishaps. The accident/incident equipment status reporting procedures in this chapter apply, in general, to all diving mishaps when malfunction or inadequate equipment performance, or unsound equipment operating and maintenance procedures are a factor.

In many instances a Diving Life Support Equipment Failure Analysis Report (FAR) may also be required. The primary purpose of this requirement is to identify any material deficiency that may have contributed to the mishap. Any suspected malfunction or deficiency of life support equipment will be thoroughly investigated by controlled testing at the Navy Experimental Diving Unit (NEDU). NEDU has the capability to perform engineering investigations and full unmanned testing of all Navy diving equipment under all types of pressure and environmental conditions. Depth, water turbidity, and temperature can be duplicated for all conceivable U.S. Navy dive scenarios.

Contact NAVSEA/00C3 to assist diving units with investigations and data collection following a diving mishap. 00C3 will assign a representative to inspect the initial condition of equipment and to pick up or ship all pertinent records and equipment to NEDU for full unmanned testing. Upon receiving the defective equipment, NEDU will conduct unmanned tests as rapidly as possible and will then return the equipment to the appropriate activity.

NOTE **Do not tamper with equipment without first contacting NAVSEA/00C3 for guidance.**

5-11 REPORTING CRITERIA

The diving and diving related accident/incident equipment status requirements set forth in this chapter are mandatory for all U.S. Navy diving units in each of the following circumstances:

- In all cases when an accident/incident results in a fatality or serious injury.
- When an accident/incident occurs and a malfunction or inadequate performance of the equipment may have contributed to the accident/incident.

5-12 ACTIONS REQUIRED

U.S. Navy diving units shall perform the following procedure when a diving accident/incident or related mishap meets the criteria stated in paragraph 5-11.

1. Immediately secure and safeguard from tampering all diver-worn and ancillary/support equipment that may have contributed to the mishap. This equipment should also include, but is not limited to, the compressor, regulator, depth gauge, submersible pressure gauge, diver dress, buoyancy compensator/ life preserver, weight belt, and gas supply (scuba, emergency gas supply, etc.).

2. Expeditiously report circumstances of the accident/incident by message (see OPNAVINST 5100.19 (Series) for format requirements) to:

   - NAVSAFECEN NORFOLK VA//JJJ// with information copies to
     CNO WASHINGTON DC//N773//
     COMNAVSEASYSCOM WASHINGTON DC//00C// and
     NAVXDIVINGU PANAMA CITY FL//JJJ//.

   - If the accident/incident is MK 16 related, also send information copies to
     PEO MINEWAR WASHINGTON DC//PMS-EOD// and
     NAVEODTECHDIV INDIAN HEAD MD//70//.

   - If the accident/incident is MK 25 (LAR V) related, also send information copies to COMNAVSEASYSCOM WASHINGTON DC//PEO EXW PMS 325//.

   - If the accident/incident occurs at a shore based facility (NAVFAC), also send information copies to NFESC EAST COAST DET WASHINGTON DC//00CE//.

3. Expeditiously prepare a **separate, written report** of the accident/incident. The report shall include:

   - A completed Equipment Accident/Incident Information Sheet (Figure 5-2a)

   - A completed Accident/Incident Equipment Status Data Sheet (Figure 5-2b)

   - A sequential narrative of the mishap including relevant details that might not be apparent in the data sheets

4. The data sheets and the written narrative shall be mailed by traceable registered mail to:

   Commanding Officer
   Navy Experimental Diving Unit
   321 Bullfinch Road
   Panama City, Florida 32407-7015
   Attn: Code 03, Test & Evaluation

APPENDIX 1A

Safe Diving Distances from Transmitting Sonar

1A-1 INTRODUCTION

The purpose of this appendix is to provide guidance regarding safe diving distances and exposure times for divers operating in the vicinity of ships transmitting with sonar. Table 1A-1 provides guidance for selecting Permissible Exposure Limits Tables; Table 1A-2 provides additional guidance for helmeted divers. Tables 1A-3 through 1A-5 provide specific procedures for diving operations involving AN/SQS-23, -26, -53, -56; AN/BSY-1, -2; and AN/BQQ-5 sonars. Table 1A-6 provides procedures for diving operations involving AN/SQQ-14, -30, and -32. Section 1A-5 provides guidance and precautions concerning diver exposure to low-frequency sonar (160-320Hz). Contact NAVSEA Supervisor of Diving (00C3B) for guidance on other sonars. This appendix has been substantially revised from Safe Diving Distances from Transmitting Sonar (NAVSEAINST 3150.2 Series) and should be read in its entirety.

1A-2 BACKGROUND

Chapter 18 of OPNAVINST 5100.23 Series is the basic instruction governing hearing conservation and noise abatement, but it does not address exposure to waterborne sound. Tables 1A-3 through 1A-6 are derived from experimental and theoretical research conducted at the Naval Submarine Medical Research Laboratory (NSMRL) and Naval Experimental Diving Unit (NEDU). This instruction provides field guidance for determining safe diving distances from transmitting sonar. This instruction supplements OPNAVINST 5100.23 Series, and should be implemented in conjunction with OPNAVINST 5100.23 Series by commands that employ divers.

The Sound Pressure Level (SPL), not distance, is the determining factor for establishing a Permissible Exposure Limit (PEL). The exposure SPLs in Tables 1A-3 through 1A-6 are based upon the sonar equation and assume omni-directional sonar and inverse square law spreading. Any established means may be used to estimate the SPL at a dive site, and that SPL may be used to determine a PEL. When the exposure level is overestimated, little damage, except to working schedules, will result. Any complaints of excessive loudness or ear pain for divers require that corrective action be taken. Section 1A-5 provides guidance for diver exposure to low-frequency active sonar (LFA), which should be consulted if exposure to LFA is either suspected or anticipated.

This appendix does not preclude the operation of any sonar in conjunction with diving operations, especially under operationally compelling conditions. It is based upon occupational safety and health considerations that should be implemented for routine diving operations. It should be applied judiciously under special operational circumstances. The guidance in Tables 1A-3 through 1A-6 is intended to facilitate the successful integration of operations.

1A-3 ACTION

Commanding Officers or Senior Officers Present Afloat are to ensure that diving and sonar operations are integrated using the guidance given by this appendix. Appropriate procedures are to be established within each command to effect coordination among units, implement safety considerations, and provide efficient operations using the guidance in Tables 1A-3 though 1A-6.

1A-4 SONAR DIVING DISTANCES WORKSHEETS WITH DIRECTIONS FOR USE

1A-4.1 **General Information/Introduction.** Permissible Exposure Limits (PEL) in minutes for exposure of divers to sonar transmissions are given in Tables 1A-3 through 1A-6.

1A-4.1.1 **Effects of Exposure.** Tables 1A-3 through 1A-5 are divided by horizontal double lines. Exposure conditions above the double lines should be avoided for routine operations. As Sound Pressure Level (SPL) increases above 215 dB for hooded divers, slight visual-field shifts (probably due to direct stimulation of the semicircular canals), fogging of the face plate, spraying of any water within the mask, and other effects may occur. In the presence of long sonar pulses (one second or longer), depth gauges may become erratic and regulators may tend to free-flow. Divers at Naval Submarine Medical Research Laboratory experiencing these phenomena during controlled research report that while these effects are unpleasant, they are tolerable. Similar data are not available for un-hooded divers but visual-field shifts may occur for these divers at lower levels. If divers need to be exposed to such conditions, they must be carefully briefed and, if feasible, given short training exposures under carefully controlled conditions. Because the probability of physiological damage increases markedly as sound pressures increase beyond 200 dB at any frequency, exposure of divers above 200 dB is prohibited unless full wet suits and hoods are worn. Fully protected divers (full wet suits and hoods) must not be exposed to SPLs in excess of 215 dB at any frequency for any reason.

1A-4.1.2 **Suit and Hood Characteristics.** There is some variation in nomenclature and characteristics of suits and hoods used by divers. The subjects who participated in the Naval Submarine Medical Research Laboratory experiments used 3/8-inch nylon-lined neoprene wet suits and hoods. Subsequent research has shown that 3/16-inch wet suit hoods provide about the same attenuation as 3/8-inch hoods. Hoods should be well fitted and cover the skull completely including cheek and chin areas. The use of wet-suit hoods as underwater ear protection is strongly recommended.

1A-4.1.3 **In-Water Hearing vs. In-Gas Hearing.** A distinction is made between in-water hearing and in-gas hearing. In-water hearing occurs when the skull is directly in contact with the water, as when the head is bare or covered with a wet-suit hood. In-gas hearing occurs when the skull is surrounded by gas as in the MK 21 diving helmet. In-water hearing occurs by bone conduction—sound incident anywhere on the skull is transmitted to the inner ear, bypassing the external and middle ear. In-gas hearing occurs in the normal way—sound enters the external ear canal and stimulates the inner ear through the middle ear.

1A-4.2 **Directions for Completing the Sonar Diving Distances Worksheet.** Follow the steps listed below to determine Permissible Exposure Limits (PELs) for the case when the actual dB Sound Pressure Level (SPL) at the dive site is unknown. Figure 1A-1 is a worksheet for computing the safe diving distance/exposure time. Figures 1A-2 through 1A-5 are completed worksheets using example problems. Work through these example problems before applying the worksheet to your particular situation.

Step 1. **Diver Dress**. Identify the type of diving equipment—wet-suit un-hooded; wet-suit hooded; helmeted. Check the appropriate entry on step 1 of the worksheet.

Step 2. **Sonar Type(s)**. Identify from the ship's Commanding Officer or representative the type(s) of sonar that will be transmitting during the period of time the diver is planned to be in the water. Enter the sonar type(s) in step 2 of the worksheet.

Step 3. **PEL Table Selection**. Use the Table 1A-1 to determine which PEL table you will use for your calculations. For swimsuit diving use wet suit un-hooded tables. Check the table used in step 3 of the worksheet.

Table 1A-1. *PEL Selection Table.*

	SONAR		
DIVER DRESS:	**All except AN/SQQ -14, - 30, -32**	**AN/SQQ -14, -30, -32**	**Unknown Sonar**
Wet suit - Un-hooded	Table 1A-3	Table 1A-6	Start at 1000 yards and move in to diver comfort
Wet suit - Hooded	Table 1A-4	Table 1A-6	Start at 600 yards and move in to diver comfort
Helmeted	Table 1A-5	No restriction	Start at 3000 yards and move in to diver comfort

For guidance for sonars not addressed by this instruction, contact NAVSEA (00C32) DSN 327-2766.

NOTE **If the type of sonar is unknown, start diving at 600–3,000 yards, depending on diving equipment (use greater distance if helmeted), and move in to limits of diver comfort.**

Step 4. **Distance to Sonar**. Determine the distance (yards) to the transmitting sonar from place of diver's work. Enter the range in yards in step 4 of the worksheet.

SONAR SAFE DIVING DISTANCE/EXPOSURE TIME WORKSHEET

1. Diver dress: Wet Suit - Un-hooded ______
Wet Suit - Hooded _____
Helmeted _____

2. Type(s) of sonar: ____________________

3. PEL Table 1A-3 ___; 1A-4 _____; 1A-5 ___ ; 1A-6 ___

4. Range(s) to sonar (yards): _____________________

5. Estimated SPL at range(s) in step 3 (from table/column in step 3): __________________

Reminder: If range is between two values in the table, use the shorter range.
If the SPL is measured at the dive site, use the measured value.

6. Depth Reduction ______ dB

Reminder: **0 if <u>not</u> helmeted, see table in instructions if helmeted**.

7. Corrected SPL (Step 5 minus Step 6) ___________________________________

8. Estimated PEL at SPL (from table/column in step 3 of the appendix): ___________________________

9. Duty Cycle Known: Yes _______ (do step 9); No _____ (stop)

Adjusted PEL for actual duty cycle

Actual DC % = 100 × ____ sec. (pulse length / ___ sec. (pulse repetition period)
Actual DC % = ____
Adjusted PEL = PEL (from step 8) ____ min. × 20 / actual duty cycle (%) ___ = ____ min.

PEL1 = _____ minutes; PEL2 = _____ minutes

Reminder: Do not adjust the PEL if duty cycle is unknown.

10. Multiple Sonars: Yes _____ (do step 10); No ____ (stop)

Sonar 1: DT1 = ______ (Desired dive duration)

PEL1 = _______ (from Step 8 or 9, as applicable)

DT1/PEL1 = ____________ .

Sonar 2: DT1 = ______ (Desired dive duration)

PEL1 = ________ (from Step 8 or 9, as applicable)

DT1/PEL1 = ____________ .

ND = ______ + _______ = ________ (This is less than 1.0, so dive is acceptable and may proceed.)

Reminder: The Noise Dose must not exceed a value of 1.0.

Figure 1A-1. Sonar Safe Diving Distance/Exposure Time Worksheet.

PEL1 (for SQS-53A) = 50 minutes
DT1/PEL1 = 15/50 = .3

DT2 = 15 minutes
PEL2 (for SQS-23) = 285 minutes
DT2/PEL2 = 15/285 = .05

ND = .3 + .05 = .35
This is less than 1.0 and therefore is acceptable.

Example 1: *You are planning a routine dive for 160 minutes using wet-suited divers without hoods at a dive site 17 yards from an AN/SQQ-14 sonar. The duty cycle for the AN/SQQ-14 sonar is unknown. Is this dive permitted? Provide justification for your decision.*

SONAR SAFE DIVING DISTANCE/EXPOSURE TIME WORKSHEET

1. Diver dress: Wet Suit - Un-hooded ___X___
   Wet Suit - Hooded _____
   Helmeted ______

2. Type(s) of sonar: AN/SQQ-14

3. PEL Table 1A-3 __; 1A-4 __; 1A-5 __; 1A-6 _X_

4. Range(s) to sonar (yards): 17

5. Estimated SPL at range(s) in step 3 (from table/column in step 3): SPL = 198 dB

   Reminder: If range is between two values in the table, use the shorter range.
   If the SPL is measured at the dive site, use the measured value.

6. Depth Reduction ___0___ dB

   Reminder: 0 if not helmeted, see table in instructions if helmeted.

7. Corrected SPL (Step 5 minus Step 6) _SPL1 198 – 0 = 198 dB_

8. Estimated PEL at SPL (from table/column in step 3 of the appendix): PEL1 = 170 minutes

9. Duty Cycle Known: Yes ______ (do step 9); No ___X___ (stop)
   Adjusted PEL for actual duty cycle
   Actual DC % = 100 × ______ sec. (pulse length / ______ sec. (pulse repetition period)
   Actual DC % = ______
   Adjusted PEL = PEL (from step 8) ___ min. × 20 / actual duty cycle (%) ___ = ___ min.

   Reminder: Do not adjust the PEL if duty cycle is unknown.

10. Multiple Sonars: Yes _____ (do step 10); No __X___ (stop)

Sonar 1:
DT1 = ____ (Desired dive duration)
PEL1 = ____ (from Step 8 or 9, as applicable)
DT1/PEL1 = _______ .

Sonar 2:
DT1 = ____ (Desired dive duration)
PEL1 = ____ (from Step 8 or 9, as applicable)
DT1/PEL1 = _______ .

ND = ____ + _____ = ____ (This is less than 1.0, so dive is acceptable and may proceed.)

Reminder: The Noise Dose must not exceed a value of 1.0.

The dive time of 160 minutes is permitted because the PEL is 171 minutes.

Figure 1A-2. Sonar Safe Diving Distance/Exposure Time Worksheet (Completed Example).

***Example 2:** You are planning a routine dive for 75 minutes using wet-suited divers without hoods at a dive site which is 1000 yards from an AN/SQS-23 sonar. The SPL was measured at 185 dB. The duty cycle for the AN/SQS-23 sonar is unknown. Is this dive permitted? Provide justification for your decision.*

SONAR SAFE DIVING DISTANCE/EXPOSURE TIME WORKSHEET

1. Diver dress: Wet Suit - Un-hooded __X___
   Wet Suit - Hooded _____
   Helmeted ______

2. Type(s) of sonar: AN/SQS-23

3. PEL Table 1A-3 __X__; 1A-4 __; 1A-5 __; 1A-6 ___

4. Range(s) to sonar (yards): 1000

5. Estimated SPL at range(s) in step 3 (from table/column in step 3): SPL = 185 dB

   Reminder: If range is between two values in the table, use the shorter range.
   If the SPL is measured at the dive site, use the measured value.

6. Depth Reduction ___0___ dB

   Reminder: 0 if not helmeted, see table in instructions if helmeted.

7. Corrected SPL (Step 5 minus Step 6) SPL1 185 – 0 = 185 dB

8. Estimated PEL at SPL (from table/column in step 3 of the appendix): PEL1 = 170 minutes

9. Duty Cycle Known: Yes ______ (do step 9); No ___X___ (stop)
   Adjusted PEL for actual duty cycle
   Actual DC % = 100 × ______ sec. (pulse length / ______ sec. (pulse repetition period)
   Actual DC % = ______
   Adjusted PEL = PEL (from step 8) ___ min. × 20 / actual duty cycle (%) ___ = ___ min.

   Reminder: Do not adjust the PEL if duty cycle is unknown.

10. Multiple Sonars: Yes _____ (do step 10); No __X___ (stop)

    Sonar 1: DT1 = ____ (Desired dive duration)
    PEL1 = ____ (from Step 8 or 9, as applicable)
    DT1/PEL1 = _______ .

    Sonar 2: DT1 = ____ (Desired dive duration)
    PEL1 = ____ (from Step 8 or 9, as applicable)
    DT1/PEL1 = _______ .

    ND = ____ + _____ = ____ (This is less than 1.0, so dive is acceptable and may proceed.)
    Reminder: The Noise Dose must not exceed a value of 1.0.

The dive time of 75 minutes is permitted because the PEL is 170 minutes.

Figure 1A-3. Sonar Safe Diving Distance/Exposure Time Worksheet (Completed Example).

Example 3: *You are planning a 98 fsw dive for 35 minutes using the MK 21 at a dive site which is 3000 yards from an AN/SQS-53C sonar. The duty cycle for the AN/SQS-53C sonar is unknown. Is this dive permitted? Provide justification for your decision.*

SONAR SAFE DIVING DISTANCE/EXPOSURE TIME WORKSHEET

1. Diver dress: Wet Suit - Un-hooded ______
Wet Suit - Hooded _____
Helmeted __X___

2. Type(s) of sonar: AN/SQS-53C

3. PEL Table 1A-3 ___; 1A-4 __; 1A-5 _X_ ; 1A-6 ___

4. Range(s) to sonar (yards): 3000

5. Estimated SPL at range(s) in step 3 (from table/column in step 3): SPL1 = 181 dB

Reminder: If range is between two values in the table, use the shorter range.
If the SPL is measured at the dive site, use the measured value.

6. Depth Reduction __6___ dB

Reminder: **0 if not helmeted, see table in instructions if helmeted**.

7. Corrected SPL (Step 5 minus Step 6) _SPL1 181 – 6 = 175 dB_

8. Estimated PEL at SPL (from table/column in step 3 of the appendix): PEL1 = 50 minutes

9. Duty Cycle Known: Yes ______ (do step 9); No __X___ (stop)
Adjusted PEL for actual duty cycle
Actual DC % = 100 × ______ sec. (pulse length / ______ sec. (pulse repetition period)
Actual DC % = ______
Adjusted PEL = PEL (from step 8) ___ min. × 20 / actual duty cycle (%) ___ = ___ min.

Reminder: Do not adjust the PEL if duty cycle is unknown.

10. Multiple Sonars: Yes _____ (do step 10); No __X___ (stop)

Sonar 1: DT1 = ____ (Desired dive duration)
PEL1 = ____ (from Step 8 or 9, as applicable)
DT1/PEL1 = _______ .

Sonar 2: DT1 = ____ (Desired dive duration)
PEL1 = ____ (from Step 8 or 9, as applicable)
DT1/PEL1 = _______ .

ND = ____ + _____ = ____ (This is less than 1.0, so dive is acceptable and may proceed.)
Reminder: The Noise Dose must not exceed a value of 1.0.

The dive time of 35 minutes is permitted because the PEL is 50 minutes.

Figure 1A-4. Sonar Safe Diving Distance/Exposure Time Worksheet (Completed Example).

Example 4: *You are planning a routine dive for 120 minutes using wet-suited divers with hoods at a dive site which is 200 yards from an AN/SQS-53A sonar and 120 yards from an AN/SQS-23 sonar. The AN/SQS-53A sonar is transmitting an 800 msec pulse (0.8 sec) every 20 seconds. The duty cycle for the AN/SQS-23 sonar is unknown. Is this dive permitted? Provide justification for your decision.*

SONAR SAFE DIVING DISTANCE/EXPOSURE TIME WORKSHEET

1. Diver dress: Wet Suit - Un-hooded ____
   Wet Suit - Hooded X
   Helmeted ____

2. Type(s) of sonar: AN/SQS-53A and AN/SQS-23

3. PEL Table 1A-3 ___; 1A-4 X; 1A-5 ___ ; 1A-6 ___

4. Range(s) to sonar (yards): 200 (from SQS-53A); 120 (from SQS-23)

5. Estimated SPL at range(s) in step 3 (from table/column in step 3): SPL1 = 201; SPL2 = 196
   (per reminder, use SPL for 112 yard range)
   Reminder: If range is between two values in the table, use the shorter range.
   If the SPL is measured at the dive site, use the measured value.

6. Depth Reduction 0 dB

   Reminder: **0 if not helmeted, see table in instructions if helmeted**.

7. Corrected SPL (Step 5 minus Step 6) SPL1 201 – 0 = 201 dB; SPL2 196 – 0 = 196 dB;

8. Estimated PEL at SPL (from table/column in step 3 of the appendix): PEL1 = 143 min; PEL 2 = 339 min

9. Duty Cycle Known: Yes X (do step 9); No ____ (stop)
   Adjusted PEL for actual duty cycle
   Actual DC % = 100 × 0.8 sec. (pulse length / 20 sec. (pulse repetition period)
   Actual DC % = 4
   Adjusted PEL = PEL (from step 8) 143 min. × 20 / actual duty cycle (%) 4 = 715 min.
   PEL1 = 715 minutes; PEL2 = 339 minutes
   Reminder: Do not adjust the PEL if duty cycle is unknown.

10. Multiple Sonars: Yes X (do step 10); No ____ (stop)

    Sonar 1: DT1 = 120 (Desired dive duration)
    PEL1 = 715 (from Step 8 or 9, as applicable)
    DT1/PEL1 = 120/715 = 0.17 .

    Sonar 2: DT1 = 120 (Desired dive duration)
    PEL1 = 339 (from Step 8 or 9, as applicable)
    DT1/PEL1 = 120/339 = .35 .

    ND = 0.17 + 0.35 = 0.52 (This is less than 1.0, so dive is acceptable and may proceed.)
    Reminder: The Noise Dose must not exceed a value of 1.0.

The dive time of 120 minutes is permitted because the ND is less than 1.0.

Figure 1A-5. Sonar Safe Diving Distance/Exposure Time Worksheet (Completed Example).

Table 1A-3. *Wet Suit Un-Hooded.*

Permissible Exposure Limit (PEL) within a 24-hour period for exposure to AN/SQS-23, -26, -53, -56, AN/BSY-1, -2 and AN/BQQ-5 sonars, including versions and upgrades. Exposure conditions shown above the double line should be avoided except in cases of compelling operational necessity.

Estimated Ranges in yards for given SPL and PEL for sonar.

SPL (dB)	PEL (MIN)	BSY-1 SQS-53C	BQQ-5 BSY-2 SQS-26CX(U) SQS-53A, SQS-53B SQS-56(U)	SQS-23 SQS-26AX SQS-26BX, SQS-26CX SQS-56		
200	13	316	224	71	**A**	
199	15	355	251	79	**V**	**E**
198	18	398	282	89	**O**	**X**
197	21	447	316	100	**I**	**P**
196	25	501	355	112	**D**	**O**
195	30	562	398	126		**S**
194	36	631	447	141	**T**	**U**
193	42	708	501	158	**H**	**R**
192	50	794	562	178	**I**	**E**
191	60	891	631	200	**S**	
190	71	1,000	708	224		
189	85	1,122	794	251		
188	101	1,259	891	282		
187	120	1,413	1,000	316		
186	143	1,585	1,122	355		
185	170	1,778	1,259	398		
184	202	1,995	1,413	447		
183	240	2,239	1,585	501		
182	285	2,512	1,778	562		
181	339	2,818	1,995	631		
180	404	3,162	2,239	708		
179	480	3,548	2,512	794		
178	571	3,981	2,818	891		
177	679	4,467	3,162	1,000		
176	807	5,012	3,548	1,122		
175	960	5,623	3,981	1,259		

All ranges and SPLs are nominal.

*SPL is measured in dB/1 µPA at the dive site. To convert SPL for sound levels referenced to mbar, subtract 100 dB from tabled levels.

(U) = upgrade

APPENDIX 1C

Telephone Numbers

Command	Department	Telephone	Fax
Coastal Systems Station (CSS)	Air Sampling	DSN 436-4482	(850) 234-4482
MED-21		(202) 762-3444	
National Oceanic and Atmospheric Administration (NOAA)	HAZMAT	(206) 526-6317	(206) 526-6329
Naval Sea Systems Command Code (COMNAVSEASYSCOM)		DSN 327-XXXX	(703) 607-2757 DSN 327-2757
00C	Director	(703) 607-2753	
00C1	Finance	(703) 607-2762	
00C2	Salvage	(703) 607-2758	
00C3	Diving	(703) 607-2766	
00C4	Certification	(703) 607-1570	
00C5	Husbandry	(703) 607-2761	
Naval Sea Systems Command Code 92Q		(703) 602-0141	
Naval Facilities Engineering Command (NAVFAC)	Chief Engineer (Code CHENG)	Comm: (202) 685-9165 DSN: 325-9165	(202) 685-1577
NAVFAC Ocean Facilities Program	(Code OFP)	(202) 433-5596 DSN 288-5596.	(202) 433-2280
Naval Facilities Engineering Service Center East Coast DET	Certification (Code 07FH)	Comm: (202) 433-8772 DSN: 288-8772	(202) 433-8777
	Acquisition/Design (Code 551H)	Comm: (202) 433-5480 DSN: 288-5480	(202) 433-5089
Navy Diving Salvage and Training Center (NDSTC)		Comm: (850) 234-4651 DSN: 436-4651	
CSS, Code 5110		DSN: 436-5414	
Navy Experimental Diving Unit		Comm: (850) 230-3100 or (850) 235-1668 DSN: 436-4351	

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DDS	Dry Deck Shelter
DHMLS	Divers Helmet Mounted Lighting System
DLSE	Diving Life-Support Equipment
DLSS	Divers Life Support System
DMO	Diving Medical Officer
DMS	Dive Monitoring System
DMT	Diving Medical Technician
DOT	Department of Transportation
DRS	Dive Reporting System
DSI	Diving Systems International
DSM	Diving System Module
DSRG	Deep Submergence Review Group
DSRV	Deep Submergence Rescue Vehicle
DSSP	Deep Submergence System Project
DT	Dive Time *or* Descent Time
DT/DG	Dive Timer/Depth Gauge
DTC	Definitive Treatment Chamber
DUCTS	Divers Underwater Color Television System
DV	Diver
DVPS	Diver Propulsion Vehicles
EAD	Equivalent Air Depth
EBA	Emergency Breathing Apparatus
EBS I	Emergency Breathing System I
EBS II	Emergency Breathing System II
EDF	Experimental Diving Facility

EDU	Experimental Diving Unit (Canadian)
EDWS	Enhanced Diver Warning System
EEC	Emergency Evacuation Chamber
EGS	Emergency Gas Supply
ENT	Ear, Nose, and Throat
EOD	Explosive Ordnance Disposal
EPs	Emergency Procedures
ESDS	Enclosed Space Diving System
ESDT	Equivalent Single Dive Time
ESSM	Emergency Ship Salvage Material
FADS I	Flyaway Air Dive System I
FADS II	Flyaway Air Dive System II
FADS III	Flyaway Dir Dive System III
FAIR	Failure Analysis or Inadequacy Report
FAR	Failure Analysis Report
FARCC	Flyaway Recompression Chamber
FED SPEC	Federal Specifications
FFM	Full Face Mask
FFW	Feet of Fresh Water
FMGS	Flyaway Mixed-Gas System
FPM	Feet per Minute
FSW	Feet of Sea Water
FV	Floodable Volume
GFI	Ground Fault Interrupter
GPM	Gallons per Minute
HBO_2	Hyperbaric Oxygen

HCU	Harbor Clearance Unit
HOSRA	Helium-Oxygen Supply Rack Assembly
HP	High Pressure
HPNS	High Pressure Nervous Syndrome
HSU	Helium Speech Unscrambler
ICCP	Impressed-Current Cathodic Protection
IDV	Integrated Divers Vest
IL	Inner Lock
ILS	Integrated Logistics Support
ISIC	Immediate Senior in Command
IUSS	Submarine Integrated Undersea Surveillance System
JAG	Judge Advocate General
J/L	Joules per Liter, Unit of Measure for Work of Breathing
KwHr	Kilowatt Hour
LARU	Lambertsen Amphibious Respiratory Unit
LAR V	Draeger Lung Automatic Regenerator
LB	Left Bottom
LCM	Landing Craft
LFA	Low Frequency Acoustic
LFS	Low Frequency Sonar
LP	Low Pressure
LPM	Liters per Minute
LS	Left Surface
LSS	Life Support System *or* Life Support Skid
LWDS	Light Weight Diving System

MBC	Maximal Breathing Capacity
MCC	Main Control Console
MD	Maximum Depth
MDSU	Mobile Diving and Salvage Unit
MDV	Master Diver
MEFR	Maximum Expiratory Flow Rate
MEV	Manual Exhaust Valve
MFP	Minimum Flask Pressure
MGCCA	Mixed-Gas Control Console Assembly
MIFR	Maximum Inspiratory Flow Rate
MILSTD	Military Standards
MMP	Minimum Manifold Pressure
MP	Medium Pressure
MRC	Maintenance Requirement Card
MSW	Meters of Sea Water
MVV	Maximum Ventilatory Volume
NAVEDTRA	Naval Education Training
NAVFAC	Naval Facilities Engineer Command
NAVMED	Naval Medical Command
NAVSEA	Naval Sea Systems Command
ND	Noise Dose
NDSTC	Naval Diving and Salvage Training Center
NEC	Navy Enlisted Classification
NEDU	Navy Experimental Diving Unit
NEURO	Neurological Examination
NID	Non-Ionic Detergent

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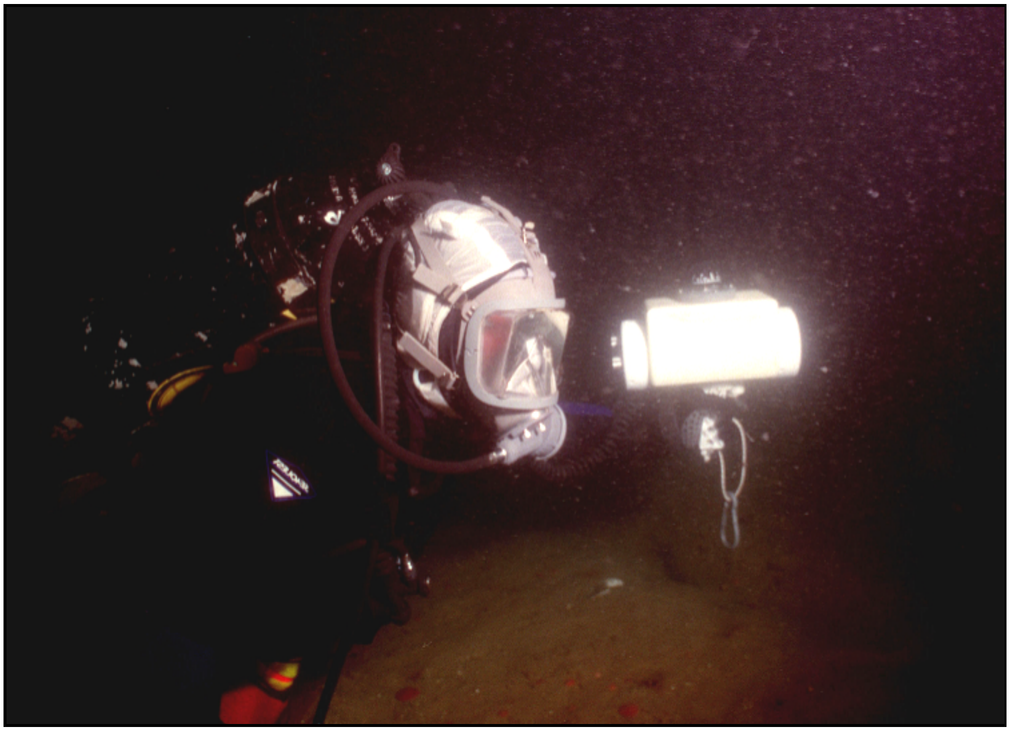


Figure 6-3. Explosive Ordnance Disposal Diving. An EOD diver using handheld sonar to locate objects underwater.

6-4.6 **Underwater Construction.** Underwater construction is the construction, inspection, repair, and removal of in-water facilities in support of military operations. An in-water facility can be defined as a fixed harbor, waterfront, or ocean structure located in or near the ocean. Pipelines, cables, sensor systems, and fixed/advanced-base structures are examples of in-water facilities (Figure 6-4).

6-4.6.1 **Diver Training and Qualification Requirements.** Seabee divers are specifically trained in the special techniques used to accomplish underwater construction tasks.

6-4.6.2 **Equipment Requirements.** Tools and equipment used include common underwater tools in addition to specialized ocean construction equipment. Specific tools and components for large ocean engineering projects are maintained in the Ocean Construction Equipment Inventory (OCEI) located at St. Julian Creek, Norfolk, Virginia.

6-4.6.3 **Underwater Construction Planning Resources.** References for underwater construction planning can be found in:

- *UCT Conventional Inspection and Repair Techniques Manual* NAVFAC P-990

- *Expedient Underwater Repair Techniques* NAVFAC P-991

- *UCT Arctic Operations Manual* NAVFAC P-992
- *Design and Installation of Near-shore Ocean Cable Protection Systems* FPO-5-78

For more information on ocean construction, commands should consult NAVFAC Ocean Facilities Program.

6-4.7 **Demolition Missions.** Diving operations may include demolition duties to remove man-made structures such as barriers, sunken naval craft, and damaged piers. Demolition operations are conducted by blasting, freeing, flattening, or cutting with explosives. Divers may also be assigned to destroy natural formations, such as reefs, bars, and rock structures that interfere with transportation routes. All personnel involved in handling explosives shall be qualified in accordance with the OPNAVINST 8023.2 series.

Figure 6-4. Underwater Construction Diving.

6-4.8 **Combat Swimmer Missions.** Combat swimmers conduct reconnaissance and neutralization of enemy ships, shore-based installations, and personnel. Some missions may require an underwater approach to reach coastal installations undetected. Reconnaissance missions and raids may expose the combat swimmers to additional risk but may be necessary to advance broader warfare objectives.

6-4.9 **Enclosed Space Diving.** Divers are often required to work in enclosed or confined spaces. Using surface-supplied Underwater Breathing Apparatus (UBA) (MK 20 MOD 0, MK 21 MOD 1, or EXO BR MS), divers may enter submarine ballast tanks, mud tanks, or cofferdams, which may be in either a flooded or dry condition. Access to these spaces is normally restrictive, making it difficult for the diver to enter and exit. Enclosed space diving shall be supported by a surface-supplied air system. Refer to section 8-11.4 for more information on the hazards of enclosed space diving.

6-5 COLLECT AND ANALYZE DATA

Information pertinent to the mission objective shall be collected, organized, and analyzed to determine what may affect successful accomplishment of the objective. This process aids in:

These currents may run as fast as two knots and may extend as far as one-half mile from shore. Rip currents, not usually identified in published tables, can vary significantly from day to day in force and location.

- **Surface Current Generated by Wind**. Wind-generated surface currents are temporary and depend on the force, duration, and fetch of the wind. If the wind has been blowing steadily for some time, this current should be taken into consideration especially when planning surface swims and scuba dives.

6-5.3.5.1 ***Equipment Requirements for Working in Currents.*** A diver wearing a surface-supplied outfit, such as the MK 21 SSDS with heavy weights, can usually work in currents up to 1.5 knots without undue difficulty. A diver supplied with an additional weighted belt may be able to accomplish useful work in currents as strong as 2.5 knots. A scuba diver is severely handicapped by currents greater than 1.0 knot. If planning an operation in an area of strong current, it may be necessary to schedule work during periods of slack water to minimize the tidal effect.

6-6 IDENTIFY ENVIRONMENTAL AND OPERATIONAL HAZARDS

Underwater environmental conditions have a major influence on the selection of divers, diving technique, and the equipment to be used. In addition to environmental hazards, a diver may be exposed to operational hazards that are not unique to the diving environment. This section outlines the environmental and operational hazards that may impact an operation.

6-6.1 **Underwater Visibility.**

Underwater visibility varies with depth and turbidity. Horizontal visibility is usually quite good in tropical waters; a diver may be able to see more than 100 feet at a depth of 180 fsw. Horizontal visibility is almost always less than vertical visibility. Visibility is poorest in harbor areas because of river silt, sewage, and industrial wastes flowing into the harbor. Agitation of the bottom caused by strong currents and the passage of large ships can also affect visibility.

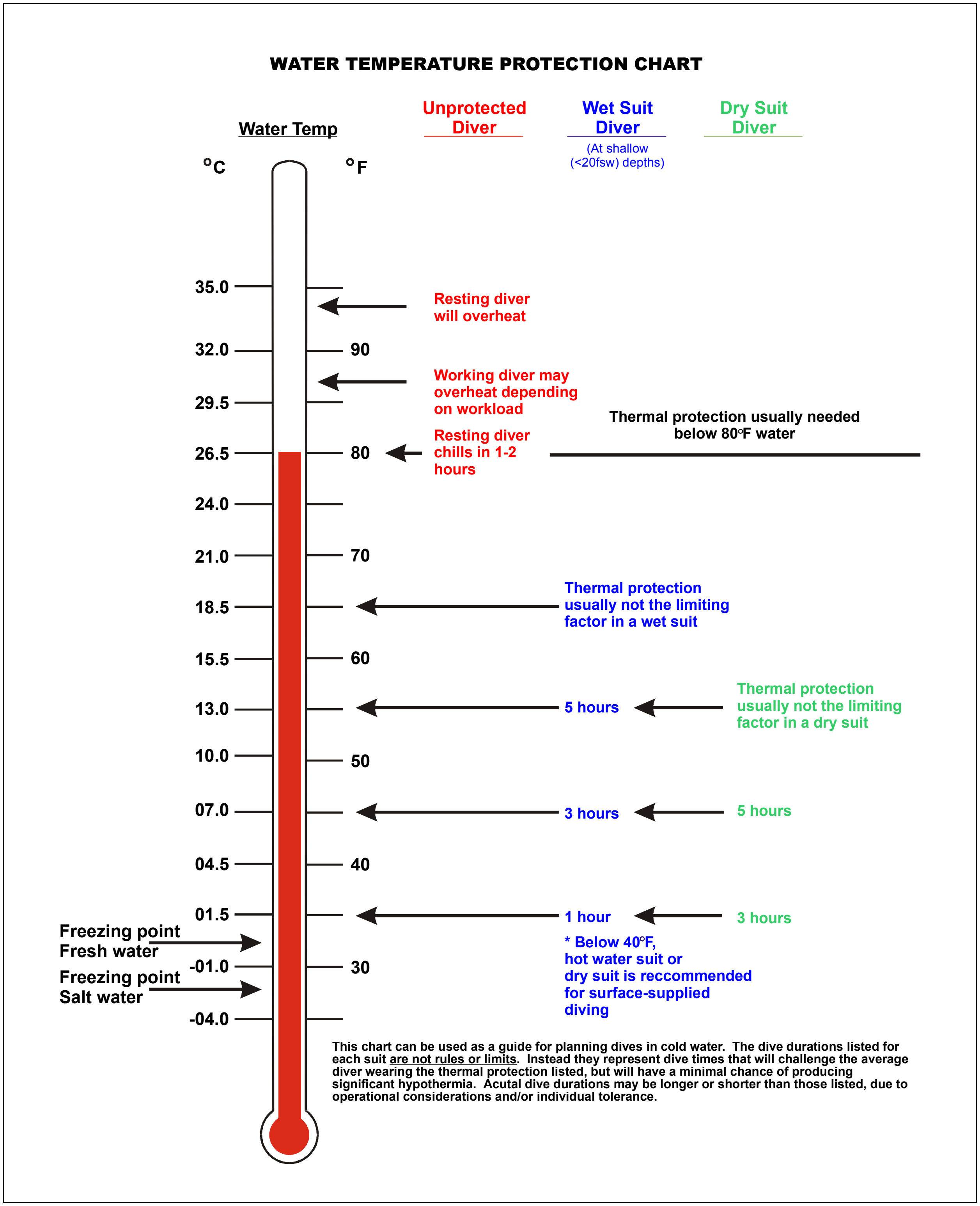
The degree of underwater visibility influences selection of dive technique and can greatly increase the time required for a diver to complete a given task. For example, a diving team preparing for harbor operations should plan for extremely limited visibility, possibly resulting in an increase in bottom time, a longer period on station for the diving unit, and a need for additional divers on the team.

6-6.2 **Temperature.**

Figure 6-11 illustrates how water temperature can affect a diver's performance, and is intended as a planning guide. A diver's physical condition, amount of body fat, and thermal protection equipment determine how long exposure to extreme temperatures can be endured safely. In cold water, ability to concentrate and work efficiently will decrease rapidly. Even in water of moderate temperature (60–70°F, 15.5–21.5°C), the loss of body to the water can quickly bring on diver exhaustion.

6-6.3 **Warm Water Diving.**

Warm water diving is defined as those diving operations that occur in water temperatures exceeding 88° F. During recent studies at the Navy Experimental Diving Unit, physiological limits have been developed for diving



This chart can be used as a guide for planning dives in cold water. The dive durations listed for each suit are not rules or limits. Instead they represent dive times that will challenge the average diver wearing the thermal protection listed, but will have a minimal chance of producing significant hypothermia. Acutal dive durations may be longer or shorter than those listed, due to operational considerations and/or individual tolerance.

Figure 6-11. Water Temperature Protection Chart.

operations using MK 16 UBA, MK 25 UBA, Viper VSW UBA, SCUBA, and surface supplied UBA in water temperatures up to 99°F. Diving in water temperatures above 99°F should not be attempted without first contacting NAVSEA 00C.

6-6.3.1 **Operational Guidelines and Safety Precautions.** These guidelines are based on data collected from heat acclimated divers dressed in UDT swim trunks and t-shirts who were well rested, calorically replete, well hydrated, and had no immediate heat exposure prior to starting exercise. Exercise rate for the divers replicated a moderate swimming effort. Conditions that contribute to thermal loading such as heavy work rates, significant pre/post dive activities, and various diver dress (dive skins/wetsuits/dry suits) can reduce exposure limits appreciably. Define guidelines for exposure limits based on diver dress are currently being developed by NEDU. Until further guidance is provided regarding the measurable effects of these factors, the limits provided shall serve as maximum levels of exposure.

The following precautions apply to all warm water diving operations above 88°F:

- Weight losses up to 15 lbs (or 6-8% of body weight) due to fluid loss may occur and mental and physical performance can be affected. Divers should hydrate fully (approximately 500 ml or 17 oz) two hours before diving. Fluid loading in excess of the recommended 500 ml may cause life-threatening pulmonary edema and should not be attempted.

- Hydrating with water or a glucose/electrolyte beverage should occur as soon as possible after diving. Approximately 500 ml should be replaced for each hour of diving.

- Exposure limits represent maximum cumulative exposure over a 12 hour period. Divers should be hydrated and calorically replete to baseline weight, rested, and kept in a cool environment for at least 12 hours before a repeat exposure to warm water is deemed safe.

NOTE **This guidance does not change NAVSEA-approved canister duration limits for the MK 16, MK 25, and Viper VSW UBAs. Maximum warm water dive time exposure limits for these UBAs shall always be the lesser of the approved UBA canister duration limits or diver physiological exposure limits.**

The following guidance is broken down into specific UBAs:

- **MK 25 UBA** A diver working at a moderate rate, swimming at 0.8 kts or less (combat swimmer):

  88°-94°F - limited to canister/O_2 bottle duration

  94°-97°F - limited to three hours based on physiological limits.

  97°-99°F - limited to one hour based on physiological limits.

A resting diver (SDV OPS):

NOTE **In cases of SDV and DDS operations, thermal loading may change during the course of the mission. Exposure times should be reduced and fluids replaced during the dive when possible.**

88°-94°F - limited to canister/O_2 bottle duration.

94°-97°F - limited to canister/O_2 bottle duration.

97°-99°F - limited to two hours based on physiological limits.

- **MK 16 UBA** A working diver:

  88°-94°F - limited to canister duration as specified in Table 17-4.

  94°-97°F - limited to three hours based on physiological limits.

  97°-99°F - limited to one hour based on physiological limits.

  A resting diver (SDV OPS, during decompression):

  88°-94°F - limited to canister duration as specified in Table 17-4.

  94°-97°F - limited to canister duration as specified in Table 17-4.

  97°-99°F - limited to two hours based on physiological limits.

- **Viper VSW UBA** A diver working at a moderate rate, swimming at 0.8 kts or less:

  88°-94°F - limited to canister duration.

  94°-97°F - limited to three hours based on physiological limits.

  97°-99°F - limited to one hour based on physiological limits.

  A resting diver:

  88°-94°F - limited to canister duration.

  94°-97°F - limited to canister duration.

  97°-99°F - limited to two hours based on physiological limits.

- **SCUBA and Surface Supplied (MK 21, MK 20, EXO BR MS)** A diver working at a moderate rate, swimming at 0.8 kts or less:

  88°-94°F - limited to diver's aerobic endurance.

  94°-97°F - limited to three hours based on physiological limits.

  97°-99°F - limited to one hour based on physiological limits.

  A resting diver (during decompression):

  88°-94°F - unlimited duration.

  94°-97°F - limited to eight hours based on physiological limits.

  97°-99°F - limited to two hours based on physiological limits.

6-6.3.2 **Mission Planning Factors.** The following mission planning factors may mitigate thermal loading and allow greatest utilization of the exposure limits:

1. Conduct diving operations at night, dusk, or dawn to reduce heat stress incurred from sun exposure and high air temperatures.

2. Avoid wearing a hood with a dive skin to allow evaporative cooling.

3. When possible avoid wearing dive skin or anti-chafing dress. Although the effect of various diver dress is not known, it is expected that safe exposure durations at temperatures above 96^0F will be less.

4. Follow the guidelines in para 3-12.3.2 regarding acclimatization. Reduce the intensity of the diving for five days immediately prior to the diving operation.

5. Ensure divers maintain physical conditioning during periods of warm water diving.

6. Methods of cooling the diver should be employed whenever possible. These include using hot water suits to supply cold water to the diver and the use of ice vests.

Mission planning should also include recognition and management of heat stress injuries as part of pre-dive training and briefing. The diver and topside personnel shall be particularly alert for the symptoms of heat stress. Further guidance is contained in paragraph 3-12.3 (Excessive Heat - Hyperthermia), paragraph 3-12.4 (Dehydration), and paragraph 19-7 (Thermal Stress), and Figure 7-6 (Oxygen Consumption and RMV at Different Work Rates).

6-6.4 **Contaminated Water.** When planning for contaminated water diving, medical personnel should be consulted to ensure proper predive precautions are taken and postdive monitoring of divers is conducted. In planning for operations in waters known to be polluted, protective clothing and appropriate preventative medical procedures shall be taken. Diving equipment shall be selected that gives the diver maximum protection consistent with the threat. Resources outside the scope of this manual may be required to deal with nuclear, biological, or chemical contaminants. Resources and technical advice for dealing with contaminated water diving conditions are available through NAVSEA 00C3.

6-6.5 **Chemical Contamination.** Oil leaking from underwater wellheads or damaged tanks can foul equipment and seriously impede a diver’s movements. Toxic materials or volatile fuels leaking from barges or tanks can irritate the skin and corrode equipment. Diving units should not conduct the dive until the contaminant has been identified, the safety factors evaluated, and a process for decontamination set up. Contact NAVSEA 00C3 for further guidance and assistance. Divers operating in waters where a chemical or chemical warfare threat is known or suspected shall evaluate the threat and protect themselves as appropriate. The MK 21 UBA with a double exhaust and a dry suit dress assembly affords limited protection for diving in polluted and contaminated water. Refer to the *MK 21 UBA NAVSEA Technical Manual*, S6560-AG-OMP-010-UBA-MK21/1 for more information on using the MK 21 UBA with a dry suit assembly.

6-6.6 **Biological Contamination.** A diver working near sewer outlets may be exposed to biological hazards. Scuba divers are especially vulnerable to ear and skin infections when diving in waters that contain biological contamination. Divers may also inadvertently take polluting materials into the mouth, posing both physiological and psychological problems. External ear prophylaxis should be provided to diving personnel to prevent ear infections.

6-6.7 **Altitude Diving.** Divers may be required to dive in bodies of water at higher altitudes. Planning shall address the effects of the atmospheric pressures that may be much lower than those at sea level. U.S. Navy Air Decompression Tables are authorized for use at altitudes up to 300 feet above sea level without corrections (see paragraph 9-12). Transporting divers out of the diving area, which may include movement into even higher elevations either overland or by plane, requires special consideration and planning. The Diving Supervisor shall be alert for symptoms of hypoxia and decompression sickness after the dive due to the lower oxygen partial pressure and atmospheric pressure.

6-6.8 **Underwater Obstacles.** Various underwater obstacles, such as wrecks or discarded munitions, offer serious hazards to diving. Wrecks and dumping grounds are often noted on charts, but the actual presence of obstacles might not be discovered until an operation begins. This is a good reason for scheduling a preliminary inspection dive before a final work schedule and detailed dive plan is prepared.

6-6.9 **Electrical Shock Hazards.** Electrical shock may occur when using electric welding or power equipment. All electrical equipment shall be in good repair and be inspected before diving. Although equipped with test buttons, electrical Grounds Fault Interrupters (GFI) often do not provide any indication when the unit has experienced an internal component failure in the fault circuitry. Therefore, GFI component failure during operation (subsequent to testing the unit) may go unnoticed. Although this failure alone will not put the diver at risk, the GFI will not protect the diver if he is placed in contact with a sufficiently high fault current. The following is some general information concerning GFIs:

- GFIs are required when line voltage is above 7.5 VAC or 30 VDC.
- GFIs shall be capable of tripping within 20 milliseconds (ms) after detecting a maximum leakage current of 30 milliamps (ma).
- GFIs require an established reference ground in order to function properly. Cascading GFIs could result in loss of reference ground; therefore, GFIs or equipment containing built-in GFIs should not be plugged into an existing GFI circuit.

In general, three independent actions must occur simultaneously to electrically shock a diver:

- The GFI must fail.
- The electrical equipment which the diver is operating must experience a ground fault.

- The diver must place himself in the path between the fault and earth ground.

6-6.9.1 **Reducing Electrical Shock Hazards.** The only effective means of reducing electrical shock hazards are to ensure:

- Electrical equipment is properly maintained.
- All electrical devices and umbilicals are inspected carefully before all operations.
- Electrical umbilicals are adequately protected to reduce the risk of being abraded or cut when pulled over rough or sharp objects.
- Personnel are offered additional protection through the use of rubber suits (wet, dry, or hot-water) and rubber gloves.
- GFI circuits are tested at regular intervals throughout the operation using built-in test circuits.

Divers operating with remotely operated vehicles (ROVs) should take similar precautions to ensure the ROV electrical system offers the required protection. Many new ROVs use extremely high voltages which make these protective actions even more critical to diver safety.

NEDU has been tasked with repair and testing of the Daniel Woodhead company Model 1670 and 1680 GFIs. Woodhead GFIs needing repair or testing should be sent to:

Navy Experimental Diving Unit
Shipping and Receiving Officer
321 Bullfinch Road
Panama City, FL 32407-7015
ATTN: Code 03D1

Units should be sent to the above address with a DD-1149 and complete return address and written details of problem.

6-6.9.2 **Securing Electrical Equipment.** The Ship Repair Safety Checklist for Diving requires underwater electrical equipment to be secured while divers are working over the side. While divers are in the water:

- Ship impressed-current cathodic protection (ICCP) systems must be secured, tagged out, and confirmed secured before divers may work on an ICCP device such as an anode, dielectric shield, or reference cell.
- When divers are required to work close to an active ICCP anode and there is a risk of contact with the anode, the system must also be secured.
- In situations other than those described above, the ICCP is to remain active.

- Divers working within 15 feet of active systems must wear a full dry suit, unisuit, or wet suit with hood and gloves.

- All other underwater electrical equipment shall be secured while divers are working over the side.

6-6.10 **Explosions.** Explosions may be set off in demolition tasks intentionally, accidentally, or as the result of enemy action. When working with or near explosives, the procedures outlined in SWO 60-AA-MMA-010 shall be followed. Divers should stay clear of old or damaged munitions. Divers should get out of the water when an explosion is imminent.

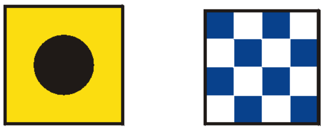
WARNING **Welding or cutting torches may cause an explosion on penetration of gas-filled compartments, resulting in serious injury or death.**

6-6.11 **Sonar.** Appendix 1A provides guidance regarding safe diving distances and exposure times for divers operating in the vicinity of ships transmitting with sonar. This appendix has been substantially revised from Safe Diving Distances from Transmitting Sonar (NAVSEAINST 3150.2A) and should be read in its entirety.

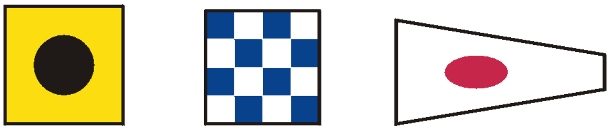
6-6.12 **Nuclear Radiation.** Radiation may be encountered as the result of an accident, proximity to weapons or propulsion systems, weapons testing, or occasionally natural conditions. Radiation exposure can cause serious injury and illness. Safe tolerance levels have been set and shall not be exceeded. These levels may be found in the *Radiological Control Manual*, NAVSEA 0389-LP-660-6542. Local instructions may be more stringent and in such case shall be followed. Prior to diving, all dive team members shall be thoroughly knowledgeable of the local/ command radiological control requirements. All divers shall have a Thermal Luminescence Dosimeter (TLD) or similar device and be apprised of the locations of items such as the reactor compartment, discharges, etc.

6-6.13 **Marine Life.** Certain marine life, because of its aggressive or venomous nature, may be dangerous to man. Some species of marine life are extremely dangerous, while some are merely an uncomfortable annoyance. Most dangers from marine life are largely overrated because most underwater animals leave man alone. All divers should be able to identify the dangerous species that are likely to be found in the area of operation and should know how to deal with each. Refer to Appendix 5C for specific information about dangerous marine life, including identification factors, dangerous characteristics, injury prevention, and treatment methods.

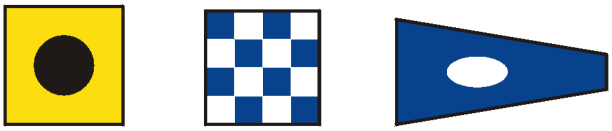
6-6.14 **Vessel and Small Boat Traffic.** The presence of other ships is often a serious problem. It may be necessary to close off an area or limit the movement of other ships. A local Notice to Mariners should be issued. At any time that diving operations are to be conducted in the vicinity of other ships, they shall be properly notified by International Code signal flags (Figure 6-12). An operation may have to be conducted in an area with many small boats operated by people with varied levels of seamanship and knowledge of Nautical Rules of the Road. The diving team should assume that these operators are not acquainted with diving signals



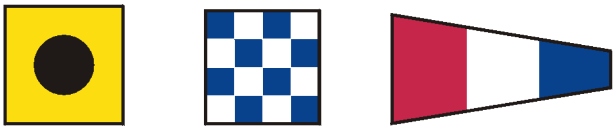
IN: “I require a diver.”



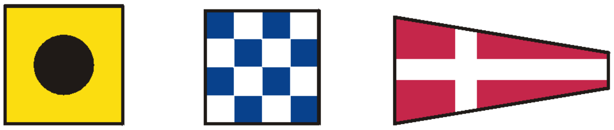
IN1: “I require a diver to clear my propeller.”



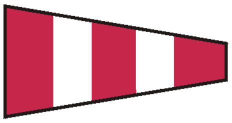
IN2: “I require a diver to examine bottom.”



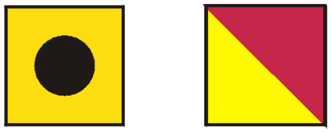
IN3: “I require a diver to place collision mat.”



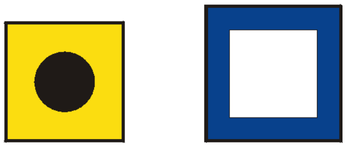
IN4: “I require a diver to clear my anchor.”



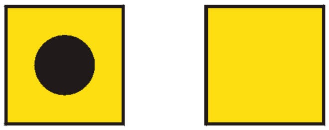
Code Flag (Note 1)



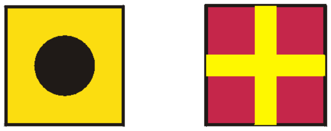
IO: “I have no diver.”



IP: “A diver will be sent as soon as possible or at time indicated.”

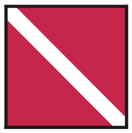


IQ: “Diver has been attacked by diver’s disease and requires decompression chamber treatment.”



IR: “I am engaged in submarine survey work (underwater operations). Keep clear of me and go slow.”

A: “I have a diver down; Keep well clear at slow speed.”



Sport Diver (Unofficial)

General Note: Rule 27 of Navigation Rules-International -Inland of December 1983 states the lights and shapes that must be displayed when engaged in diving operations.

Note 1: International Signal Code – All signals must be preceded by the code flag to signify that they are international signals. (Do not use code flag in inland waters.)

Figure 6-12. International Code Signal Flags.

and take the precautions required to ensure that these vessels remain clear of the diving area. Hazards associated with vessel traffic are intensified under conditions of reduced visibility.

NOTE **When small civilian boats are in the area, use the civilian Sport Diver flag (red with white diagonal stripe) as well as "Code Alpha."**

6-6.15 **Territorial Waters.** Diving operations conducted in the territorial waters of other nations shall be properly coordinated prior to diving. Diving units must be alert to the presence of foreign intelligence-collection ships and the potential for hostile action when diving in disputed territorial waters or combat zones.

6-7 SELECT DIVING TECHNIQUE

The four main types of air diving equipment used in U.S. Navy diving operations are (Figure 6-13):

1. Open-circuit scuba
2. MK 20 MOD 0 surface-supplied gear
3. MK 21 MOD 1 surface-supplied gear
4. EXO BR MS Full Face Mask surface-supplied or open-circuit scuba

6-7.1 **Factors to Consider when Selecting the Diving Technique.** When selecting the technique to be used for a dive, the following factors must be considered:

- Duration and depth of the dive
- Type of work to be performed
- Environmental conditions
- Time constraints

A dive of extended length, even in shallow water, may require an air supply exceeding that which could be provided by scuba. Specific depth limits have been established for each type of diving gear and shall not be exceeded without specific approval of the Chief of Naval Operations in accordance with the OPNAVINST 3150.27 series (see Figure 6-14).

The increase of air consumption with depth limits open-circuit scuba to 130 fsw for reasonable working dives. The hazards of nitrogen narcosis and decompression further limit open-circuit scuba to 190 fsw even for short duration dives. Surface-supplied equipment is generally preferred between 130 and 190 fsw, although open-circuit scuba may be used under some circumstances. Decompression scuba dives and scuba dives deeper than 130 fsw may be conducted when dictated by operational necessity and with the specific approval of the Commanding Officer. All open-circuit scuba dives beyond 100 fsw shall employ twin cylinders, with each having a capacity at least equal to a steel 72 cylinder (64.7 cubic feet).

In some operations there may be no clear-cut choice of which diving technique to use. Selecting a diving technique may depend upon availability of equipment or trained personnel. The following comparison of scuba and surface-supplied tech-

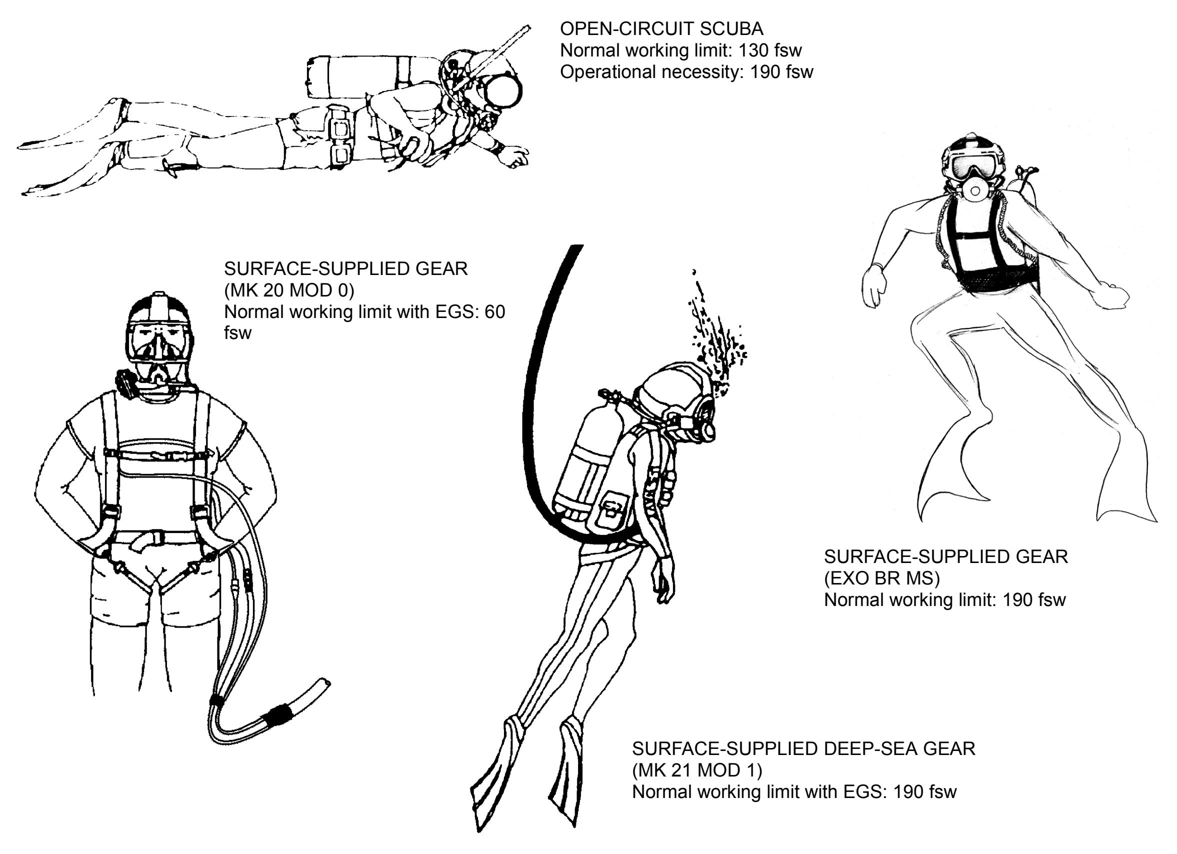


Figure 6-13. Air Diving Techniques. A choice of three air diving techniques are available: open circuit scuba, surface-supplied gear (MK 20 MOD 0), surface-supplied deep-sea gear (MK 21 MOD 1), and surface-supplied deep sea gear (EXO BR MS).

niques highlights the significant differences between the methods and outlines the effect these differences will have on planning.

6-7.2 **Operational Characteristics of Scuba.** The term *scuba* refers to open-circuit air scuba unless otherwise noted. The main advantages of scuba are mobility, depth flexibility and control, portability, and reduced requirement for surface support. The main disadvantages are limited depth, limited duration, lack of voice communications (unless equipped with a through-water communications system), limited environmental protection, remoteness from surface assistance, and the negative psychological and physiological problems associated with isolation and direct exposure to the underwater environment.

6-7.2.1 **Mobility.** The scuba diver is not hindered by bulky or heavy equipment and can cover a considerable distance, with an even greater range through the use of diver propulsion vehicles (DPVs), moving freely in any direction. However, the scuba diver shall be able to ascend directly to the surface in case of emergency.

WARNING **Scuba equipment is not authorized for use in enclosed space diving.**

NORMAL AND MAXIMUM LIMITS FOR AIR DIVING

Depth fsw (meters)	Limit for Equipment	Notes
60 (18)	MK 21 MOD 0 diving equipment, maximum working limit without Emergency Gas Supply (EGS)	a
60 (18)	MK 20 MOD 0 equipment surface-supplied	a
60 (18)	Maximum depth for standby scuba diver using a single cylinder with less than 100 SCF capacity	
100 (30)	Open-circuit scuba with less than 100 SCF cylinder capacity	b
130 (40)	Open-circuit scuba, normal working limit	b
190 (58)	Open-circuit scuba, maximum working limit with Commanding Officer's and Officer-in-Charge's permission	b, d
190 (58)	MK 21 MOD 1 and EXO BR MS (air) diving equipment with EGS, normal working limit	c, d, e
285 (87)	MK 21 MOD 1 and EXO BR MS (air) diving equipment with EGS, maximum working limit, exceptional exposure with authorization from the Chief of Naval Operations (N873)	c, d, e

General Operating Notes (Apply to all):

1. These limits are based on a practical consideration of working time versus decompression time and oxygen-tolerance limits. These limits shall not be exceeded except by specific authorization from the Chief of Naval Operations (N873).
2. Do not exceed the limits for exceptional exposures for the Standard Air Decompression Table.
3. In an emergency, any operable recompression chamber may be used for treatment if deemed safe to use by the Diving Supervisor.

Specific Notes:

a. When diving in an enclosed space an EGS must be used by each diver.

b. Under normal circumstances, do not exceed the limits of the No-Decompression Table. Dives requiring decompression may be made if considered necessary with approval by the Commanding Officer or Officer-in-Charge of the diving command. The total time of a scuba dive (including decompression) shall not exceed the duration of the apparatus in use, disregarding any reserves.

c. A Diving Medical Officer is required at the site for all air dives deeper than 190 fsw, where the maximum working depth of the diving apparatus may be exceeded, and for exceptional exposure dives.

d. All planned air decompression dives deeper than 130 fsw require a certified recompression chamber on site. **An on-site chamber is defined as a certified and ready chamber accessible within 30 minutes of the dive site by available transportation.**

e. The Exceptional Exposure Tables, printed in red in the Standard Air Tables, have a significantly higher probability of DCS and CNS oxygen toxicity.

Figure 6-14. Normal and Maximum Limits for Air Diving.

6-7.2.2 **Buoyancy.** Scuba equipment is designed to have nearly neutral buoyancy when in use, permitting the diver to change or maintain depth with ease. This allows the scuba diver to work at any level in the water column.

6-7.2.3 **Portability.** The portability and ease with which scuba can be employed are distinct advantages. Scuba equipment can be transported easily and put into operation with minimum delay. Scuba offers a flexible and economical method for accomplishing a range of tasks.

6-7.2.4 **Operational Limitations.** Divers shall adhere to the operational limitations contained in Figure 6-14. Bottom time is limited by the scuba's fixed air supply, which is depleted more rapidly when diving deep or working hard.

6-7.2.5 **Environmental Protection.** The scuba diver is not as well protected from cold or from contact with marine plants and animals as a diver in surface-supplied gear, and is more easily swept along by current.

6-7.3 **Operational Characteristics of SSDS.** Surface-supplied diving systems can be divided into two major categories: lightweight full face mask (MK 20), and deep-sea (MK 21) gear.

6-7.3.1 **Mobility.** Surface-supplied gear allows the diver almost as much mobility as scuba. The primary use for deep-sea gear is bottom work in depths up to 190 fsw.

6-7.3.2 **Buoyancy.** The buoyancy associated with SSDS varies with the diving dress selected. Variable Volume Dry Suit (VVDS) provides the greatest buoyancy control (see paragraph 7-3.1.2), making it a desirable technique for working on muddy bottoms, conducting jetting or tunneling, or working where the reaction forces of tools are high.

6-7.3.3 **Operational Limitations.** Divers using surface supplied gear are restricted to the operational limitations described in Figure 6-14. Additional limitations of using surface-supplied gear includes additional topside support personnel and lengthy predive and postdive procedures.

6-7.3.4 **Environmental Protection.** Surface-supplied diving systems can offer the diver increased thermal protection when used with a Hot Water or VVDS. The MK 21 helmet can increase protection of the diver's head. Because the diver's negative buoyancy is easily controlled, an SSDS allows diving in areas with strong currents.

6-8 SELECT EQUIPMENT AND SUPPLIES

6-8.1 **Equipment Authorized for Navy Use.** Equipment procured for use in the U.S. Navy has been tested under laboratory and field conditions to ensure that it will perform according to design specifications. A vast array of equipment and tools is available for use in diving operations. The NAVSEA/00C Diving Equipment Authorized for U.S. Navy Use (ANU) list identifies much of this equipment and categorizes diving equipment authorized for U.S. Navy use.

6-8.2 **Air Supply.**

The quality of diver's breathing air is vitally important. Air supplies provided to the diver in tanks or through a compressor shall meet five basic criteria.

1. Air shall conform to standards for diving air purity found in sections 4-3 and 4-4.

2. Flow to the diver must be sufficient. Refer to the appropriate equipment operations and maintenance manual for flow requirements.

3. Adequate overbottom pressure shall be maintained at the dive station.

4. Adequate air supply shall be available to support the duration and depth of the dive (see paragraph 7-4.1 for scuba; paragraph 8-2.2 for MK 21).

5. A secondary air supply shall be available for surface-supplied diving.

6-8.3 **Diving Craft and Platforms.**

Regardless of the technique being supported, craft used for diving operations shall:

- Be seaworthy
- Include required lifesaving and other safety gear
- Have a reliable engine (unless it is a moored platform or barge)
- Provide ample room for the divers to dress
- Provide adequate shelter and working area for the support crew
- Be able to carry safely all equipment required for the operation
- Have a well-trained crew

Other support equipment—including barges, tugs, floating cranes or vessels and aircraft for area search—may be needed, depending on the type of operation. The need for additional equipment should be anticipated as far in advance as possible.

6-8.3.1 **Deep-Sea Salvage/Rescue Diving Platforms.**

- **Auxiliary Rescue/Salvage Ship (ARS) (Safeguard Class).** The mission of the ARS ship is to assist disabled ships, debeach stranded vessels, fight fires alongside other ships, lift heavy objects, recover submerged objects, tow other vessels, and perform manned diving operations. The ARS class ships carry a complement of divers to perform underwater ship husbandry tasks and salvage operations as well as underwater search and recovery. This class of vessel is equipped for all air diving techniques. Onboard equipment allows diving with air to a depth of 190 fsw.

- **Submarine Tender (AS)**. U.S. submarine tenders are designed specifically for servicing nuclear-powered submarines. Submarine tenders are fitted with a recompression chamber used for hyperbaric treatments. Submarine tenders support underwater ship husbandry and maintenance and security swims.

- **Fleet Ocean Tug (T-ATF)**. T-ATFs are operated by the Military Sealift Command. Civilian crews are augmented with military communications and diving detachments. In addition to towing, these large ocean-going tugs serve as salvage and diving platforms.

- **Diving Tender (YDT)**. These vessels are used to support shallow-water diving operations. Additionally, a wide variety of Standard Navy Dive Boats (SNDB), LCM-8, LCM-6, 50-foot work boats, and other yard craft have been fitted with surface-supplied dive systems.

6-8.3.2 **Small Craft.** Scuba operations are normally conducted from small craft. These can range in size and style from an inflatable rubber raft with an outboard engine to a small landing craft. If divers are operating from a large ship or diving float, a small boat must be ready as a rescue craft in the event a surfacing diver is in trouble some distance from the support site. A small boat used by scuba divers must be able to slip its moorings quickly and move to a diver needing assistance.

6-9 SELECT AND ASSEMBLE THE DIVING TEAM

When planning diving assignments and matching the qualifications and experience of diving personnel to specific requirements of the operation, a thorough knowledge of the duties, responsibilities and relationships of the various members of the diving team is essential. The diving team may include the Diving Officer, Master Diver, Diving Supervisor, Diving Medical Officer, divers qualified in various techniques and equipment, support personnel (tenders—qualified divers if possible), recorder, and medical personnel, as indicated by the type of operation (Figure 6-15). Other members of the ship's company, when properly instructed, provide support in varying degrees in such roles as boat crew, winch operators, and line handlers.

6-9.1 **Manning Levels.** The size of the diving team may vary with the operation, depending upon the type of equipment being used, the number of divers needed to complete the mission, and the depth. Other factors, such as weather, planned length of the mission, the nature of the objective, and the availability of various resources will also influence the size of the team. The minimum number of personnel required on station for each particular type of diving equipment is provided in Figure 6-16. The minimum levels shall be maintained; levels should be increased as necessary to meet anticipated operational conditions and situations.

6-9.2 **Commanding Officer.** The ultimate responsibility for the safe and successful conduct of all diving operations rests with the Commanding Officer. The Commanding Officer's responsibilities for diving operations are defined and specific authority is confirmed by the provisions of U.S. Navy Regulations and other fleet, force, or command regulations. To ensure diving operations are efficiently conducted, the Commanding Officer delegates appropriate authority to selected members of the command who, with subordinate personnel, make up the diving team.

Figure 6-15. MK 21 Dive Requiring Two Divers. The team consists of o
Supervisor, two divers, a standby diver, one tender per diver, comms and lo
operator, and extra personnel (as required).

6-9.3 Diving Officer.

6-9.3.1 **Command Diving Officer.** The Command Diving Officer's primary responsibility is the safe conduct of all diving operations within the command. The Command Diving Officer will become thoroughly familiar with all command diving techniques and have a detailed knowledge of all applicable regulations and is responsible for all operational and administrative duties associated with the command diving program. The Command Diving Officer is designated in writing by the Commanding Officer. Although preferably a qualified diver, any commissioned officer, or in the absence of a commissioned officer, a Master Diver may be assigned as the Command Diving Officer.

6-9.3.2 **Watchstation Diving Officer.** Personnel assigned as the Watchstation Diving Officer are responsible to the Commanding Officer for the safe and successful conduct of the diving operation. The Watchstation Diving Officer provides overall supervision of diving operations, ensuring strict adherence to procedures and precautions. Although preferably a qualified diver, any PQS qualified commissioned officer or Master Diver may be assigned this watchstation. The Watchstation Diving Officer must be designated in writing by the Commanding Officer.

MINIMUM MANNING LEVELS FOR AIR DIVING

	EOD Scuba		Scuba Operations		Surface-Supplied Operations	
	Single Diver	Buddy Pair	Single Diver	Buddy Pair	Diver's Helmet MK 21 MOD 1	MK 20 MOD 0
Diving Supervisor	1	1	1	1	1	1
Comms and Logs	(a)	(a)	(a)	(a)	1	1
Console Operator					(j)	(j)
Diver	1 (c)	2 (c)	1 (b) (c)	2 (b) (c)	1 (b)	1 (b)
Standby Diver	1 (c)	1 (c)	1 (c)	1 (c)	1 (k)	1 (k)
Diver Tender (b, c)	1 (d)		1		1	1
Standby Diver Tender	(i)	(i)	(i)	(i)	1	1
Total	4 (f) (h)	4 (f,h)	4 (e,g,h,i)	4 (h)	6	6 (g)

WARNING

These are the minimum personnel levels required, below which diving operations are not permitted. Circumstances may require that these minimum personnel levels be increased so the diving operations can be conducted safely.

NOTES:

(a) Diving Supervisor may fill requirement for Comms and Logs for scuba operations.

(b) Each additional surface-supplied diver or tended scuba diver will require an additional tender. The number of surface-supplied divers may be increased as necessary to the extent that the air system can support them.

(c) Scuba divers, except SPECWAR divers and divers involved in Limpet operations (see paragraph 6-4.5 and paragraph 7-8.2 for more information), must be surface tended if direct ascent to surface is not available, such as when diving under the bilge keel. Situations may require that a diver be tended by a second diver situated at the bilge keel .

(d) The EOD Diving Officer may authorize a single untethered EOD diver when disarming live ordnance in an operational (non-training) situation.

(e) Submarines that have only three qualified scuba divers assigned are authorized to conduct dives with a non-diver Commissioned Officer acting as the Diving Supervisor. In all cases, submarines will endeavor to obtain the prerequisite number of qualified divers to support their mission. All other commands are to conduct all scuba diving operations with a minimum of four divers.

(f) EOD Diving Officers are required for all EOD operations involving Render Safe Procedures (RSP).

(g) Manning levels for Multi-place Underwater Egress Trainer Device 9D5, are contained in the NASTP SOP. Use of qualified non-divers as Comms and Logs is authorized.

(h) Chase boat is required for scuba diving operations when conditions exist where the diver could be displaced from the dive site (i.e. bottom search in a strong current or a long-duration swim).

(i) If the standby diver is deployed, the Diving Supervisor shall tend the standby diver.

(j) Comms and Logs may serve as Console Operator.

(k) Standby diver can be deployed as a working diver in accordance with paragraph 6-9.8.2.

Figure 6-16. Minimum Personnel Levels for Air Diving Stations.

6-9.4 Master Diver.

6-9.4.1 **Master Diver Responsibilities.** The Master Diver is the most qualified person to supervise air and mixed-gas dives (using scuba and surface-supplied diving equipment) and recompression treatments (Figure 6-17). He is directly responsible to the Commanding Officer, via the Diving Officer, for the safe conduct of all phases of diving operations. The Master Diver manages preventive and corrective maintenance on diving equipment, support systems, salvage machinery, handling systems, and submarine rescue equipment. Training and requalification of divers attached to the command is conducted by the Master Diver, who also ensures that divers are trained in emergency procedures. The Master Diver recommends to the Commanding Officer, via the Diving Officer, which enlisted divers are qualified to serve as Diving Supervisors. The Master Diver oversees the efforts of the Diving Supervisor and provides advice and technical expertise. If circumstances warrant, the Master Diver shall relieve the Diving Supervisor and assume control of the dive station. In the absence of a Diving Officer, the Master Diver can assume the duties and responsibilities of the Diving Officer.

6-9.4.2 **Master Diver Qualifications.** The Master Diver has completed Master Diver evaluation course (CIN A-433-0019) successfully and is proficient in the operation of Navy-approved underwater breathing equipment, support systems, and recompression chambers. He is also trained in diagnosing and treating diving injuries and illnesses. The Master Diver is thoroughly familiar with operating and emergency procedures for diving systems, and possesses a working knowledge of gas mixing and analysis, computations, salvage theory and methods, submarine rescue procedures, towing, and underwater ship husbandry. The Master Diver shall possess a comprehensive knowledge of the scope and application of all Naval instructions and publications pertaining to diving, and shall ensure that logs and reports are maintained and submitted as required.

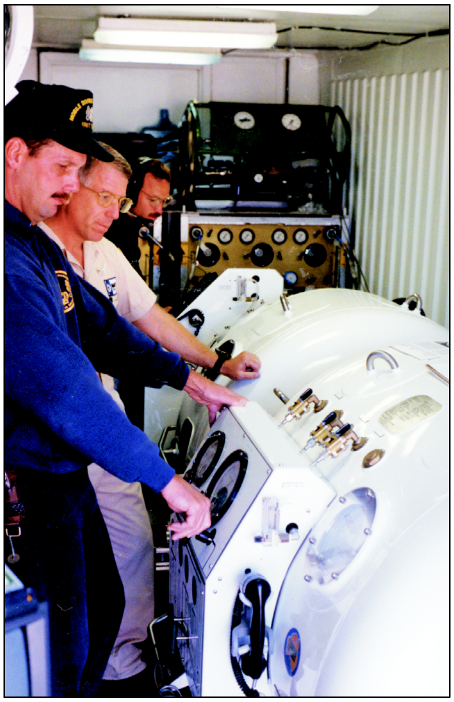


Figure 6-17. Master Diver Supervising Recompression Treatment.

6-9.5 Diving Supervisor.

While the Master Diver is in charge of the overall diving operation, the Diving Supervisor is in charge of the actual diving operation for a particular dive or series of dives. Diving operations shall not be conducted without the presence of the Diving Supervisor.

6-9.5.1 **Predive Responsibilities.** The Diving Supervisor shall be included in preparing the operational plans. The Diving Supervisor shall consider contingencies, determine equipment requirements, recommend diving assignments, and establish back-up requirements for the operation. The Diving Supervisor shall be familiar with all divers on the team and shall evaluate the qualifications and physical fitness of the divers selected for each particular job. The Diving Supervisor inspects all equipment and conducts predive briefings of personnel.

6-9.5.2 **Responsibilities While Operation is Underway.** While the operation is underway, the Diving Supervisor monitors progress; debriefs divers; updates instructions to subsequent divers; and ensures that the Master Diver, Diving Officer, Commanding Officer, and other personnel as necessary are advised of progress and of any changes to the original plan. The Diving Supervisor should not hesitate to call upon the technical advice and expertise of the Master Diver during the conduct of the dive operation.

6-9.5.3 **Postdive Responsibilities.** When the mission has been completed, the Diving Supervisor gathers appropriate data, analyzes the results of the mission, prepares reports to be submitted to higher authority, and ensures that required records are completed. These records may range from equipment logs to individual diving records.

6-9.5.4 **Diving Supervisor Qualifications.** The Diving Supervisor may be commissioned or enlisted depending on the size of the operation and the availability of qualified personnel. When qualifying a Diving Supervisor, selection is based on knowledge, experience, level of training, and the competence of the available personnel in the following order:

1. Master Diver
2. First Class Diver/Saturation Diver/Seal Diver/EOD Diver
3. Diving Medical Technician
4. Second Class Diver
5. Scuba Diver

Regardless of rank, the Diving Supervisor shall be a qualified diver of demonstrated ability and experience. The Diving Supervisor shall be designated in writing by the Commanding Officer. Diving Supervisors under instruction shall stand their watches under the supervision of a qualified Diving Supervisor.

6-9.6 **Diving Medical Officer.** The Diving Medical Officer defines the proper course of medical action during medical emergencies. The Diving Medical Officer provides on-site medical care for divers as conditions arise and ensures that diving personnel receive proper attention before, during, and after dives. The Diving Medical Officer may modify recompression treatment tables, with the specific concurrence of the Commanding Officer. A Diving Medical Officer is required on site for all air dives deeper than 190 fsw, when the maximum working depth of the diving apparatus may be exceeded, or for exceptional exposure air dives.

6-9.7 Diving Personnel.

6-9.7.1 **Diving Personnel Responsibilities.** While working, the diver shall keep topside personnel informed of conditions on the bottom, progress of the task, and of any developing problems that may indicate the need for changes to the plan or a call for assistance from other divers. To ensure safe conduct of the dive, the diver shall always obey a signal from the surface and repeat all commands when using voice communications. The diver is responsible for the diving gear worn and shall ensure that it is complete and in good repair.

6-9.7.2 **Diving Personnel Qualifications.** Military divers shall be qualified and designated in accordance with instructions issued by the Naval Personnel Command (NPC) or as appropriate by USMC, U.S. Army, or U.S. Air Force orders. Civilian divers diving under military cognizance must be qualified in accordance with SECNAVINST 12000.20. The diver selected for an operation shall be qualified for the diving technique used, the equipment involved, and for diving to the depth required. Diving personnel assigned to the Navy Experimental Diving Unit (NEDU) and Naval Submarine Medical Research Laboratory (NSMRL) are exempt from such requirements as they are assigned as experimental diving test subjects and may be employed in experimental dive profiles as required within approved test protocols.

6-9.8 Standby Diver.

A standby diver with a tender is required for all diving operations. The standby diver need not be equipped with the same equipment as the primary diver (except as otherwise specified), but shall have equivalent depth and operational capabilities. Scuba shall not be used for the standby diver for surface-supplied diving operations.

Figure 6-18. Standby Diver.

6-9.8.1 **Standby Diver Qualifications.** The standby diver is a fully qualified diver, assigned for back-up or to provide emergency assistance, and is ready to enter the water immediately. For surface-supplied operations, the standby diver shall be dressed to the following points, MK 20 or MK 21 MOD 1, with strain relief connected to the harness. Under certain conditions, the Diving Supervisor may require that the helmet be worn. A standby scuba diver shall don all equipment and be checked by the Diving Supervisor. The standby diver may then remove the mask and fins and have them ready to don immediately for quick deployment. For safety reasons at the discretion of the Diving Supervisor, the standby diver may remove the tank. The standby diver receives the same briefings and instructions as the working diver, monitors the progress of the dive, and is fully prepared to respond if called upon for assistance. The scuba standby diver shall be equipped with an octopus rig.

6-9.8.2 **Deploying the Standby Diver as a Working Diver.** The standby diver may be deployed as a working diver provided all of the following conditions are met:

1. Surface-supplied no-decompression dive of 60 fsw or less.
2. Same job/location, e.g., working on port and starboard propellers on the same vessel:
   - Prior to deploying the standby diver, the work area shall be determined to be free of hazards (i.e., suctions, discharges) by the first diver on the job site.
   - When working in ballast tanks or confined spaces, the standby diver may be deployed as a working diver, but both divers shall be tended by a third diver who is outside the confined space (also see paragraph 6-4.9).

NOTE The standby diver shall remain on deck ready for deployment when salvage operations diving is being done.

6-9.9 **Buddy Diver.** A buddy diver is the diver's partner for a scuba operation. The buddy divers are jointly responsible for the assigned mission. Each diver keeps track of depth and time during the dive. Each diver shall watch out for the safety and well-being of his buddy and shall be alert for symptoms of nitrogen narcosis, decompression sickness, and carbon dioxide build up. A diver shall keep his buddy within sight and not leave his buddy alone except to obtain additional assistance in an emergency. If visibility is limited, a buddy line shall be used to maintain contact and communication. If scuba divers get separated and cannot locate each other, both divers shall surface immediately.

6-9.10 Diver Tender.

6-9.10.1 **Diver Tender Responsibilities.** The tender is the surface member of the diving team who works closely with the diver on the bottom. At the start of a dive, the tender checks the diver's equipment and topside air supply for proper operation and dresses the diver. Once the diver is in the water, the tender constantly tends the lines to eliminate excess slack or tension (certain UWSH tasking may preclude this requirement, e.g., working in submarine ballast tanks, shaft lamination, dry habitat welding, etc.). The tender exchanges line-pull signals with the diver, keeps the Diving Supervisor informed of the line-pull signals and amount of diving hose/tending line over the side and remains alert for any signs of an emergency.

6-9.10.2 **Diver Tender Qualifications.** The tender should be a qualified diver. When circumstances require the use of a non-diver as a tender, the Diving Supervisor shall ensure that the tender has been thoroughly instructed in the required duties. If a substitute tender shall be employed during an operation, the Diving Supervisor must make certain that the substitute is adequately briefed before assuming duties.

6-9.11 **Recorder.** The recorder shall be a qualified diver. The recorder maintains worksheets, fills out the diving log for the operation, and records the diver's descent time, depth of dive, and bottom time. The recorder reports to the Diving Supervisor the ascent time, first stop, and time required at the decompression stop. In scuba operations, the Diving Supervisor may assume the duties of the recorder. The recorder is required to have on hand a copy of the U.S. Navy Standard Decompression Tables being used. When decompression begins, the schedule selected by the Diving Supervisor is recorded on the chart and log. The recorder keeps all members of the team advised of the decompression requirements of the divers.

6-9.12 **Medical Personnel.** Diving Medical Officers and Diving Medical Technicians are given special training in hyperbaric medicine and in diving. They provide medical advice and treatment to diving personnel. They also instruct members of the diving team in first aid procedures and participate in diving operations when the presence of diving medical personnel is indicated, as when particularly hazardous operations are being conducted.

Diving medical personnel evaluate the fitness of divers before operations begin and are prepared to handle any emergencies which might arise. They also observe the condition of other support personnel and are alert for signs of fatigue, overexposure, and heat exhaustion.

6-9.13 **Other Support Personnel.** Other support personnel may include almost any member of the command when assigned to duties that support diving operations. Some personnel need specific indoctrination. Small-Boat operators shall understand general diving procedures, know the meanings of signals, and be aware of the mission objectives. Other personnel, such as winch operators or deck crew, might interact with the operation directly, but only when under the control of the Diving Supervisor. Engineering personnel may be directed to secure overboard discharges and lock the shafts; a sonar operator might be required to secure equipment and put a Do Not Energize tag on the power switch (see Figure 6-20a for a detailed Ship Repair Safety Checklist).

The Officer of the Deck (OOD) or Command Duty Officer (CDO) is responsible to the Commanding Officer for the operation and safety of the ship and crew during the watch. He shall be concerned with the activities of the diving team. The OOD/CDO shall stay informed of the progress of the operation, of any changes to the original plan and shall be notified as far in advance as possible of any special requirements. The Officer of the Deck or Command Duty Officer shall be alert for any shifting of the moor or changing weather/sea conditions. He shall inform the Diving Officer and/or Diving Supervisor of any changes in these conditions.

6-9.14 **Cross-Training and Substitution.** Each member of the diving team should be qualified to act in any position on the team. Because it is probable that substitutions will be made at some point during a lengthy mission, dive plans and diving schedules should organize personnel and work objectives so that experienced personnel will always be available on site. All personnel who participate in the operation should be included in initial briefings.

6-9.15 **Physical Condition.** Diving candidates shall meet the specific physical requirements for divers set forth by the Commander Naval Medical Command and pass a physical screening test as outlined in MILPERSMAN Article 1220.100. Once qualified, the diver is responsible for maintaining good health and top physical condition.

Reference NAVMEDCOMINST 6200.15 (series) to provide guidance on suspension of diving duty of pregnant servicewomen.

Medical personnel assigned to a diving unit shall evaluate the day-to-day condition of each diver and the Diving Supervisor shall verify the fitness of each diver immediately before a dive. Any symptom such as cough, nasal congestion, apparent fatigue, emotional stress, skin or ear infection is reason for placing the diver on the binnacle list until the problem is corrected.

Physical condition is often best judged by the diver who is obligated to report to the Diving Supervisor when not feeling fit to dive. A diver who, for any reason, does not want to make a dive should not be forced. A diver who regularly declines diving assignments shall be disqualified as a diver.

6-9.16 **Underwater Salvage or Construction Demolition Personnel.** Underwater salvage demolition personnel are trained in underwater precision explosives techniques and hold Navy Enlisted Classification (NEC) 5375. Salvage/Construction Demolition Diver personnel shall be currently certified and designated in accordance with the requirements specified in the OPNAVINST 8023.2 series.

6-9.16.1 **Blasting Plan.** The senior Salvage/Construction Demolition Diver NEC 5375 is responsible for providing the Commanding Officer with a comprehensive and written blasting plan. At a minimum, the blasting plan contains:

- Demolition team organization
- Work description with alternatives
- Range standard operating procedures
- Prefiring procedures
- Postfiring procedures
- Area security plan
- Misfire procedures
- Personnel and equipment casualty procedures
- Blasting sequence of events

The NEC 5375 should direct all phases of demolition operations using only approved operating and safety procedures. The NEC 5375 shall ensure the operation is not allowed to proceed until receiving specific approval from the Diving Supervisor and shall take charge of all misfires, ensuring they are handled in accordance with the approved plan.

6-9.16.2 **Explosive Handlers.** All divers who handle explosives shall be trained and certified in accordance with the OPNAVINST 8023.2 series.

6-10 OSHA REQUIREMENTS FOR U.S. NAVY CIVILIAN DIVING

U.S. Navy Civilian Divers are governed by the provisions of the U.S. Navy Diving Program, yet they must also comply with U.S. Government Occupational Safety and Health Administration (OSHA) diving standards, delineated in 29 CFR Part 1910 Subpart T; Subj: Commercial Diving Operations. U.S. Navy Civilian Divers are identified as all permanent Navy employees who have been formally trained at an approved U.S. Navy diving school as either a scuba diver, Second Class diver, or First Class diver. Commercial divers contracted by the Navy who are not permanent government employees are not subject to these provisions.

Most directives of the U.S. Navy Diving Program provide parallel requirements, or are similar enough not to be considered of substantive difference. Several requirements of OSHA do, however, exceed those delineated for U.S. Navy divers and must be identified to ensure compliance by USN civilian divers to both standards. Therefore, the following restrictions, in addition to all other requirements addressed in this manual, apply to USN civilian divers:

6-10.1 Scuba Diving (Air) Restriction.

1. Scuba diving shall not be conducted:

- To depths deeper than 130 fsw
- To depths deeper than 100 fsw unless a recompression chamber is on station

2. All scuba cylinder manifolds shall be equipped with a manual reserve (J valve), or an independent reserve cylinder gas supply with a separate regulator.

3. A scuba cylinder submersible pressure gauge shall be worn by each diver.

6-10.2 Surface Supplied Air Diving Restrictions.

1. Surface supplied air diving shall not be conducted to depths greater than 190 fsw.

2. Dives shall be limited to in-water decompression times of less than 120 minutes.

3. An emergency gas supply (come-home bottle) is required for any dive greater than 60 fsw planned decompression dives or for which direct access to the surface is not available.

6-10.3 Mixed Gas Diving Restrictions.

All mixed gas diving shall be limited to:

- A maximum depth of 220 fsw
- Less than 120 minutes total in-water decompression time
- Having a recompression chamber on station

6-10.4 Recompression Chamber Requirements.

1. An on-station recompression chamber is defined as a certified and ready chamber on the dive site.

2. A recompression chamber shall be on station for all planned decompression dives or dives deeper than 100 fsw.

3. Civilian divers shall remain at the location of a manned recompression chamber for 1 hour after surfacing from a dive that requires a recompression chamber on station.

6-11 ORGANIZE AND SCHEDULE OPERATIONS

6-11.1 Task Planning and Scheduling. All phases of an operation are important. A common failure when planning an operation is to place excessive emphasis on the actual dive phases, while not fully considering predive and postdive activities. Another failure is to treat operations of a recurring nature with an indifference to safety that comes with overfamiliarity. In developing a detailed task-by-task schedule for an operation, the following points shall be considered.

- The schedule shall allocate sufficient time for preparation, transit to the site, rendezvous with other vessels or units, and establishing a secure mooring.

- Bottom time is always at a premium, and all factors that shall affect bottom time shall be carefully considered. These include depth, decompression, number of divers available, support craft size, and surface and underwater environmental conditions.

- The number and profile of repetitive dives in a given time period are limited. This subject is discussed in Chapter 10.

- Plans may include the option to work night and day; however, there is an increased risk of a diving mishap from fatigue.

- The level of personnel support depends on the diving techniques selected (see Minimum Manning Levels, Figure 6-16).

- In planning tasks, non-diving topside support personnel shall be selected carefully, especially those who are not members of the diving team.

- Any schedule must be flexible to accommodate unexpected complications, delays, and changing conditions.

- The Diving Supervisor shall anticipate difficulties and be prepared to either overcome them or find alternative methods to circumvent them.

- If divers have been inactive and operating conditions permit, work-up dives should be conducted in-water or in the recompression chamber.

6-11.2 Postdive Tasks. A diving operation is completed when the objective has been met, the diving team demobilized, and records and reports are filed. Time shall be allocated for:

- Recovering, cleaning, inspecting, maintaining, repairing, and stowing all equipment
- Disposing materials brought up during the operation
- Debriefing divers and other team members
- Analyzing the operation, as planned and as actually carried out
- Restocking expended materials
- Ensuring the readiness of the team to respond to the next assignment

6-12 BRIEF THE DIVING TEAM

6-12.1 Establish Mission Objective. The Master Diver or the Diving Supervisor shall brief the team on the overall mission and the aspects of the operation necessary to safely achieve the objective. Major points of discussion include:

1. Clear, brief statement of the mission objective
2. Dominant factors that may determine mission outcome (i.e., environment, enemy/friendly actions, and hazards)
3. All tasks required to accomplish the mission
4. Time factors that may prevail
5. Any changes or augmentations of the dive plan

Prior to starting a dive mission or dive day, coordination with other commands and/or shipboard departments shall be accomplished.

6-12.2 Identify Tasks and Procedures. A briefing may be elaborate or simple. For complex operations, briefing with charts, slides, and diagrams may be required. For most operations, the briefing need not be complex and may be an informal meeting. The briefing shall present a breakdown of the dive objective, primary tasks, diving procedures, and related work procedures for the mission or dive day. Prompt debriefing of divers returning to the surface provides the Diving Supervisor with information that may influence or alter the next phase of the operation. Divers should be questioned about the progress of the work, bottom conditions and anticipated problems. They should also be asked for suggestions for immediate changes.

6-12.3 Review Diving Procedures. Diving and work procedures to be used for the task at hand shall be reviewed during the briefing. The Diving Safety and Planning

Checklist (Figure 6-19a), Ship Repair Safety Checklist for Diving (Figure 6-20a) and the Surface-Supplied Diving Operations Predive Checklist (Figure 6-21a) support control of diving operations. These checklists may be tailored to specific missions and environmental circumstances.

6-12.4 **Assignment of Personnel.** All personnel assignments shall be reviewed and verified to ensure properly trained personnel are assigned to operations.

6-12.5 **Assistance and Emergencies.** In any diving operation, three types of assistance may be required:

1. Additional equipment, personnel, supplies, or services
2. Clarification, authorization, or decisions from higher command
3. Emergency assistance in the event of an accident or serious illness

Unexpected developments or emergency situations may be accompanied by confusion. The source and availability of any needed assistance and the method for obtaining it as quickly as possible, shall be determined in advance. The location of the nearest recompression chamber shall be identified and the chamber operators notified before the operation begins. The sources of emergency transportation, military or civilian, shall be established and alerted and the nearest Diving Medical Officer should be located and notified. Arrangements must be made to ensure a 24-hour availability for emergency assistance.

When a recompression chamber is required by Figure 6-14, the chamber shall be currently certified and within 30 minutes' travel time from the dive site. If a recompression chamber is required in an emergency, a non-certified chamber may be used if the Diving Supervisor is of the opinion that it is safe to operate.

Figure 6-22 is a suggested format for the Emergency Assistance Checklist that shall be completed and posted at the diving station to provide necessary information so that any member of the team could take prompt action.

6-12.5.1 **Notification of Ship's Personnel.** In the event of a diving casualty or mishap on dive station, calm must be maintained. Maintain silence on the side and take orders from the Diving Officer, Master Diver, and/or Diving Supervisor.

6-12.5.2 **Fouling and Entrapment.** Fouling and entrapment are more common with surface-supplied gear than scuba because of the ease with which the umbilicals can become entangled. Divers shall be particularly careful and watch their own umbilicals and those of their partners as well.

The surface-supplied diver may become fouled more easily, but will usually have an ample air supply while working to get free. The scuba diver may have no other recourse but to remove the gear and make a free ascent. If trapped, the scuba diver must face the possibility of running out of air before being able to work free.

DIVING SAFETY AND PLANNING CHECKLIST

(Sheet 1 of 4)

STEPS IN PLANNING OF DIVING OPERATIONS

Detailed, advanced planning is the foundation of diving safety.

A. ANALYZE THE MISSION FOR SAFETY.

- __ Ensure mission objective is defined.
- __ Determine that non-diving means of mission accomplishment have been considered and eliminated as inappropriate.
- __ Coordinate emergency assistance.
- __ Review relevant Naval Warfare Publications (NWP) and OPNAV instructions.

B. IDENTIFY AND ANALYZE POTENTIAL HAZARDS.

- __ **Natural Hazards:**
  1. Atmospheric:
     - __ Exposure of personnel to extreme conditions
     - __ Adverse exposure of equipment and supplies to elements
     - __ Delays or disruption caused by weather
  2. Surface:
     - __ Sea sickness
     - __ Water entry and exit
     - __ Handling of heavy equipment in rough seas
     - __ Maintaining location in tides and currents
     - __ Ice, flotsam, kelp, and petroleum in the water
     - __ Delays or disruption caused by sea state
  3. Underwater and Bottom:
     - __ Depth which exceeds diving limits or limits of available equipment
     - __ Exposure to cold temperatures
     - __ Dangerous marine life
     - __ Tides and currents
     - __ Limited visibility
     - __ Bottom obstructions
     - __ Ice (underwater pressure ridges, loss of entry hole, loss of orientation, etc.)
     - __ Dangerous bottom conditions (mud, drop-offs, etc.)
- __ **On-Site Hazards:**
  - __ Local marine traffic or other conflicting naval operations
  - __ Other conflicting commercial operations
  - __ High-powered, active sonar
  - __ Radiation contamination and other pollution (chemical, sewer outfalls, etc.)
- __ **Mission Hazards:**
  - __ Decompression sickness
  - __ Communications problems
  - __ Drowning
  - __ Other trauma (injuries)
  - __ Hostile action
- __ **Object Hazards:**
  - __ Entrapment and entanglement
  - __ Shifting or working of object
  - __ Explosives or other ordnance

Figure 6-19a. Diving Safety and Planning Checklist (sheet 1 of 4).

DIVING SAFETY AND PLANNING CHECKLIST

(Sheet 2 of 4)

C. SELECT EQUIPMENT, PERSONNEL and EMERGENCY PROCEDURES.

__ **Diving Personnel:**

__ 1. Assign a complete and properly qualified Diving Team.
__ 2. Assign the right man to the right task.
__ 3. Verify that each member of the Diving Team is properly trained and qualified for the equipment and depths involved.
__ 4. Determine that each man is physically fit to dive, paying attention to:
__general condition and any evidence of fatigue
__record of last medical exam
__ears and sinuses
__severe cold or flu
__use of stimulants or intoxicants
__ 5. Observe divers for emotional readiness to dive:
__motivation and professional attitude
__stability (no noticeably unusual or erratic behavior)

__ **Diving Equipment:**

__ 1. Verify that diving gear chosen and diving techniques are adequate and authorized for mission and particular task.
__ 2. Verify that equipment and diving technique are proper for depth involved.
__ 3. Verify that life support equipment has been tested & approved for U.S. Navy use.
__ 4. Determine that all necessary support equipment and tools are readily available and are best for accomplishing job efficiently and safely.
__ 5. Determine that all related support equipment such as winches, boats, cranes, floats, etc. are operable, safe and under control of trained personnel.
__ 6. Check that all diving equipment has been properly maintained (with appropriate records) and is in full operating condition.

__ **Provide for Emergency Equipment:**

__ 1. Obtain suitable communications equipment with sufficient capability to reach outside help; check all communications for proper operation.
__ 2. Verify that a recompression chamber is ready for use, or notify the nearest command with one that its use may be required within a given timeframe.
__ 3. Verify that a completely stocked first aid kit is at hand.
__ 4. If oxygen will be used as standby first aid, verify that the tank is full and properly pressurized, and that masks, valves, and other accessories are fully operable.
__ 5. If a resuscitator will be used, check apparatus for function.
__ 6. Check that fire-fighting equipment is readily available and in full operating condition.
__ 7. Verify that emergency transportation is either standing by or on immediate call.

__ **Establish Emergency Procedures:**

__ 1. Know how to obtain medical assistance immediately.
__ 2. For each potential emergency situation, assign specific tasks to the diving team and support personnel.
__ 3. Complete and post Emergency Assistance Checklist; ensure that all personnel are familiar with it.
__ 4. Verify that an up-to-date copy of U.S. Navy Decompression Tables is available.
__ 5. Ensure that all divers, boat crews and other support personnel understand all diver hand signals.
__ 6. Predetermine distress signals and call-signs.

Figure 6-19b. Diving Safety and Planning Checklist (sheet 2 of 4).

DIVING SAFETY AND PLANNING CHECKLIST

(Sheet 3 of 4)

__ 7. Ensure that all divers have removed anything from their mouths on which they might choke during a dive (gum, dentures, tobacco).
__ 8. Thoroughly drill all personnel in Emergency Procedures, with particular attention to cross-training; drills should include:

Emergency recompression
Fire
Rapid dressing
Restoration of breathing
Electric shock
Entrapment
Rapid undressing
First aid
Embolism
Near-drowning
Blowup
Lost diver

D. ESTABLISH SAFE DIVING OPERATIONAL PROCEDURES

__ **Complete Planning, Organization, and Coordination Activities:**

__ 1. Ensure that other means of accomplishing mission have been considered before deciding to use divers.
__ 2. Ensure that contingency planning has been conducted.
__ 3. Carefully state goals and tasks of each mission and develop a flexible plan of operations (Dive Plan).
__ 4. Completely brief the diving team and support personnel (paragraph 6-12).
__ 5. Designate a Master Diver or properly qualified Diving Supervisor to be in charge of the mission.
__ 6. Designate a recorder/timekeeper and verify that he understands his duties and responsibilities.
__ 7. Determine the exact depth at the job-site through the use of a lead line, pneumofathometer, or commercial depth sounder.
__ 8. Verify existence of an adequate supply of compressed air available for all planned diving operations **plus an adequate reserve for emergencies**.
__ 9. Ensure that no operations or actions on part of diving team, support personnel, technicians, boat crew, winch operators, etc., take place without the knowledge of and by the direct command of the Diving Supervisor.
__ 10.All efforts must be made through planning, briefing, training, organization, and other preparations to minimize bottom time. Water depth and the condition of the diver (especially fatigue), rather than the amount of work to be done, shall govern diver's bottom time.
__ 11.Current decompression tables shall be on hand and shall be used in all planning and scheduling of diving operations.
__ 12.Instruct all divers and support personnel not to cut any lines until approved by the Diving Supervisor.
__ 13.Ensure that ship, boat, or diving craft is securely moored and in position to permit safest and most efficient operations (exceptions are emergency and critical ship repairs).
__ 14.Verify that, when using surface-supplied techniques, the ship, boat, or diving craft has at least a two-point moor.
__ 15.Ensure that, when conducting SCUBA operations in hazardous conditions, a boat can be quickly cast off and moved to a diver in distress.

__ **Perform Diving Safety Procedures, Establish Safety Measures:**

__ 1. Ensure that each diver checks his own equipment in addition to checks made by tenders, technicians or other support personnel.
__ 2. Designate a standby diver for all diving operations; standby diver shall be dressed to the necessary level and ready to enter the water if needed.
__ 3. Assign buddy divers, when required, for all scuba operations.

Figure 6-19c. Diving Safety and Planning Checklist (sheet 3 of 4).

DIVING SAFETY AND PLANNING CHECKLIST

(Sheet 4 of 4)

- __ 4. Take precautions to prevent divers from being fouled on bottom. If work is conducted inside a wreck or other structure, assign a team of divers to accomplish task. One diver enters wreck, the other tends his lines from point of entry.
- __ 5. When using explosives, take measures to ensure that no charge shall be fired while divers are in water.
- __ 6. Use safety procedures as outlined in relevant Naval publications for all U/W cutting and welding operations.
- __ 7. Brief all divers and deck personnel on the planned decompression schedules for each particular dive. Check provisions for decompressing the diver.
- __ 8. Verify that ship, boat, or diving craft is displaying proper signals, flags, day shapes, or lights to indicate diving operations are in progress. (Consult publications governing International or Inland Rules, International/Inland local signals, and Navy communications instructions.)
- __ 9. Ensure that protection against harmful marine life has been provided. (See Appendix 5C.)
- __ 10. Check that the quality of diver's air supply is periodically and thoroughly tested to ensure purity.
- __ 11. Thoroughly brief boat crew.
- __ 12. Verify that proper safety and operational equipment is aboard small diving boats or craft.

__ **Notify Proper Parties that Dive Operations Are Ready to Commence:**

- __ 1. Diving Officer
- __ 2. Commanding Officer
- __ 3. Area Commander
- __ 4. Officer of the Deck/Day
- __ 5. Command Duty Officer or Commanding Officer of ships alongside
- __ 6. Bridge, to ensure that ship's personnel shall not:
  - __ turn the propeller or thrusters
  - __ get underway
  - __ activate active sonar or other electronics
  - __ drop heavy items overboard
  - __ shift the moor
- __ 7. Ship Duty Officer, to ensure that ship's personnel shall not:
  - __ activate sea discharges or suctions
  - __ operate bow or stern-planes or rudder
  - __ operate vents or torpedo shutters
  - __ turn propellers
- __ 8. Other Interested Parties and Commands:
  - __ Harbor Master/Port Services Officer
  - __ Command Duty Officers
  - __ Officers in tactical command
  - __ Cognizant Navy organizations
  - __ U.S. Coast Guard (if broadcast warning to civilians is required)
- __ 9. Notify facilities having recompression chambers and sources of emergency transportation that diving operations are underway and their assistance may be needed.

Figure 6-19d. Diving Safety and Planning Checklist (sheet 4 of 4).

SHIP REPAIR SAFETY CHECKLIST FOR DIVING

(Sheet 1 of 2)

When diving operations will involve underwater ship repairs, the following procedures and safety measures are required in addition to the Diving Safety Checklist.

SAFETY OVERVIEW

A. The Diving Supervisor shall advise key personnel of the ship undergoing repair:

1. OOD
2. Engineering Officer
3. CDO
4. OODs of ships alongside
5. Squadron Operations (when required)
6. Combat Systems Officer (when required)

B. The Diving Supervisor shall request that OOD/Duty Officer of ship being repaired ensure that appropriate equipment is secured and tagged out.

C. The Diving Supervisor shall request that OOD/Duty Officer advise him when action has been completed and when diving operations may commence.

D. When ready, the diving Supervisor shall request that the ship display appropriate diving signals and pass a diving activity advisory over the 1MC every 30 minutes. For example, “There are divers working over the side. Do not operate any equipment, rotate screws, cycle rudder, planes or torpedo shutters, take suction from or discharge to sea, blow or vent any tanks, activate sonar or underwater electrical equipment, open or close any valves, or cycle trash disposal unit before checking with the Diving Supervisor.”

E. The Diving Supervisor shall advise the OOD/Duty Officer when diving operations commence and when they are concluded. At conclusion, the ship will be requested to pass the word on the 1MC, “Diving operations are complete. Carry out normal work routine.”

F. Diving within 50 feet of an active sea suction (located on the same side of the keel) that is maintaining a suction of 50 gpm or more, is not authorized unless considered as an emergency repair and is authorized by the Commanding Officers of both the repair activity and tended vessel. When it is determined that the sea suction is maintaining a suction of less than 50 gpm and is less than 50 feet, or maintaining a suction of more than 50 gpm and is less than 50 feet but on the opposite side of the keel, the Diving Supervisor shall determine if the sea suction is a safety hazard to the divers prior to conducting any diving operation. In all cases the Diving Supervisor shall be aware of the tend of the diver’s umbilical to ensure that it will not cross over or become entrapped by an active sea suction.

NOTIFY KEY PERSONNEL.

1. OOD ______________________________ (signature)
2. Engineering Officer ______________________________ (signature)
3. CDO USS ________________________ (signature)
4. OOD USS ________________________
   OOD USS ________________________
   OOD USS ________________________
   OOD USS ________________________
5. Squadron Operations ______________________________
6. Port Services Officer ______________________________

(Diving Supervisor (Signature))

Figure 6-20a. Ship Repair Safety Checklist for Diving (sheet 1 of 2).

SHIP REPAIR SAFETY CHECKLIST FOR DIVING

(Sheet 2 of 2)

TAG OUT EQUIPMENT

TAG OUT	SIGNATURE AND RATE
Rudder	________________________
Anchors	________________________
Planes	________________________
Torpedo tube shutters	________________________
Trash disposal unit	________________________
Tank blows	________________________
Tank vents	________________________
Shaft(s) locked	________________________
Sea suctions	________________________
Sea discharges	________________________
U/W electrical equipment	________________________
Sonars	________________________
Other U/W equipment	________________________

USS ________________________

(name of ship)

CDO ________________________

(signature of CDO)

Figure 6-20b. Ship Repair Safety Checklist for Diving (sheet 2 of 2).

SURFACE-SUPPLIED DIVING OPERATIONS PREDIVE CHECKLIST

(Sheet 1 of 3)

CAUTION

This checklist is an overview intended for use with the detailed Operating Procedures (OPs) from the appropriate equipment O&M technical manual.

A. Basic Preparation:

__ 1. Verify that a recompression chamber, Diving Officer, and Diving Medical Officer shall be present on the diving station for dives of more than 190 fsw.

__ 2. Verify that proper signals indicating underwater operations being conducted are displayed correctly.

__ 3. Ensure that all personnel concerned, or in the vicinity, are informed of diving operations.

__ 4. Determine that all valves, switches, controls, and equipment components affecting diving operation are tagged-out to prevent accidental shut-down or activation.

__ 5. Verify that diving system and recompression chamber are currently certified or granted a Chief of Naval Operations (CNO) waiver to operate.

B. Equipment Protection:

__ 1. Assemble all members of the diving team and support personnel (winch operators, boat crew, watchstanders, etc.) for a predive briefing.

__ 2. Assemble and lay out all dive equipment, both primary equipment and standby spares for diver (or standby diver), including all accessory equipment and tools.

__ 3. Check all equipment for superficial wear, tears, dents, distortion, or other discrepancies.

__ 4. Check all masks, helmets, view ports, faceplates, seals, and visors for damage.

__ 5. Check all harnesses, laces, strain reliefs, and lanyards for wear; renew as needed.

C. MK 21 MOD1:

__ Ensure that all Operating Procedures (OPs) have been completed in accordance with *UBA MK 21 MOD 1 Technical Manual*, NAVSEA S6560-AG-OMP-010-UBA-21/1.

D. MK 20 MOD 0:

__ Ensure that all Operating Procedures (OPs) have been completed in accordance with *UBA MK 20 MOD 0 Technical Manual*, NAVSEA SS600-AK-MMO-010/MK 20 MOD 0.

E. General Equipment:

__ 1. Check that all accessory equipment – tools, lights, special systems, spares, etc., – are on site and in working order. In testing lights, tests should be conducted with lights submerged in water and extinguished before removal, to prevent overheating and failure.

__ 2. Erect diving stage or attach diving ladder. In the case of the stage, ensure that the screw pin shackle connecting the stage line is securely fastened with the shackle pin seized with wire or a safety shackle is used to help prevent opening.

F. Preparing the Diving System:

__ 1. Check that a primary and suitable back-up air supply is available with a capacity in terms of purity, volume, and supply pressure to completely service all divers including decompression, recompressions and accessory equipment throughout all phases of the planned operation.

__ 2. Verify that all diving system operating procedures have been conducted to properly align the dive system.

__ 3. Ensure that qualified personnel are available to operate and stand watch on the dive system.

Figure 6-21a. Surface-Supplied Diving Operations Predive Checklist (sheet 1 of 3).

SURFACE-SUPPLIED DIVING OPERATIONS PREDIVE CHECKLIST

(Sheet 2 of 3)

__ 4. Compressors:
  ___ a. Determine that sufficient fuel, coolant, lubricants, and antifreeze are available to service all components throughout the operation. All compressors should be fully fueled, lubricated, and serviced (with all spillage cleaned up completely).
  ___ b. Verify that all diving system operating procedures have been conducted properly to align the dive system.
  ___ c. Check maintenance and repair logs to ensure the suitability of the compressor (both primary and back-up) to support the operation.
  ___ d. Verify that all compressor controls are properly marked and any remote valving is tagged with “Divers Air Supply - Do Not Touch” signs.
  ___ e. Ensure that compressor is secure in diving craft and shall not be subject to operating angles, caused by roll or pitch, that will exceed 15 degrees from the horizontal.
  ___ f. Verify that oil in the compressor is an approved type. Check that the compressor oil does not overflow Fill mark; contamination of air supply could result from fumes or oil mist.
  ___ g. Check that compressor exhaust is vented away from work areas and, specifically, does not foul the compressor intake.
  ___ h. Check that compressor intake is obtaining a free and pure suction without contamination. Use pipe to lead intake to a clear suction if necessary.
  ___ i. Check all filters, cleaners and oil separators for cleanliness IAW PMS.
  ___ j. Bleed off all condensed moisture from filters and from the bottom of volume tanks. Check all manifold drain plugs, and that all petcocks are closed.
  ___ k. Check that all belt-guards are properly in place on drive units.
  ___ l. Check all pressure-release valves, check valves and automatic unloaders.
  ___ m. Verify that all supply hoses running to and from compressor have proper leads, do not pass near high-heat areas such as steam lines, are free of kinks and bends, and are not exposed on deck in such a way that they could be rolled over, damaged, or severed by machinery or other means.
  ___ n. Verify that all pressure supply hoses have safety lines and strain reliefs properly attached.

H. Activate the Air Supply in accordance with approved OPs.

__ 1. Compressors:
  ___ a. Ensure that all warm-up procedures are completely followed.
  ___ b. Check all petcocks, filler valves, filler caps, overflow points, bleed valves, and drain plugs for leakage or malfunction of any kind.
  ___ c. Verify that there is a properly functioning pressure gauge on the air receiver and that the compressor is meeting its delivery requirements.
__ 2. Cylinders:
  ___ a. Gauge all cylinders for proper pressure.
  ___ b. Verify availability and suitability of reserve cylinders.
  ___ c. Check all manifolds and valves for operation.
  ___ d. Activate and check delivery.
__ 3. For all supply systems, double check “Do Not Touch” tags (tags outs).

Figure 6-21b. Surface-Supplied Diving Operations Predive Checklist (sheet 2 of 3).

SURFACE-SUPPLIED DIVING OPERATIONS PREDIVE CHECKLIST

(Sheet 3 of 3)

I. Diving Hoses:

__ 1. Ensure all hoses have a clear lead and are protected from excessive heating and damage.
__ 2. Check hose in accordance with PMS.
__ 3. Ensure that the hose (or any length) has not been used in a burst test program. No hose length involved in such a program shall be part of an operational diving hose.
__ 4. Check that hoses are free of moisture, packing material, or chalk.
__ 5. Soap test hose connections after connection to air supply and pressurization.
__ 6. Ensure umbilical boots are in good condition.

J. Test Equipment with Activated Air Supply in accordance with approved OPs.

__ 1. Hook up all air hoses to helmets, masks and chamber; make connections between back-up supply and primary supply manifold.
__ 2. Verify flow to helmets and masks.
__ 3. Check all exhaust and non-return valves.
__ 4. Hook up and test all communications.
__ 5. Check air flow from both primary and back-up supplies to chamber.

K. Recompression Chamber Checkout (Predive only):

__ 1. Check that chamber is completely free and clear of all combustible materials.
__ 2. Check primary and back-up air supply to chamber and all pressure gauges.
__ 3. Check that chamber is free of all odors or other “contaminants.”
__ 4. Hook up and test all communications.
__ 5. Check air flow from both primary and back-up supplies to chamber.

Final Preparations:

__ 1. Verify that all necessary records, logs, and timesheets are on the diving station.
__ 2. Check that appropriate decompression tables are readily at hand.
__ 3. Place the dressing bench in position, reasonably close to the diving ladder or stage, to minimize diver travel.

Figure 6-21c. Surface-Supplied Diving Operations Predive Checklist (sheet 3 of 3).

EMERGENCY ASSISTANCE CHECKLIST

RECOMPRESSION CHAMBER

Location

Name/Phone Number

Response Time

AIR TRANSPORTATION

Location

Name/Phone Number

Response Time

SEA TRANSPORTATION

Location

Name/Phone Number

Response Time

HOSPITAL

Location

Name/Phone Number

Response Time

DIVING MEDICAL OFFICER

Location

Name/Phone Number

Response Time

GAS SUPPLIES

Location

Name/Phone Number

Response Time

COMMUNICATIONS

Location

Name/Phone Number

Response Time

DIVING UNITS

Location

Name/Phone Number

Response Time

COMMAND

Location

Name/Phone Number

Response Time

EMERGENCY CONSULTATION

Duty Phone Numbers 24 Hours a Day

Navy Experimental Dive Unit (NEDU)

Commercial (850) 234-4351
(850) 230-3100
DSN 436-4351

Navy Diving Salvage and Training Center (NDSTC)

Commercial (850) 234-4651
DSN 436-4651

Figure 6-22. Emergency Assistance Checklist.

The first and most important action that a trapped diver can take is to stop and think. The diver shall remain calm, analyze the situation, and carefully try to work free. Panic and overexertion are the greatest dangers to the trapped diver. If the situation cannot be resolved readily, help should be obtained. A new umbilical can be provided to the surface-supplied diver; the scuba diver can be given a new apparatus or may be furnished air by the dive partner.

Once the diver has been freed and returns to the surface, the diver shall be examined and treated, bearing in mind the following considerations:

- The diver will probably be overtired and emotionally exhausted.
- The diver may be suffering from or approaching hypothermia.
- The diver may have a physical injury.
- A scuba diver may be suffering from asphyxia. If a free ascent has been made, gas embolism may have developed.
- Significant decompression time may have been missed.

6-12.5.3 **Equipment Failure.** With well-maintained equipment that is thoroughly inspected and tested before each dive, operational failure is rarely a problem. When a failure does occur, the correct procedures will depend upon the type of equipment and dive. As with most emergencies, the training and experience of the diver and the diving team will be the most important factor in resolving the situation safely.

6-12.5.3.1 ***Loss of Gas Supply.*** Usually, when a diver loses breathing gas it should be obvious almost immediately. Some diving apparatus configurations may have an emergency gas supply (EGS). When breathing gas is interrupted, the dive shall be aborted and the diver surfaced as soon as possible. Surfacing divers may be suffering from hypoxia, hypercapnia, missed decompression, or a combination of the three, and should be treated accordingly.

6-12.5.3.2 ***Loss of Communications.*** If audio communications are lost with surface-supplied gear, the system may have failed or the diver could be in trouble. If communications are lost:

1. Use line-pull signals at once. Depth, current, bottom or work site conditions may interfere.
2. Check the rising bubbles of air. A cessation or marked decrease of bubbles could be a sign of trouble.
3. Listen for sounds from the diving helmet. If no sound is heard, the circuit is probably out of order. If the flow of bubbles seems normal, the diver may be all right.

4. If sounds are heard and the diver does not respond to signals, assume the diver is in trouble.

5. Have divers already on the bottom investigate, or send down the standby diver to do so.

6-12.5.4 **Lost Diver.** In planning for an operation using scuba, lost diver procedures shall be included in the dive plan and dive brief. Losing contact with a scuba diver can be the first sign of a serious problem. If contact between divers is lost, each diver shall surface. If the diver is not located quickly, or not found at the surface following correct lost communications procedure, the Diving Supervisor shall initiate search procedures immediately. At the same time, medical personnel should be notified and the recompression chamber team alerted.

A lost diver is often disoriented and confused and may have left the operating area. Nitrogen narcosis or other complications involving the breathing mixture, which can result in confusion, dizziness, anxiety, or panic, are common in recovered lost divers. The diver may harm the rescuers unknowingly. When the diver is located, the rescuer should approach with caution to prevent being harmed and briefly analyze the stricken diver's condition.

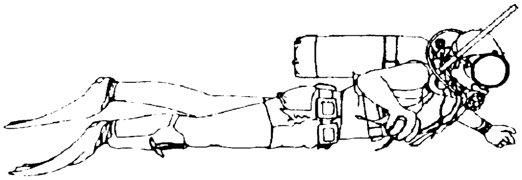
If the diver is found unconscious, attempts should be made to resupply breathing gas and restore consciousness. If this cannot be accomplished, the diver shall be brought to the surface immediately. Gas Embolism may occur during ascent and significant decompression may be missed and immediate recompression may be required. If it is possible to provide the diver with an air supply such as a single-hose demand scuba, the rescuer should do so during the ascent.

6-12.5.5 **Debriefing the Diving Team.** After the day's diving has been completed (or after a shift has finished work if the operation is being carried on around the clock), all members of the diving team should be brought together for a short debriefing of the day's activities. This offers all personnel a chance to provide feedback to the Diving Supervisor and other members of the team. This group interaction can help clarify any confusion that may have arisen because of faulty communications, lack of dive site information, or misunderstandings from the initial briefing.

6-13 AIR DIVING EQUIPMENT REFERENCE DATA

There are several diving methods which are characterized by the diving equipment used. The following descriptions outline capabilities and logistical requirements for various air diving systems.

Scuba General Characteristics



Principle of Operation:

Self contained, open-circuit demand system

Minimum Equipment:

1. Open-circuit scuba with J-valve or submersible pressure gauge
2. Life preserver/buoyancy compensator
3. Weight belt (if required)
4. Dive knife
5. Face mask
6. Swim fins
7. Submersible wrist watch
8. Depth gauge

Principal Applications:

1. Shallow water search
2. Inspection
3. Light repair and recovery

Advantages:

1. Rapid deployment
2. Portability
3. Minimum support requirements
4. Excellent horizontal and vertical mobility
5. Minimum bottom disturbances

Disadvantages:

1. Limited endurance (depth and duration)
2. Limited physical protection
3. Influenced by current
4. Lack of voice communication (unless equipped with a through-water communications system or full face mask)

Restrictions:

Work limits:

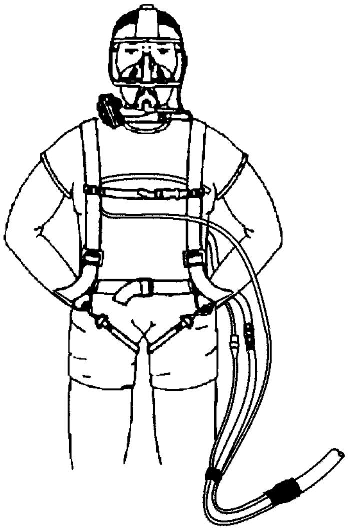
1. Normal 130 fsw
2. Maximum 190 fsw with Commanding Officer or Officer-in-Charge's permission
3. 100 fsw using single scuba cylinder with less than 100 SCF
4. Standby diver with at least 100 SCF cylinder capacity below 60 fsw
5. Within no-decompression limits
6. Current - 1 knot maximum
7. Diving team - minimum 4 persons

Operational Considerations:

1. Standby diver required
2. Small craft mandatory for diver recovery during open-ocean diving.
3. Moderate to good visibility preferred
4. Ability to free ascend to surface required (see paragraph 7-8.2)

Figure 6-23. Scuba General Characteristics.

MK 20 MOD 0 General Characteristics



Principle of Operation:

Surface-supplied, open-circuit lightweight system

Minimum Equipment:

1. MK 20 MOD 0 mask
2. Harness
3. Weight belt (as required)
4. Dive knife
5. Swim fins or boots
6. Surface umbilical

Principal Applications:

Diving in mud tanks and enclosed spaces

Advantages:

1. Unlimited by air supply
2. Good horizo ntal mobility
3. Voice and/or line-pull signal capabilities

Disadvantages:

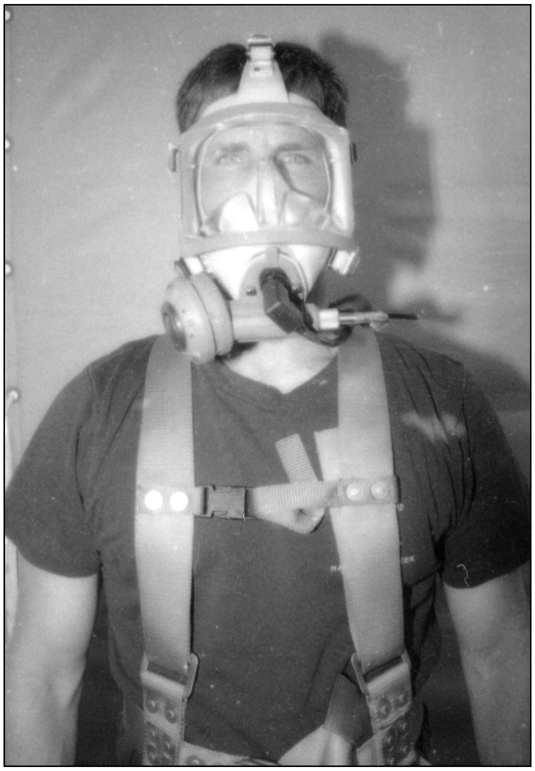
1. Limited physical protection

Restrictions:

1. Work limits: 60 fsw
2. Current - Above 1.5 knots requires extra weights
3. Enclosed space diving requires an Emergency Gas Supply (EGS) with 50 to 150 foot whip and second-stage regulator.

Operational Considerations:

1. Adequate air supply system required
2. Standby diver required



MK 20 MOD 0 Helmet.

Figure 6-24. MK 20 MOD 0 General Characteristics.

MK 21 MOD 1 General Characteristics

Principle of Operation:

Surface-supplied, open-circuit system

Minimum Equipment:

1. MK 21 MOD 1 Helmet
2. Harness
3. Weight belt (if required)
4. Dive knife
5. Swim fins or boots
6. Surface umbilical
7. EGS bottle deeper than 60 fsw

Principal Applications:

1. Search
2. Salvage
3. Inspection
4. Underwater Ships Husbandry and enclosed space diving

Advantages:

1. Unlimited by air supply
2. Head protection
3. Good horizontal mobility
4. Voice and/or line pull signal capabilities
5. Fast deployment

Disadvantages:

1. Limited mobility

Restrictions:

1. Work limits: 190 fsw
2. Emergency air supply (EGS) required deeper than 60 fsw or diving inside a wreck or enclosed space
3. Current - Above 1.5 knots requires extra weights
4. Enclosed space diving requires an Emergency Gas Supply (EGS) with 50 to 150 foot whip and second stage regulator.

Operational Considerations:

1. Adequate air supply system required
2. Standby diver required

MK 21 MOD 1 Helmet.

Figure 6-25. MK 21 MOD 1 General Characteristics.

EXO BR MS Characteristics

Principle of Operation:

Surface-supplied, open-circuit system
Self contained, open-circuit demand system

Minimum Equipment:

1. EXO BR MS Full Face Mask
2. Manifold Block (except for scuba and ship husbandry enclosed spaces)
3. Harness
4. Weight belt (if required)
5. Dive knife
6. Swim fins or boots
7. Surface umbilical
8. EGS bottle deeper than 60 fsw

Principal Applications:

1. Search
2. Salvage
3. Inspection
4. Underwater Ships Husbandry and enclosed space diving

Advantages:

1. Unlimited by air supply
2. Good horizontal mobility
3. Voice and/or line pull signal capabilities
4. Fast deployment

Disadvantages:

1. Limited physical protection

Restrictions:

1. Work limits: 190 fsw
2. Emergency air supply (EGS) required deeper than 60 fsw or diving inside a wreck or enclosed space
3. Current - Above 1.5 knots requires extra weights
4. Enclosed space diving requires an Emergency Gas Supply (EGS) with 50 to 150 foot whip and second stage regulator.

Operational Considerations:

1. Adequate air supply system required
2. Standby diver required

EXO BR MS Full Face Mask.

Figure 6-26. EXO BR MS Characteristics

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CHAPTER 7

Scuba Air Diving Operations

7-1 INTRODUCTION

7-1.1 Purpose. The purpose of this chapter is to familiarize divers with standard and emergency procedures when diving with scuba equipment.

7-1.2 Scope. This chapter covers the use of open-circuit scuba, which is normally deployed in operations not requiring decompression. Decompression diving using open-circuit air scuba may be undertaken only if no other option exists and only with the concurrence of the Commanding Officer or Officer-in-Charge (OIC). Closed-circuit underwater breathing apparatus is the preferred method of performing scuba decompression dives. Operation of open-circuit, closed-circuit, and semiclosed-circuit systems designed for use with mixed-gas or oxygen is covered in Volume 4.

7-2 REQUIRED EQUIPMENT FOR SCUBA OPERATIONS

At a minimum, each diver must be equipped with the following items to safely conduct an open-circuit scuba dive:

- Open-circuit scuba.
- Face mask.
- Life preserver/buoyancy compensator.*
- Weight belt and weights as required.**
- Knife.**
- Swim fins.
- Submersible pressure gauge or Reserve J-valve.
- Submersible wrist watch. Only one is required when diving in pairs with a buddy line.**
- Depth gauge. **
- Octopus.

* During the problem-solving pool phase of scuba training, CO_2 cartridges may be removed and replaced with plugs or expended cartridges that are painted International Orange.

** These items are not required for the pool phase of scuba training.

7-2.1 **Equipment Authorized for Navy Use.** Only diving equipment that has been certified or authorized for use by the NAVSEA/00C ANU list shall be used in a Navy dive. However, many items, such as hand tools, which are not specifically listed in the ANU list or do not fit under the scope of certification and are deemed valuable to the success of the dive, can be used. A current copy must be maintained by all diving activities. The ANU list can be found on the Internet at http://www.navsea.navy.mil/sea00c/doc/anu_disc.html.

7-2.2 **Open-Circuit Scuba.** All open-circuit scuba authorized for Navy use employ a demand system that supplies air each time the diver inhales. The basic open-circuit scuba components are:

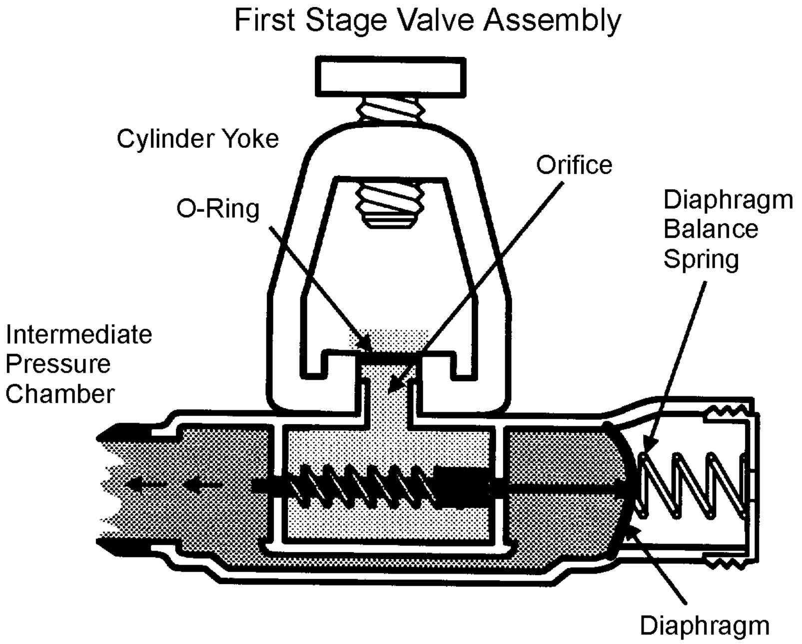
- Demand regulator assembly
- One or more air cylinders
- Cylinder valve and manifold assembly
- Backpack or harness

7-2.2.1 **Demand Regulator Assembly.** The demand regulator assembly is the central component of the open-circuit system. The regulator delivers air to the diver after reducing the high-pressure air in the cylinder to a pressure that can be used by the diver. There are two stages in a typical system (Figure 7-1).

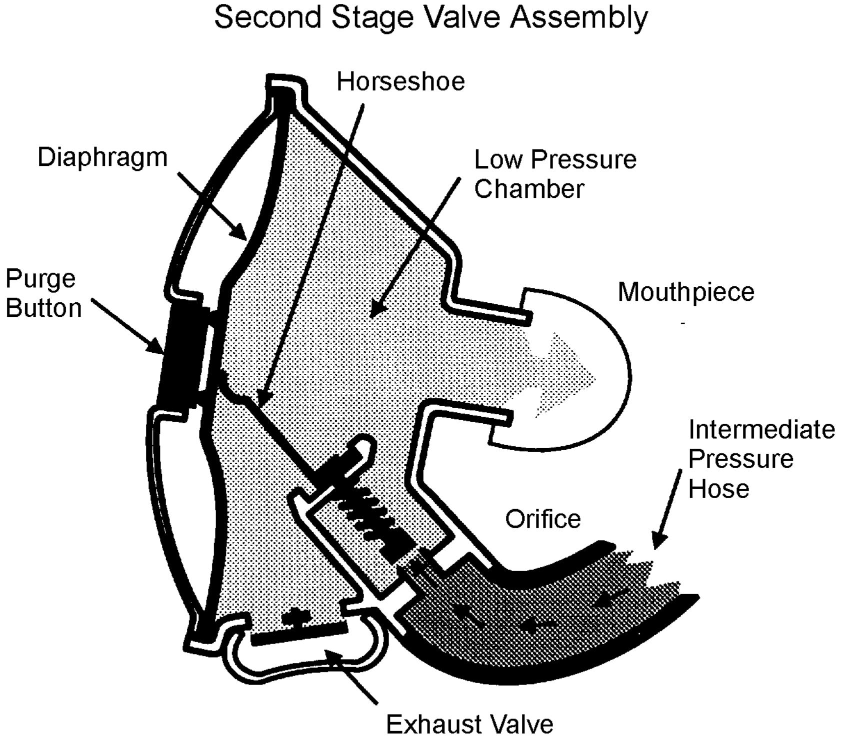
7-2.2.1.1 ***First Stage.*** In the regulator's first stage, high-pressure air from the cylinder passes through a regulator that reduces the pressure of the air to a predetermined level over ambient pressure. Refer to the regulator technical manual for the specific setting.

7-2.2.1.2 ***Second Stage.*** In the second stage of a regulator, a movable diaphragm is linked by a lever to the low-pressure valve, which leads to a low-pressure chamber. When the air pressure in the low-pressure chamber equals the ambient water pressure, the diaphragm is in the center position and the low-pressure valve is closed. When the diver inhales, the pressure in the low-pressure chamber is reduced, causing the diaphragm to be pushed inward by the higher ambient water pressure. The diaphragm actuates the low-pressure valve which opens, permitting air to flow to the diver. The greater the demand, the wider the low-pressure valve is opened, thus allowing more air flow to the diver. When the diver stops inhaling, the pressure on either side of the diaphragm is again balanced and the low-pressure valve closes. As the diver exhales, the exhausted air passes through at least one check valve and vents to the water.

7-2.2.1.3 ***Single Hose Regulators.*** In the single-hose, two-stage demand regulator the first stage is mounted on the cylinder valve assembly. The second-stage assembly includes the mouthpiece and a valve to exhaust exhaled air directly into the water. The two stages are connected by a length of low-pressure hose, which passes over the diver's right shoulder. The second stage has a purge button, which when activated allows low-pressure air to flow through the regulator and the mouthpiece, forcing out any water which may have entered the system. The principal disadvantages of the single-hose unit are an increased tendency to freeze up in very cold water and the exhaust of air in front of the diver's mask. While the Navy PMS


First Stage Valve Assembly

First Stage. High pressure air flows through the orifice of the first stage into the intermediate chamber. When the pressure in the intermediate chamber reaches ambient plus diaphragm balance spring set pressure, the first stage assembly closes.


Second Stage Valve Assembly

Second Stage. Upon inhalation the second stage diaphragm moves inward and the horseshoe lever opens the second stage valve assembly. Intermediate pressure air from the hoses is throttled across the orifice and fills the low pressure chamber to ambient pressure and flow is provided to the diver. Upon exhalation the diaphragm is pushed outward and the second stage in closed. Expired air is dumped from the low pressure chamber to the surrounding water through the exhaust valve.

Figure 7-1. Schematic of Demand Regulator.

system provides guidance for repairing and maintaining scuba regulators, the manufacturer's service manual should be followed for specific procedures.

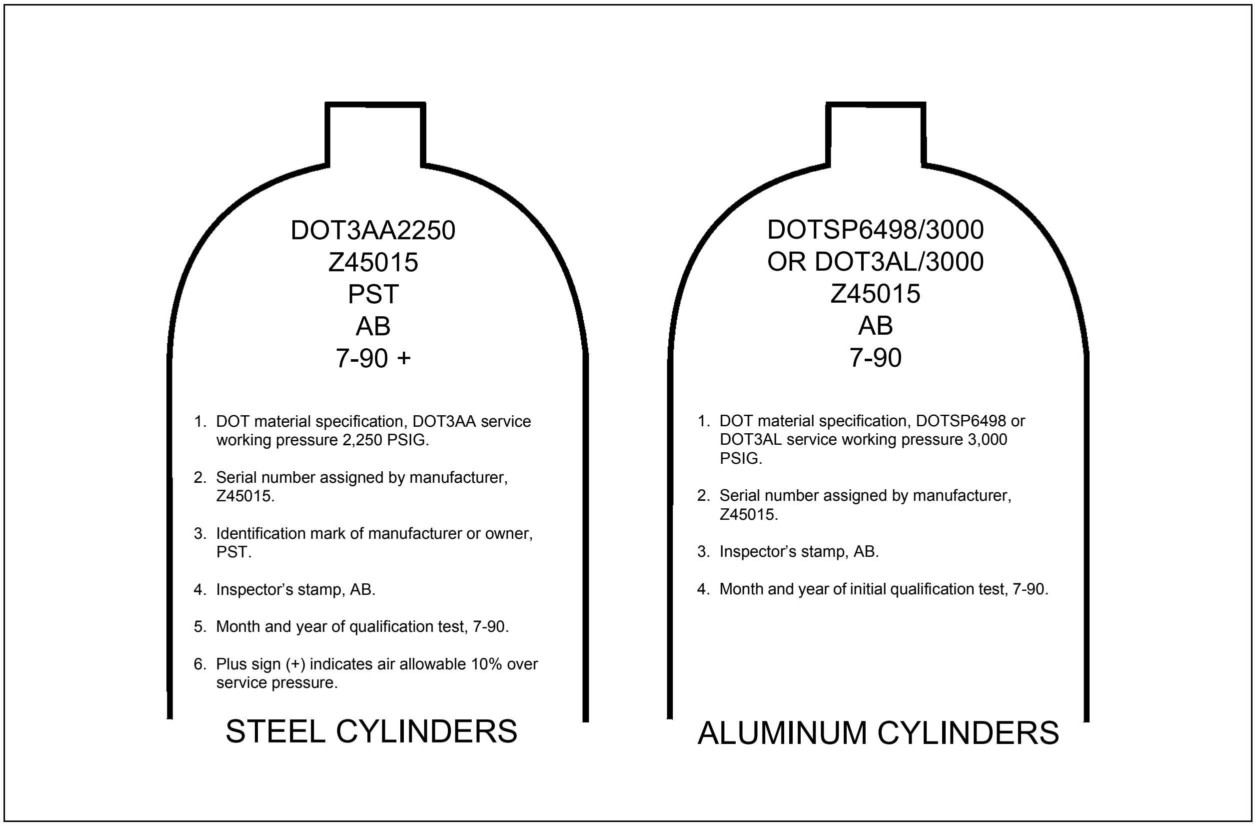
7-2.2.1.4 ***Full Face Mask.*** The AGA/Divator full face mask may be used with an approved single-hose first-stage regulator with an octopus, to the maximum approved depth of the regulator, as indicated in the NAVSEA/00C ANU list (Figure 7-2).

Figure 7-2. Full Face Mask.

7-2.2.1.5 ***Mouthpiece.*** The size and design of scuba mouthpieces differ between manufacturers, but each mouthpiece provides relatively watertight passageways for delivering breathing air into the diver's mouth. The mouthpiece should fit comfortably with slight pressure from the lips.

7-2.2.1.6 ***Octopus.*** An octopus is an additional single hose second stage regulator connected to the diver's first stage regulator and may be used in case the diver's primary second stage regulator fails or for buddy breathing. The octopus must be an ANU approved second stage regulator. Hose length and designation markings are at the discretion of the diving supervisor. An octopus is mandatory for all SCUBA divers. Use of an octopus is the preferred method to accomplish buddy breathing (see paragraph 7-7.7). During predive inspection, the diver shall breathe the octopus to ensure it is working properly.

7-2.2.2 **Cylinders.** Scuba cylinders (tanks or bottles) are designed to hold high pressure compressed air. Because of the extreme stresses imposed on a cylinder at these pressures, all cylinders used in scuba diving must be inspected and tested periodically. Seamless steel or aluminum cylinders which meet Department of Transportation (DOT) specifications (DOT 3AA, DOT 3AL, DOT SP6498, and DOT E6498) are approved for Navy use. Each cylinder used in Navy operations must have identification symbols stamped into the shoulder (Figure 7-3).



1. DOT material specification, DOT3AA service working pressure 2,250 PSIG.
2. Serial number assigned by manufacturer, Z45015.
3. Identification mark of manufacturer or owner, PST.
4. Inspector's stamp, AB.
5. Month and year of qualification test, 7-90.
6. Plus sign (+) indicates air allowable 10% over service pressure.

1. DOT material specification, DOTSP6498 or DOT3AL service working pressure 3,000 PSIG.
2. Serial number assigned by manufacturer, Z45015.
3. Inspector's stamp, AB.
4. Month and year of initial qualification test, 7-90.

Figure 7-3. Typical Gas Cylinder Identification Markings.

7-2.2.2.1 ***Sizes of Approved Scuba Cylinders.*** Approved scuba cylinders are available in several sizes and one or two cylinders may be worn to provide the required quantity of air for the dive. The volume of a cylinder, expressed in actual cubic feet or cubic inches, is a measurement of the internal volume of the cylinder. The capacity of a cylinder, expressed in standard cubic feet or liters, is the amount of gas (measured at surface conditions) that the cylinder holds when charged to its rated pressure. Table 7-1 lists the sizes of some standard scuba cylinders. Refer to the NAVSEA/00C ANU list for a list of approved scuba cylinders.

Table 7-1. *Sample Scuba Cylinder Data.*

Open-Circuit Cylinder Description (Note 1)	Rated Working Pressure (PSIG)	Floodable Volume (Cu.Ft.)	Absolute Air Capacity at Rated Pressure (Cu.Ft.)	Reserve Pressure
Steel 72	2,250	0.420	64.7	500
Steel 100	3,500	0.445	106.4	500
Steel 120	3,500	0.526	125.7	500
Aluminum 50	3,000	0.281	48.5	500
Aluminum 63	3,000	0.319	65.5	500
Aluminum 80	3,000	0.399	81.85	500
Aluminum 100	3,300	0.470	105.9	500

Note 1: Fifty cubic feet is the minimum size scuba cylinder authorized. SEAL teams are authorized smaller cylinders for special operations.

7-2.2.2.2 ***Inspection Requirements.*** Open-circuit scuba cylinders must be visually inspected at least once every 12 months and every time water or particulate matter is suspected in the cylinder. Cylinders containing visible accumulations of corrosion must be cleaned before being placed into service. Commercially available steel and aluminum scuba cylinders, as specified in the NAVSEA/00C ANU list, which meet DOT specifications, as well as scuba cylinders designed to Navy specifications, must be visually inspected at least annually and must be hydrostatically tested at least every five years in accordance with DOT regulations and Compressed Gas Association (CGA) pamphlets C-1 and C-6.

7-2.2.2.3 ***Guidelines for Handling Cylinders.*** General safety regulations governing the handling and use of compressed gas cylinders aboard Navy ships are contained in NAVSEA 0901-LP-230-0002, NSTM Chapter 550, "Compressed Gas Handling." Persons responsible for handling, storing, and charging scuba cylinders must be familiar with these regulations. Safety rules applying to scuba cylinders are contained in paragraph 7-4.5. Because scuba cylinders are subject to continuous handling and because of the hazards posed by a damaged unit, close adherence to the rules is mandatory.

7-2.2.3 **Cylinder Valves and Manifold Assemblies.** Cylinder valves and manifolds make up the system that passes the high-pressure air from the cylinders to the first-stage regulator. The cylinder valve serves as an on/off valve and is sealed to the tank by a straight-threaded male connection containing a neoprene O-ring on the valve's body.

7-2.2.3.1 ***Blowout Plugs and Safety Discs.*** The cylinder valve contains a high-pressure blowout plug or safety disc plug in the event of excessive pressure buildup. When a dual manifold is used, two blowout plugs or safety disc plugs are installed as specified by the manufacturers' technical manual.

For standard diving equipment, a safety disc plug similar to new issue equipment is recommended. The safety disc plug and safety disc are not always identified by a National Stock Number (NSN), but are available commercially.

7-2.2.3.2 ***Manifold Connectors.*** If two or more cylinders are to be used together, a manifold unit is needed to provide the necessary interconnection. Most manifolds incorporate an O-ring as a seal, but some earlier models may have a tapered (pipe) thread design. One type will not connect with the other type.

7-2.2.3.3 ***Pressure Gauge Requirements.*** A cylinder valve with an air reserve (J valve) is preferred. When a cylinder valve without an air reserve (K valve) is used, the scuba regulator must be equipped with a submersible pressure gauge to indicate pressure contents of the cylinder. The dive must be terminated when the cylinder pressure reaches 500 psi for a single cylinder or 250 psi for twin manifold cylinders. The air reserve mechanism alerts the diver that the available air supply is almost exhausted and provides the diver with sufficient reserve air to reach the surface. The air reserve mechanism contains a spring-loaded check valve. When it becomes increasingly difficult to obtain a full breath, the diver must reach over the

- Witness float
- Snorkel
- Submersible cylinder pressure gauge
- Chem light and strobe light

7-3.1 **Protective Clothing.** A diver needs some form of protection from cold water, from heat loss during long exposure in water of moderate temperature, from chemical or bacterial pollution in the water, and from the hazards posed by marine life and underwater obstacles. Protection can be provided by wet suit, or a dry suit with or without thermal underwear in Figure 7-5.

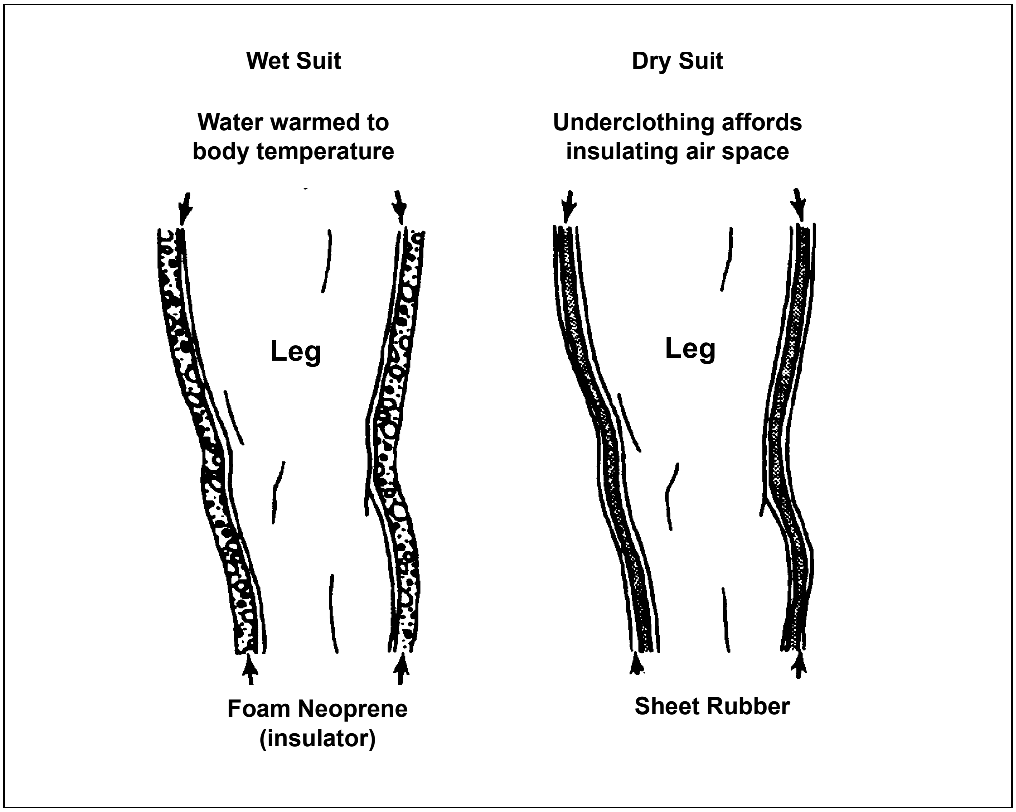


Figure 7-5. Protective Clothing.

7-3.1.1 **Wet Suits.** The wet suit is a form-fitting suit, usually made of closed-cell neoprene. The suit traps a thin layer of water next to the diver's skin, where it is warmed by the diver's body. Wet suits are available in thicknesses of 1/8-, 3/16-, 3/8-, and 1/2-inch, with the thickest providing better insulation. The selection of the type of wet suit used is left to each diver. Standard size suits are available at most commercial diving shops. Proper fit is critical in the selection of a wet suit. The suit must not restrict the diver's movements. A custom-fitted suit is recommended. The performance of a suit depends upon suit thickness, water temperature, and water depth.

7-3.1.2 **Dry Suits.** The Variable Volume Dry Suit (VVDS) has proven to be effective in keeping divers warm in near-freezing water. It is typically constructed of 1/4-inch closed-cell neoprene with nylon backing on both sides. Boots are provided as an integral part of the suit, but the hood and three finger gloves are usually separate. The suit is entered by means of a water- and pressure-proof zipper. Inflation is controlled using inlet and outlet valves which are fitted into the suit. Air is supplied from a pressure reducer on an auxiliary cylinder or from the emergency gas supply or the scuba bottle. About 0.2 actual cubic foot of air is required for normal inflation. Because of this inflation, slightly more weight than would be used with a wet suit must be carried. Normally, thermal underwear can be worn under the suit for insulation.

7-3.1.3 **Gloves.** Gloves are an essential item of protective clothing. They can be made of leather, cloth, or rubber, depending upon the degree and type of protection required. Gloves shield the hands from cuts and chafing, and provide protection from cold water. Some styles are designed to have insulating properties but may limit the diver's dexterity.

Wet or dry suits can be worn with hoods, gloves, boots, or hard-soled shoes depending upon conditions. If the diver will be working under conditions where the suit may be easily torn or punctured, the diver should be provided with additional protection such as coveralls or heavy canvas chafing gear.

7-3.1.4 **Writing Slate.** A rough-surfaced sheet of acrylic makes an excellent writing slate for recording data, carrying or passing instructions, and communicating between divers. A grease pencil or graphite pencil should be attached to the slate with a lanyard.

7-3.1.5 **Signal Flare.** A signal flare is used to attract attention if the diver has surfaced away from the support crew. Any waterproof flare that can be carried and safely ignited by a diver can be used, but the preferred type is the MK 99 MOD 3 (NSN 1370-01-177-4072; pouch is NSN 1370-01-194-0844). These are day-or-night flares that give off a heavy orange smoke for day time and a brilliant red light at night. Each signal lasts for approximately 45 seconds and will withstand submersion up to depths of 200 fsw without adverse effects. A hexagon shaped end cap marked SMOKE is threaded into the smoke assembly and a round shaped end cap with eight grooves marked FLARE is threaded onto the flare assembly. Also available are the MK 131 MOD 0 (NSN 1370-01-252-0318) and MK 132 MOD 0 (NSN 1370-01-252-0317). The MK 131 is for day time distress signaling while the MK 132 is for night. The only difference between the MK 99 and the MK 131/132, other than the fact that the MK 99 is a combined day/night signal flare which gives off yellow smoke and light, is that the MK 99 satisfies magnetic effect limits of MIL-M-19595 for explosive ordinance disposal (EOD) usage. Flares should be handled with care. For safety, each diver should carry a maximum of two flares. All divers/combat swimmers engaged in submarine Dry Deck Shelter operations should stow flares in hangar prior to reentering the host submarine.

7-3.1.6 **Acoustic Beacons.** Acoustic beacons or pingers are battery-operated devices that emit high-frequency signals when activated. The devices may be worn by divers to aid in keeping track of their position or attached to objects to serve as fixed points of reference. The signals can be picked up by hand-held sonar receivers, which are used in the passive or listening mode, at ranges of up to 1,000 yards. The hand-held sonar enables the search diver to determine the direction of the signal source and swim toward the pinger using the heading noted on a compass.

7-3.1.7 **Lines and Floats.** A lifeline should be used when it is necessary to exchange signals, keep track of the diver's location, or operate in limited visibility. There are three basic types of lifelines: the tending line, the float line, and the buddy line.

A single diver will be tended with either a tending line or a float line. When direct access to the surface is not available a tending line is mandatory. A float line may not be used.

The float line reaches from the diver to a suitable float on the surface. This float can be a brightly painted piece of wood, an empty sealed plastic bottle, a life ring, or any similar buoyant, visible object. An inner tube with a diving flag attached makes an excellent float and provides a hand-hold for a surfaced diver. If a pair of divers are involved in a search, the use of a common float gives them a rendezvous point. Additional lines for tools or other equipment can be tied to the float. A buddy line, 6 to 10 feet long, is used to connect the diver partners at night or when visibility is poor.

Any line used in scuba operations should be strong and have neutral or slightly positive buoyancy. Nylon, Dacron, and manila are all suitable materials. Always attach a lifeline to the diver, never to a piece of equipment that may be ripped away or may be removed in an emergency.

7-3.1.8 **Snorkel.** A snorkel is a simple breathing tube that allows a diver to swim on the surface for long or short distances face-down in the water. This permits the diver to search shallow depths from the surface, conserving the scuba air supply. When snorkels are used for skin diving, they are often attached to the face mask with a lanyard or rubber connector to the opposite side of the regulator.

7-3.1.9 **Compass.** Small magnetic compasses are commonly used in underwater navigation. Such compasses are not highly accurate, but can be valuable when visibility is poor. Submersible wrist compasses, watches, and depth gauges covered by NAVSUPINST 5101.6 series are items controlled by the Nuclear Regulatory Commission and require leak testing and reporting every 6 months.

7-3.1.10 **Submersible Cylinder Pressure Gauge.** The submersible cylinder pressure gauge provides the diver with a continual read-out of the air remaining in the cylinder(s). Various submersible pressure gauges suitable for Navy use are commercially available. Most are equipped with a 2- to 3-foot length of high-pressure rubber hose with standard fittings, and are secured directly into the first stage of the regulator. When turning on the cylinder air, the diver should should turn the face of the gauge away in the event of a blowout. When worn, the gauge and hose should be tucked under a shoulder strap or otherwise secured to avoid its entanglement with bottom debris or other equipment. The gauge must be calibrated in accordance with the equipment planned maintenance system.

7-4 AIR SUPPLY

An important early step in any scuba dive is computing the air supply requirement. The air supply requirement is a function of the expected duration of the dive at a specific working depth. The duration of the air supply in the scuba cylinders depends on the depth at which the air is delivered. Air consumption rate increases with depth.

7-4.1 **Duration of Air Supply.** The duration of the air supply of any given cylinder or combination of cylinders depends upon:

- The diver's consumption rate, which varies with the diver's work rate,
- The depth of the dive, and
- The capacity and minimum pressure of the cylinder(s).

Temperature is usually not significant in computing the duration of the air supply, unless the temperature conditions are extreme. When diving in extreme temperature conditions, Charles'/Gay-Lusac's law must be applied.

There are three steps in calculating how long a diver's air supply will last:

1. Calculate the diver's consumption rate by using this formula:

$$C = \frac{D + 33}{33} \times RMV$$

Where:
C = Diver's consumption rate, standard cubic feet per minute (scfm)
D = Depth, fsw
RMV = Diver's Respiratory Minute Volume, actual cubic feet per minute (acfm) (from Figure 7-6)

2. Calculate the available air capacity provided by the cylinders. The air capacity must be expressed as the capacity that will actually be available to the diver, rather than as a total capacity of the cylinder. The formula for calculating the available air capacity is:

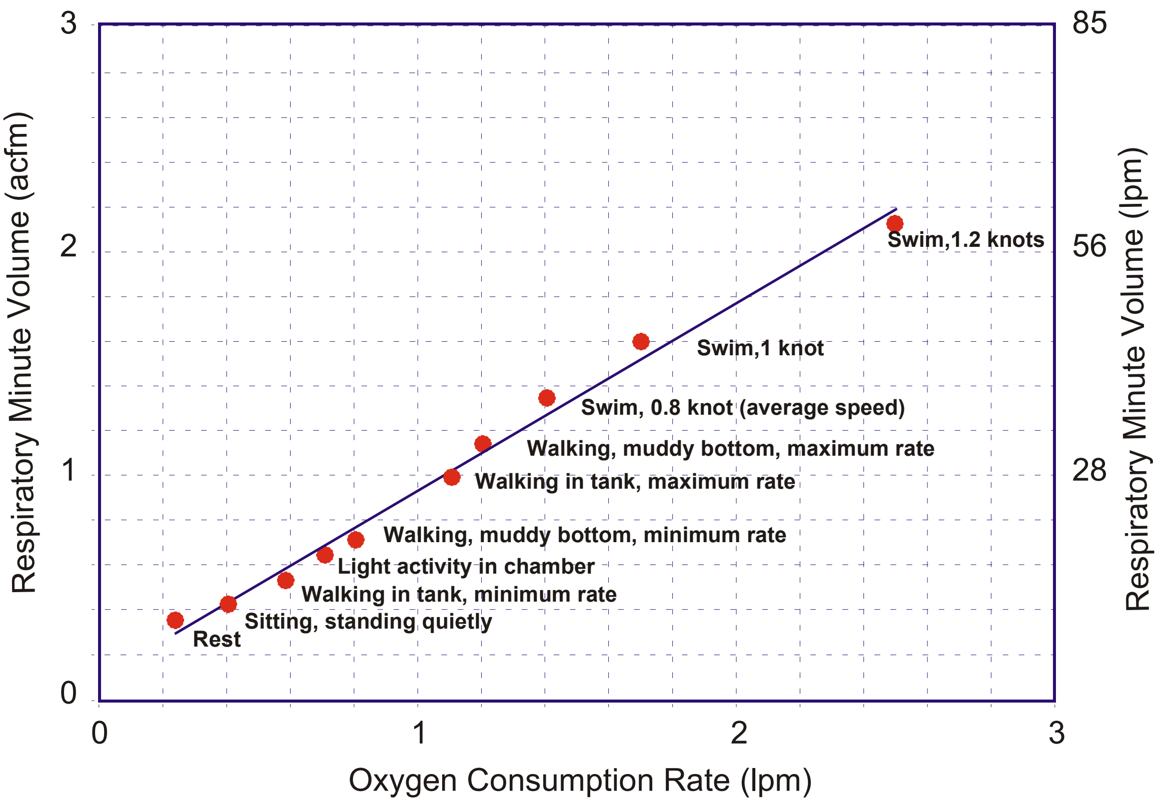
$$V_a = \frac{P_c - P_m}{14.7} \times FV \times N$$

Where:
P_c = Measured cylinder pressure, psig
P_m = Minimum pressure of cylinder, psig
FV = Floodable Volume (scf)
N = Number of cylinders
V_a = Capacity available (scf)

3. Calculate the duration of the available capacity (in minutes) by using this formula:

$$\text{Duration} = \frac{V_a}{C}$$

Where:



Work	VO_2 (lpm)	RMV (acfm)	RMV (lpm)	Work Level
Rest	0.24	0.35	10	—
Sitting, standing quietly	0.40	0.42	12	Light
Walking in tank, minimum rate	0.58	0.53	15	Light
Light activity in chamber	0.70	0.64	18	Light
Walking, muddy bottom, minimum rate	0.80	0.71	20	Moderate
Walking in tank, maximum rate	1.10	0.99	28	Moderate
Walking, muddy bottom, maximum rate	1.20	1.14	32	Moderate
Swim, 0.8 knot (average speed) (use for planning purposes, round up to 1.4)	1.40	1.34	38	Moderate
Swim, 1 knot	1.70	1.59	45	Heavy
Swim, 1.2 knot	2.50	2.12	60	Severe

Figure 7-6. Oxygen Consumption and RMV at Different Work Rates.

V_a = Capacity available, scf
C = Consumption rate, scfm

Sample Problem. Determine the duration of the air supply of a diver doing moderate work at 70 fsw using twin 72-cubic-foot steel cylinders charged to 2,250 psig.

1. Calculate the diver's consumption rate in scfm. According to Figure 7-6, the diver's consumption rate at depth is 1.4 acfm.

$$\begin{aligned} C &= \frac{D + 33}{33} \times RMV \\ &= \frac{70 + 33}{33} \times 1.4 \\ &= 4.37 \text{ scfm} \end{aligned}$$

2. Calculate the available air capacity provided by the cylinders. Table 7-1 contains the cylinder data used in this calculation:

- Floodable Volume = 0.420 scf
- Rated working pressure = 2250 psig
- Reserve pressure for twin 72-cubic-foot cylinders = 250 psig

$$\begin{aligned} V_a &= \frac{P_c - P_m}{14.7} \times FV \times N \\ &= \frac{2250 - 250}{14.7} \times 0.420 \times 2 \\ &= 114 \text{ scf} \end{aligned}$$

3. Calculate the duration of the available capacity.

$$\begin{aligned} \text{Duration} &= \frac{V_a}{C} \\ &= \frac{114 \text{ scf}}{4.37 \text{ scfm}} \\ &= 26 \text{ minutes} \end{aligned}$$

The total time for the dive, from initial descent to surfacing at the end of the dive, is limited to 26 minutes.

7-4.2 **Compressed Air from Commercial Sources.** Compressed air meeting the established standards can usually be obtained from Navy sources. In the absence of appropriate Navy sources, air may be procured from commercial sources. Usually, any civilian agency or firm which handles compressed oxygen can provide pure explosive projectile. A cylinder charged to 2,000 psi has enough potential energy to propel itself for some distance, tearing through any obstructions in its way.

- Store filled cylinders in a cool, shaded area. Never leave filled cylinders in direct sunlight.
- Cylinders should always be properly secured aboard ship or in a diving boat.

7-5 PREDIVE PROCEDURES

Predive procedures for scuba operations include equipment preparation, diver preparation, and conducting a predive inspection before the divers enter the water.

7-5.1 **Equipment Preparation.** Prior to any dive, all divers must carefully inspect their own equipment for signs of deterioration, damage, or corrosion. The equipment must be tested for proper operation. Predive preparation procedures must be standardized, not altered for convenience, and must be the personal concern of each diver.

7-5.1.1 **Air Cylinders.**

- Inspect air cylinder exteriors and valves for rust, cracks, dents, and any evidence of weakness.
- Inspect O-ring.
- Verify that the reserve mechanism is closed (lever in up position) signifying a filled cylinder ready for use.
- Gauge the cylinders according to the following procedure:
    1. Attach pressure gauge to O-ring seal face of the on/off valve.
    2. Close gauge bleed valve and open air reserve mechanism (lever in down position). Slowly open the cylinder on/off valve, keeping a cloth over the face of the gauge.
    3. Read pressure gauge. The cylinder must not be used if the pressure is not sufficient to complete the planned dive.
    4. Close the cylinder on/off valve and open the gauge bleed valve.
    5. When the gauge reads zero, remove the gauge from the cylinder.
    6. Close the air reserve mechanism (lever in up position).
    7. If the pressure in cylinders is 50 psi or greater over rating, open the cylinder on/off valve to bleed off excess and regauge the cylinder.

7-5.1.2 Harness Straps and Backpack.

- Check for signs of rot and excessive wear.
- Adjust straps for individual use and test quick-release mechanisms.
- Check backpack for cracks and other unsafe conditions.

7-5.1.3 Breathing Hoses.

- Check the hoses for cracks and punctures.
- Test the connections of each hose at the regulator and mouthpiece assembly by tugging on the hose.
- Check the clamps for corrosion and damage; replace as necessary and in accordance with PMS procedures.

7-5.1.4 Regulator.

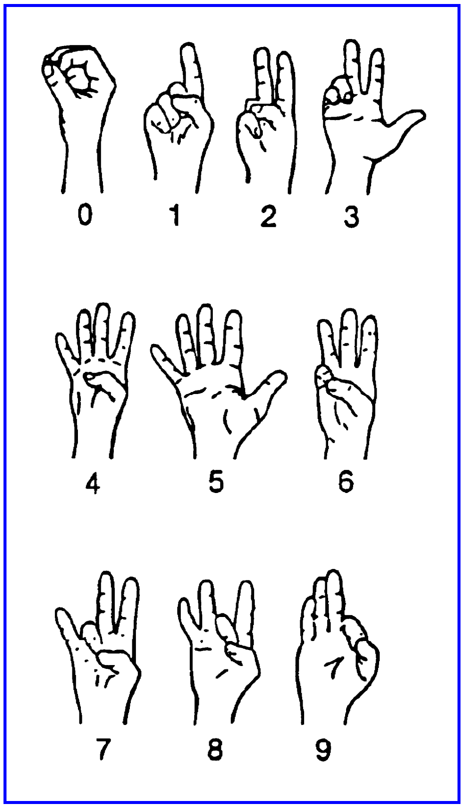
1. Ensure over-bottom pressure of first stage regulator has been set to a minimum of 135 psig or in accordance with manufacturer's recommendations within the past year.
2. Attach regulator to the cylinder manifold, ensuring that the O-ring is properly seated.
3. Crack the cylinder valve open and wait until the hoses and gauges have equalized.
4. Next open the cylinder valve completely and then close (back off) one-quarter turn.
5. Check for any leaks in the regulator by listening for the sound of escaping air. If a leak is suspected, determine the exact location by submerging the valve assembly and the regulator in a tank of water and watch for escaping bubbles. Frequently the problem can be traced to an improperly seated regulator and is corrected by closing the valve, bleeding the regulator, detaching and reseating. If the leak is at the O-ring and reseating does not solve the problem, replace the O-ring and check again for leaks.

7-5.1.5 Life Preserver/Buoyancy Compensator (BC)

- Orally inflate preserver to check for leaks and then squeeze out all air. The remaining gas should be removed after entry into the water by rolling onto the back and depressing the oral inflation tube just above the surface. Never suck the air out, as it may contain excessive carbon dioxide.

- Inspect the carbon dioxide cartridges to ensure they have not been used (seals intact) and are the proper size for the vest being used and for the depth of dive.

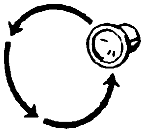
- The cartridges shall be weighed in accordance with the Planned Maintenance System.



NIGHT DIVING SIGNALS
(Buddy at Distance)

When buddy is near, use regular hand signals in front of light.

Something is wrong.
I require assistance.
(Large, rapid up-and-down motions with arm extended.)



I am Okay.
Are you Okay?
(Large, slow circles with light.)

Figure 7-10b. Scuba Hand Signals (continued).

- If one member of a dive team aborts a dive, for whatever reason, the other member also aborts and both must surface.

- Know the proper method of buddy breathing.

7-7.7 **Buddy Breathing Procedure.** If a diver runs out of air or the scuba malfunctions, air may be shared with the dive partner. The preferred method of buddy breathing is the use of an octopus. As an alternative, the two divers may face each other and alternately breathe from the same mouthpiece while ascending. Buddy breathing may be used in an emergency and must be practiced so that each diver will be thoroughly familiar with the procedure.

1. The distressed diver should remain calm and signal the partner by pointing to scuba mouthpiece.

2. The partner and the distressed diver should hold on to each other by grasping a strap or the free arm. The divers must be careful not to drift away from each other. The partner gives his octopus to the distressed diver. If an octopus is not available, proceed to step 3.

3. The partner must make the first move by taking a breath and passing the mouthpiece to the distressed diver. The distressed diver must not grab for the

dive partner's mouthpiece. The dive partner guides it to the distressed diver's mouth. Both divers maintain direct hand contact on the mouthpiece.

4. The mouthpiece may have flooded during the transfer. In this case, clear the mouthpiece by using the purge button (if single-hose) or by exhaling into the mouthpiece before a breath can be taken. If using a double-hose regulator, the mouthpiece should be kept slightly higher than the regulator so that free-flowing air will help keep the mouthpiece clear.

5. The distressed diver should take two full breaths (exercising caution in the event that all of the water has not been purged) and guide the mouthpiece back to the partner. The partner should then purge the mouthpiece as necessary and take two breaths.

6. The divers should repeat the breathing cycle and establish a smooth rhythm. No attempt should be made to surface until the cycle is stabilized and the proper signals have been exchanged.

WARNING **During ascent, the diver without the mouthpiece must exhale to offset the effect of decreasing pressure on the lungs which could cause an air embolism.**

7-7.8 Tending.

7-7.8.1 **Tending with a Surface or Buddy Line.** When a diver is being tended by a line from the surface or a buddy line, several basic considerations apply.

- Lines should be kept free of slack.
- Line signals must be given in accordance with the procedures given in Table 8-3.
- Any signals via the line must be acknowledged immediately by returning the same signal.
- The tender should signal the diver with a single pull every 2 or 3 minutes to determine that the diver is all right. A return signal of one pull indicates that the diver is all right.
- If the diver fails to respond to line-pull signals after several attempts, the standby diver must investigate immediately.
- The diver must be particularly aware of the possibilities for the line becoming snagged or entangled.

CHAPTER 8

Surface Supplied Air Diving Operations

8-1 INTRODUCTION

8-1.1 Purpose. Surface supplied air diving includes those forms of diving where air is supplied from the surface to the diver by a flexible hose. The Navy Surface Supplied Diving Systems (SSDS) are used primarily for operations to 190 feet of seawater (fsw).

8-1.2 Scope. This chapter identifies the required equipment and procedures for using the UBA MK 21 MOD 1 and the UBA MK 20 MOD 0 surface supplied diving equipment.

8-2 MK 21 MOD 1

The MK 21 MOD 1 is an open circuit, demand, diving helmet (Figure 8-1). The maximum working depth for air diving operations using the MK 21 MOD 1 system is 190 fsw. The MK 21 MOD 1 system may be used up to 60 fsw without an Emergency Gas Supply (EGS). An EGS is mandatory at depths deeper than 60 fsw and when diving inside a wreck or enclosed space. The Diving Supervisor may elect to use an EGS that can be man-carried or located outside the wreck or enclosed space and connected to the diver with a 50 to 150 foot whip. Planned air dives below 190 fsw require CNO approval.

Figure 8-1. MK 21 MOD 1 SSDS.

8-2.1 Operation and Maintenance. The technical manual for the MK 21 MOD 1 is NAVSEA S6560-AG-OMP-010, *Technical Manual, Operation and Maintenance Instructions, Underwater Breathing Apparatus MK 21 MOD 1 Surface Supported Diving System*. To ensure safe and reliable service, the MK 21 MOD 1 system must be maintained and repaired in accordance with PMS procedures and the MK 21 MOD 1 operation and maintenance manual.

8-2.2 Air Supply. Air for the MK 21 MOD 1 system is supplied from the surface by either an air compressor or a bank of high pressure air flasks as described in paragraph 8-7.2.3.

8-2.2.1 **Emergency Gas Supply Requirements.** The emergency breathing supply valve provides an air supply path parallel to the nonreturn valve and permits attachment of the EGS whip. The EGS system consists of an adequately charged ANU approved scuba cylinder with either a K- or J- valve and a first stage regulator set at manufacturer's recommended pressure, but not lower than 135 psig. A relief valve set at 180 ± 5 psig over bottom pressure must be installed on the first stage regulator to prevent rupture of the low pressure hose should the first stage regulator fail. The flexible low pressure hose from the first stage regulator attaches to the emergency supply valve on the helmet sideblock. A submersible pressure gauge is also required on the first stage regulator.

An adequately charged scuba cylinder is defined as the pressure that provides sufficient air to bring the diver to his first decompression stop or the surface for no-decompression dives. It is assumed that this will give topside personnel enough time to perform required emergency procedures to restore umbilical air to the diver.

For enclosed space diving an extended EGS whip 50 to 150 feet in length may be used. If the diving scenario requires the EGS topside, adjust the first stage regulator to 150 psig.

NOTE For open water dives 60 fsw and shallower, the diving supervisor may use an ANU approved cylinder designated for MK-21 as an emergency air source.

Sample Problem 1. Determine the minimum EGS cylinder pressure required for a MK-21 MOD 1 dive to 190 fsw for five minutes.

1. To calculate the EGS cylinder pressure, you must first determine the amount of gas required to get the diver back to the stage and leave bottom plus the gas required for ascent to the first decompression stop. The formula for calculating gas required is:

$$V_r = \frac{D + 33}{33} \times 1.4 \times T$$

Where:

V_r = Capacity required (scf)
D = Depth (fsw)
1.4 = Consumption rate in acfm per diver from Table 8-2
T = Time (minutes)

Air required while on the bottom: For this example, if the time to get the diver to the stage and leave bottom is 3 minutes, then:

$$\text{Bottom } V_r = \frac{190 + 33}{33} \times 1.4 \times 3$$

$$= 28.38 \text{ scf}$$

Air required for ascent to reach the first stop: For this example, you need to determine ascent time and average depth. Ascent time is 7 minutes (rounded up from 6 minutes 20 seconds) from 190 fsw to the surface at 30 feet per minute. Average depth is calculated as follows:

$$\text{average depth} = \frac{190}{2} = 95 \text{fsw}$$

$$\text{Ascent } V_r = \frac{95 + 33}{33} \times 1.4 \times 7$$

$$= 38.01 \text{ scf}$$

$$\text{Total } V_r = 28.38 + 38.01$$

$$= 66.39 \text{ scf}$$

2. The next step is to convert the required scf to an equivalent cylinder pressure in psig. In this example, we are using an 80 ft^3 aluminum cylinder to support this dive. Refer to Table 7-1 for cylinder data used in this calculation:

$$\text{psig required} = \frac{V_r}{FV} \times 14.7 + P_m$$

Where:

FV = Floodable Volume (scf) = 0.399 scf
14.7 = Atmospheric Pressure (psi)
P_m = Minimum cylinder pressure

Minimum Cylinder Pressure = First stage regulator setting + bottom pressure at final stop: [135 psig + (0 fsw x 0.445 psi)] = 135 psig

$$= \frac{66.39}{0.399} \times 14.7 + 135$$

$$= 2580.95 (\text{round to } 2600 \text{ psig})$$

8-2.2.2 **Flow Requirements.** When the MK 21 MOD 1 system is used, the air supply system must be able to provide an average sustained flow of 1.4 acfm to the diver. The air consumption of divers using the MK 21 MOD 1 varies between 0.75 and 1.5 acfm when used in a demand mode, with occasional faceplate and mask clearing. When used in a free-flow mode, greater than eight acfm is consumed.

NOTE **When planning a dive, calculations are based on 1.4 acfm.**

To satisfactorily support the MK 21 MOD 1 system, the air supply must:

- Replenish the air consumed from the system (average rate of flow)
- Replenish the air at a rate sufficient to maintain the required pressure
- Provide the maximum rate of flow required by the diver

8-2.2.3 **Pressure Requirements.** Because the MK 21 MOD 1 helmet is a demand type system, the regulator has an optimum overbottom pressure that ensures the lowest possible breathing resistance and reduces the possibility of overbreathing the regulator (demanding more air than is available). For those systems not capable of sustaining 165 psi overbottom due to design limitations, 135 psi overbottom is acceptable. Table 8-1 shows the MK 21 MOD 1 overbottom pressure requirements.

Table 8-1. *MK 21 MOD 1 Over Bottom Pressure Requirements*

Dive Depth	**Pressure in psig**		
	Minimum	**Desired**	**Maximum**
0-60 fsw	90*	135	165
61-130 fsw	135	135	165
131-190 fsw	165**	165	165

* Not approved for use with a double exhaust kit installed. Instead use a minimum of 135 psig.

** For diver life support systems not capable of sustaining 165 psig over bottom due to system design limitations, 135 psig is authorized.

This ensures that the air supply will deliver air at a pressure sufficient to overcome bottom seawater pressure and the pressure drop that occurs as the air flows through the hoses and valves of the mask.

Sample Problem 1. Determine the air supply manifold pressure required to dive the MK 21 MOD 1 system to 175 fsw.

1. Determine the bottom pressure at 175 fsw:

   $$\text{Bottom pressure at 175 fsw} = 175 \times .445 \text{ psi}$$
   $$= 77.87 \text{ psig (round to 78)}$$

2. Determine the overbottom pressure for the MK 21 MOD 1 system (see Table 8-1). Because the operating depth is 175 fsw, the overbottom pressure is 165 psig.

3. Calculate the minimum manifold pressure (MMP) by adding the bottom pressure to the overbottom pressure:

   $$\begin{aligned} \text{MMP} &= 78 \text{ psig} + 165 \text{ psig} \\ &= 243 \text{ psig} \end{aligned}$$

   The minimum manifold pressure for a 175 fsw dive must be 243 psig.

Sample Problem 2. Determine if air from a bank of high pressure flasks is capable of supporting two MK 21 MOD 1 divers and one standby diver at a depth of 130 fsw for 30 minutes. There are 5 flasks in the bank; only 4 are on line. Each flask has a floodable volume of 8 cubic feet and is charged to 3,000 psig.

NOTE **These calculations are based on an assumption of an average of 1.4 acfm diver air consumption over the total time of the dive. Higher consumption over short periods can be expected based on diver work rate.**

1. Calculate minimum manifold pressure (MMP).

$$\begin{aligned} \text{MMP(psig)} &= (0.445\text{D}) + 165 \text{ psig} \\ &= (0.455 \times 130) + 165 \text{ psig} \\ &= 222.85 \text{ psig} \end{aligned}$$

Round up to 223 psig

2. Calculate standard cubic feet (scf) of air available. The formula for calculating the scf of air available is:

$$\text{scf available} = \frac{\text{P}_\text{f} - (\text{P}_\text{mf} + \text{MMP})}{14.7} \times \text{FV} \times \text{N}$$

Where:

P_f = Flask pressure = 3,000 psig

P_{mf} = Minimum flask pressure = 200 psig

MMP = 223 psig

FV = Floodable Volume of flask = 8 scf

N = Number of flasks = 4

$$\begin{aligned} \text{scf available} &= \frac{3000 - (200 + 223)}{14.7} \times 8 \times 4 \\ &= 5609.79 \text{ scf (round down to 5600)} \end{aligned}$$

3. Calculate scf of air required to make the dive. You will need to calculate the air required for the bottom time, the air required for each decompression stop, and the air required for the ascent. The formula for calculating the air required is:

$$\text{scf required} = \frac{\text{D} + 33}{33} \times 1.4 \times \text{N} \times \text{T}$$

Where:

D = Depth (fsw)

1.4 = Consumption rate in acfm needed per diver from Table 8-2

N = Number of divers

T = Time at depth (minutes)

Bottom time: 30 minutes

$$\begin{aligned} \text{scf required} &= \frac{130 + 33}{33} \times 1.4 \times 3 \times 30 \\ &= 622.36 \text{ scf} \end{aligned}$$

Decompression stops: A dive to 130 fsw for 30 minutes requires the following decompression stops:

- 3 minutes at 20 fsw

$$\text{scf required} = \frac{20 + 33}{33} \times 1.4 \times 3 \times 3$$
$$= 20.24$$

- 18 minutes at 10 fsw

$$\text{scf required} = \frac{10 + 33}{33} \times 1.4 \times 3 \times 18$$
$$= 98.51 \text{ scf}$$

Ascent time: 5 minutes (rounded up from 4 minutes 20 seconds) from 130 fsw to the surface at 30 feet per minute.

$$\text{average depth} = \frac{130}{2} = 65 \text{ fsw}$$

$$\text{scf required} = \frac{65 + 33}{33} \times 1.4 \times 3 \times 5$$
$$= 62.36 \text{ scf}$$

$$\text{Total air required} = 622.36 + 20.24 + 98.51 + 62.36$$
$$= 803.48 \text{ scf (round to 804 scf)}$$

4. Calculate the air remaining at the completion of the dive to see if there is sufficient air in the air supply flasks to make the dive.

scf remaining = scf available – scf required
= 5609 scf – 804 scf
= 4805 scf

More than sufficient air is available in the air supply flasks to make this dive.

NOTE **Planned air usage estimates will vary from actual air usage. The air requirements for a standby diver must also be taken into account for all diving operations. The Diving Supervisor must note initial volume/pressure and continually monitor consumption throughout dive. If actual consumption exceeds planned consumption, the Diving Supervisor may be required to curtail the dive in order to ensure there is adequate air remaining in the primary air supply to complete decompression.**

8-3 MK 20 MOD 0

The MK 20 MOD 0 is a surface-supplied UBA consisting of a full face mask, diver communications components, equipment harness, and an umbilical assembly (Figure 8-2). One of its primary uses is in enclosed spaces, such as submarine ballast tanks. The MK 20 MOD 0 is authorized for use to a depth of 60 fsw with surface-supplied air and must have an Emergency Gas Supply when used for enclosed space diving.

Figure 8-2. MK 20 MOD 0 UBA.

8-3.1 **Operation and Maintenance.** Safety considerations and working procedures are covered in Chapter 6. NAVSEA SS600-AK-MMO-010 *Technical Manual, Operations and Maintenance Instruction Manual* is the technical manual for the MK 20 MOD 0. To ensure safe and reliable service, the MK 20 MOD 0 system must be maintained and repaired in accordance with PMS procedures and the MK 20 MOD 0 operation and maintenance manual.

8-3.2 **Air Supply.** Air for the MK 20 MOD 0 system is supplied from the surface by either an air compressor or a bank of high-pressure flasks as described in paragraph 8-7.2.3.

8-3.2.1 **EGS Requirements for MK 20 MOD 0 Enclosed-Space Diving.** In order to ensure a positive emergency air supply to the diver when working in a ballast tank, mud tank, or confined space, an Emergency Gas Supply (EGS) assembly must be used. As a minimum, the EGS assembly consists of:

- An adequately charged ANU approved scuba cylinder with either a K- or J-valve.
- An approved scuba regulator set at manufacturer's recommended pressure, but not lower than 135 psi, with an extended EGS whip 50 to 150 feet in length. If the diving scenario dictates leaving the EGS topside, adjust the first stage regulator to 150 psig.
- An approved submersible pressure gauge.

The scuba cylinder may be left on the surface and the EGS whip may be married to the diver's umbilical, or it may be secured at the opening of the enclosed space being entered. The diver may then enter the work space with the extended EGS whip trailing. The second stage regulator of the EGS is securely attached to the diver's harness before entering the work space so that the diver has immediate access to the EGS regulator in an emergency.

An adequately charged scuba cylinder is defined as the pressure that provides sufficient air to bring the diver to his first decompression stop or the surface for no-decompression dives. It is assumed that this will give topside personnel enough time to perform required emergency procedures to restore umbilical air to the diver. See paragraph 8-2.2.1 for calculating minimum cylinder pressure.

8-3.2.2 **EGS Requirements for MK 20 MOD 0 Open Water Diving.** When conducting open water dives, the diving supervisor may use a MK 20 designated ANU approved cylinder with the DSI sideblock assembly as an emergency air source.

8-3.2.3 **Flow Requirements.** The MK 20 MOD 0 requires a breathing gas flow of 1.4 acfm and an overbottom pressure of 90 psig. Flow and pressure requirement calculations are identical to those for the MK 21 MOD 1 (see paragraph 8-2.2.3).

8-4 EXO BR MS

8-4.1 **EXO BR MS.** The EXO BR MS is a commercial-off-the-self, full face mask, manufactured by Kirby Morgan Dive Systems, which can be used for either SCUBA or surface supplied diving. It is authorized for use to 190 fsw with air and 140 fsw with nitrox. An Emergency Gas Supply (EGS) is mandatory at depths deeper than 60 fsw and when diving inside an enclosed space. The Diving Supervisor may elect to use an EGS that can be man-carried or located outside the enclosed space and connected to the diver with a 50-150 foot whip. Conducting air dives below 190 fsw requires CNO approval.

8-4.2 **Operations and Maintenance.** The technical manual for the EXO BR MS is the Kirby Morgan Operations & Maintenance Manual, EXO BR MS Balanced Regulator Full Face Mask Military Standard (DSI Part #100-036). To ensure safe and reliable service, the EXO BR MS must be maintained and repaired in accordance with PMS procedures and the technical manual.

8-4.3 **Air Supply.** For surface supplied diving, air for the EXO BR MS is supplied from the surface by either an air compressor or a bank of high-pressure flasks as described in paragraph 8-6.2.3.

8-4.4 **EGS Requirements for EXO BR MS.** The EGS system consists of adequately charged ANU approved cylinder with either a K- or J- valve and an approved first stage regulator set at manufacturer's recommended pressure but no lower than 135 psi over bottom pressure. The intermediate hose of the first stage is coupled to the emergency gas supply valve on the manifold block assembly. A relief valve set at 180 +/-5 psi over bottom pressure must be installed on the first stage regulator to prevent rupture of the low pressure hose should the first stage regulator fail. The flexible low pressure hose from the first stage regulator attaches to the emergency supply valve on the manifold block. A submersible pressure gauge is also required on the first stage regulator.

When diving enclosed spaces during ship husbandry operations, the use of an approved second stage regulator with extended EGS whip 50 to 150 feet in length is permissible. The manifold block is not used and the diver's umbilical is connected directly to the low pressure high flow hose from the mask. The scuba cylinder may be left on the surface or secured at the opening of the enclosed space. The second stage regulator of the EGS is securely attached to the diver so diver has immediate access to the EGS regulator in an emergency. If the diving scenario dictates leaving the EGS topside, adjust the first stage regulator to 150 psig. When diving in submarine ballast tanks, the mask and umbilical may be left up inside the ballast tank adjacent to the opening with the extended EGS whip trailing the diver.

An adequately charged scuba cylinder is defined as the pressure that provides sufficient air to bring the diver to his first decompression stop or the surface for no-decompression dives. It is assumed that this will give topside personnel enough time to perform required emergency procedures to restore umbilical air to the diver. See paragraph 8-2.2.1 for calculating minimum cylinder pressure.

For UWSH or other unique open water dives 60 fsw and shallower, the diving supervisor may use an ANU approved cylinder designated for EXO BR MS as an emergency air source.

8-4.5 **Flow and Pressure Requirements.** The EXO BR MS requires a breathing gas flow of 1.4 acfm. For dives shallower than 130 fsw, the overbottom pressure shall be 135-165psi. For those systems which cannot maintain 135 psi overbottom pressure when diving shallower than 60 fsw, 90 psi is permissible. For dives 130-190 fsw, the overbottom pressure shall be 165-225psi. Flow and pressure calculations are identical to those for the MK21 MOD 1 (see paragraph 8-2.2.3)

8-5 PORTABLE SURFACE-SUPPLIED DIVING SYSTEMS

8-5.1 **MK 3 MOD 0 Lightweight Dive System (LWDS).** The MK 3 MOD 0 LWDS is a portable, self-contained, surface-supplied diver life-support system (DLSS). The MK 3 MOD 0 LWDS can be arranged in three different configurations and may be deployed pierside or from a variety of support platforms. Each LWDS includes a control console assembly, volume tank assembly, medium-pressure air compressor (optional), and stackable compressed-air rack assemblies, each consisting of three high-pressure composite flasks (0.935 cu ft floodable volume each). Each flask holds 191 scf of compressed air at 3,000 psi. The MK 3 MOD 0 LWDS provides sufficient air for two working divers and one standby diver operating at a moderately heavy work rate to a maximum depth of 60 fsw in configuration 1, 130 fsw in configuration 2, and 190 fsw in configuration 3. The MK 3 MOD 0 will support diving operations with both UBA MK 20 MOD 0 and UBA MK 21 Mod 1. Set-up and operating procedures for the LWDS are found in the Operating and Maintenance Instructions for Lightweight Dive System (LWDS) MK 3 MOD 0, SS500-HK-MMO-010.

8-5.1.1 **MK 3 MOD 0 Configuration 1.** Air is supplied by a medium-pressure diesel driven compressor unit supplying primary air to the divers at 18 standard cubic feet per minute (scfm) with secondary air being supplied by one air-rack assembly. Total available secondary air is 594 scf. See Figure 8-3.

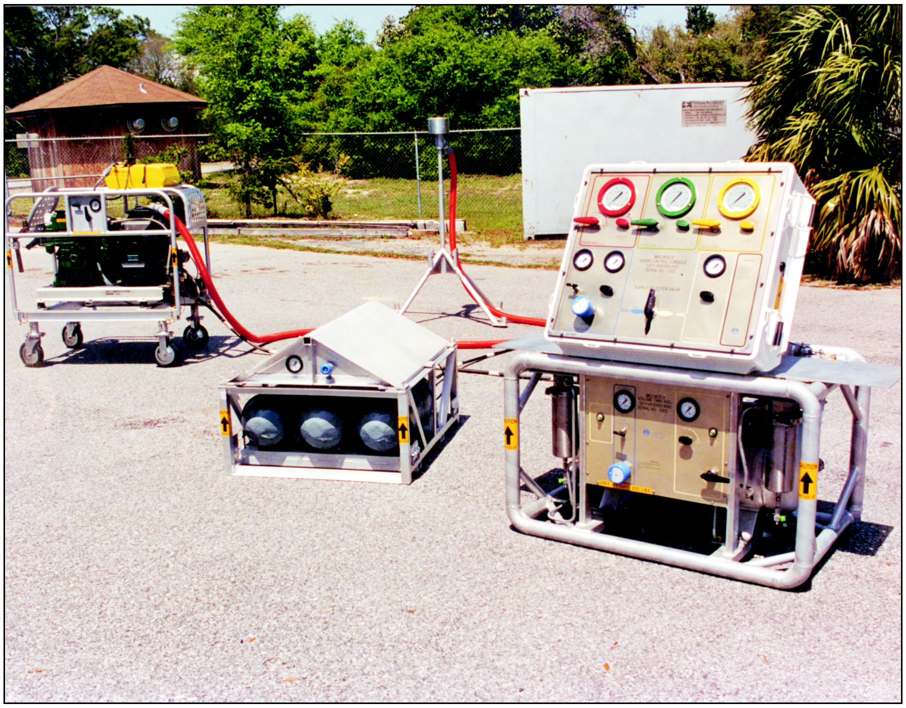


Figure 8-3. MK 3 MOD 0 Configuration 1.

8-5.1.2 **MK 3 MOD 0 Configuration 2.** Primary air is supplied to the divers using three flask rack assemblies. Secondary air is supplied by one flask rack assembly. Total available primary air is 1782 scf at 3,000 psi. Total available secondary air is 594 scf. See Figure 8-4.

8-5.1.3 **MK 3 MOD 0 Configuration 3.** Primary air is supplied to the divers using three flask rack assemblies. Secondary air is supplied by two flask rack assemblies. Total available primary air is 1,782 scf. Total available secondary air is 1,188 scf. See Figure 8-5.

8-5.2 **MK 3 MOD 1 Lightweight Dive System.** This system is identical to the MK 3 MOD 0 LWDS except that the control console and volume tank have been modified to support 5,000 psi operations for use with the Flyaway Dive System (FADS) III. With appropriate adapters the system can still be used to support normal LWDS operations. See Figure 8-6.

8-5.3 **ROPER Diving Cart.** The ROPER diving cart is a trailer-mounted diving system, designed to support one working and one standby diver in underwater operational tasks performed by Ship Repair Activities to 60 fsw (Figure 8-7). The system is self-contained, transportable, and certifiable in accordance with *U.S. Navy Diving*

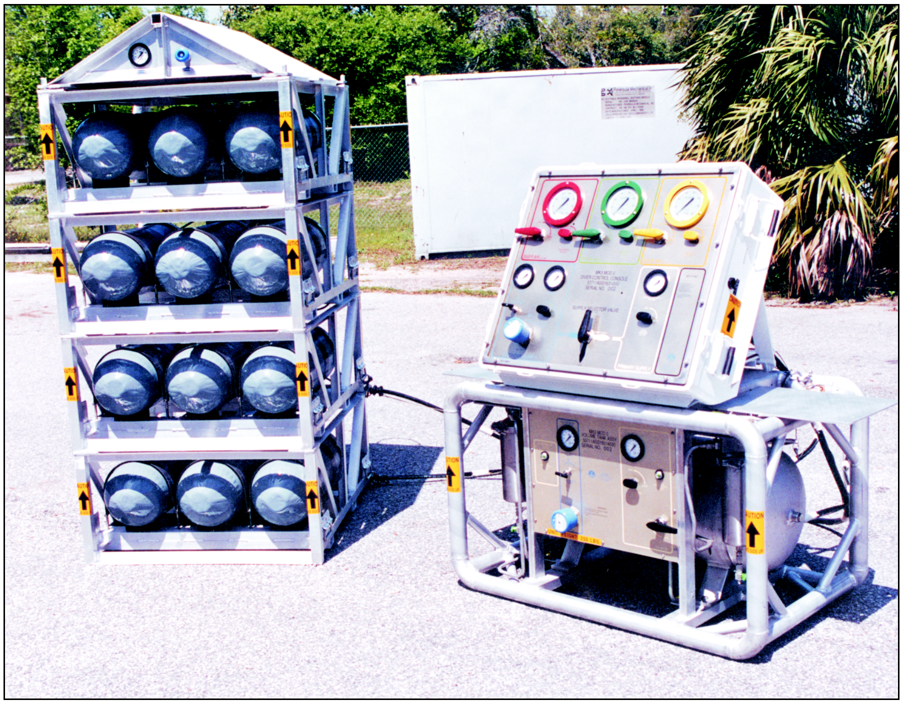


Figure 8-4. MK 3 MOD 0 Configuration 2.

Figure 8-5. MK 3 MOD 0 Configuration 3.

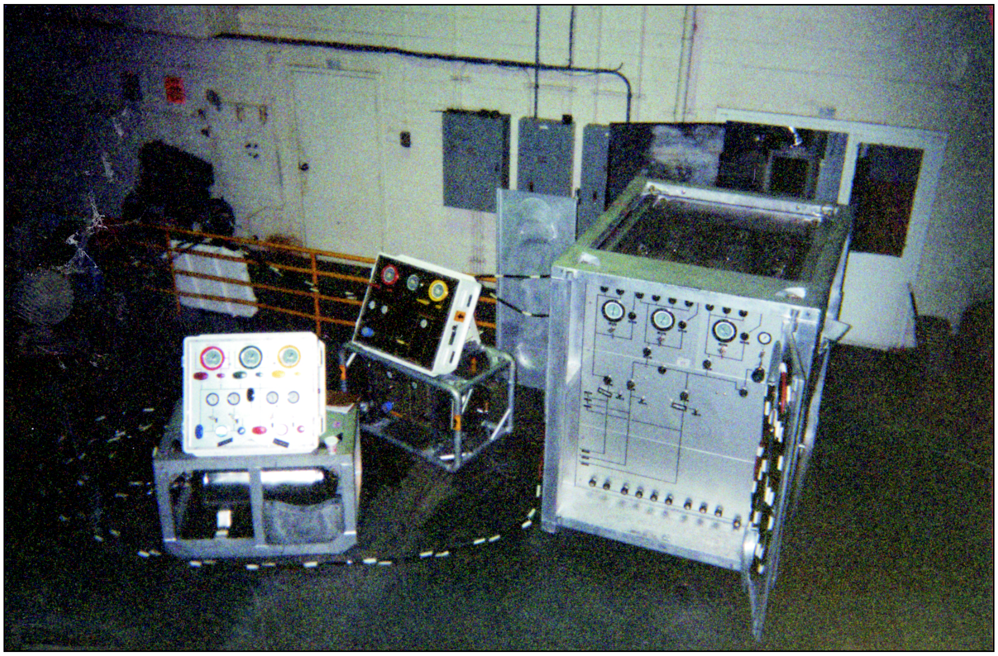


Figure 8-6. Flyaway Dive System (FADS) III.

Figure 8-7. ROPER Cart.

and Hyperbaric System Safety Certification Manual, NAVSEA SS521-AA-MAN-010. The major components/subsystems mounted within the cart body are:

- **Diving control station**. A single operator controls and monitors the air supply and operates the communication system.
- **Power distribution system**. External power for communications and control station lighting.
- **Intercommunication system (AC/DC)**. Provides communications between divers and the diving control station.
- **Air supply system**. Primary air source of two 6 cu ft, 3,000 psi air flasks; secondary air source of a single 1.52 cu ft, 3,000 psi air flask; and a scuba charging station.

Detailed information and operating instructions are covered in *Operations and Maintenance Instructions for Ready Operational Pierside Emergency Repair (ROPER) Diving Cart*, SS500-AS-MMA-010.

8-5.4 **Flyaway Dive System (FADS) I.** The FADS I is an air transportable, 0–190 fsw system that can be delivered to a suitable diving platform quickly. The system consists of a filter control console (FCC) intended for use with the medium-pressure flyaway air compressors and/or conventional air supplies. In its present configuration, the system can service up to four divers depending on the diving equipment in use. MK 21 MOD 1 and MK 20 equipment may be employed with the FADS I. See Figure 8-8.

Operational instructions for FADS I and II are covered in *Fly Away Diving System Filter/Console Operation and Maintenance Instructions, S9592-AD-MMM.FLTR CONT CSL; Fly Away Diving System Compressor Model 5120 Operation and Maintenance Instructions, S9592-AE-MMM-010/MOD 5120;* and *Fly Away Diving System Diesel Driven Compressor Unit Ex 32 Mod 0, PN 5020559, Operation and Maintenance Instructions, S9592-AC-MMM-010/Detroit DSL 3-53.*

8-5.5 **Flyaway Dive System (FADS) II.** The FADS II is a self-supported, air transportable, 0–190 fsw air diving system, designed and packaged for rapid deployment worldwide to a vessel of opportunity (see Figure 8-9). Primarily intended for use in salvage or inspection and emergency ship repairs, the system's main components are:

- **Diving outfit**. Four demand helmet (MK 21 MOD 1) assemblies with umbilicals, communication system, tool kit, and repair parts kit.
- **Two medium-pressure air compressors (MPAC)**. Diesel-driven QUINCY 250 psi, 87 standard cubic feet per minute (scfm), skid mounted.
- **High pressure air compressor (HPAC)**. Diesel-driven INGERSOLL RAND 10T2, 3,000 psi, 15 scfm, skid-mounted.

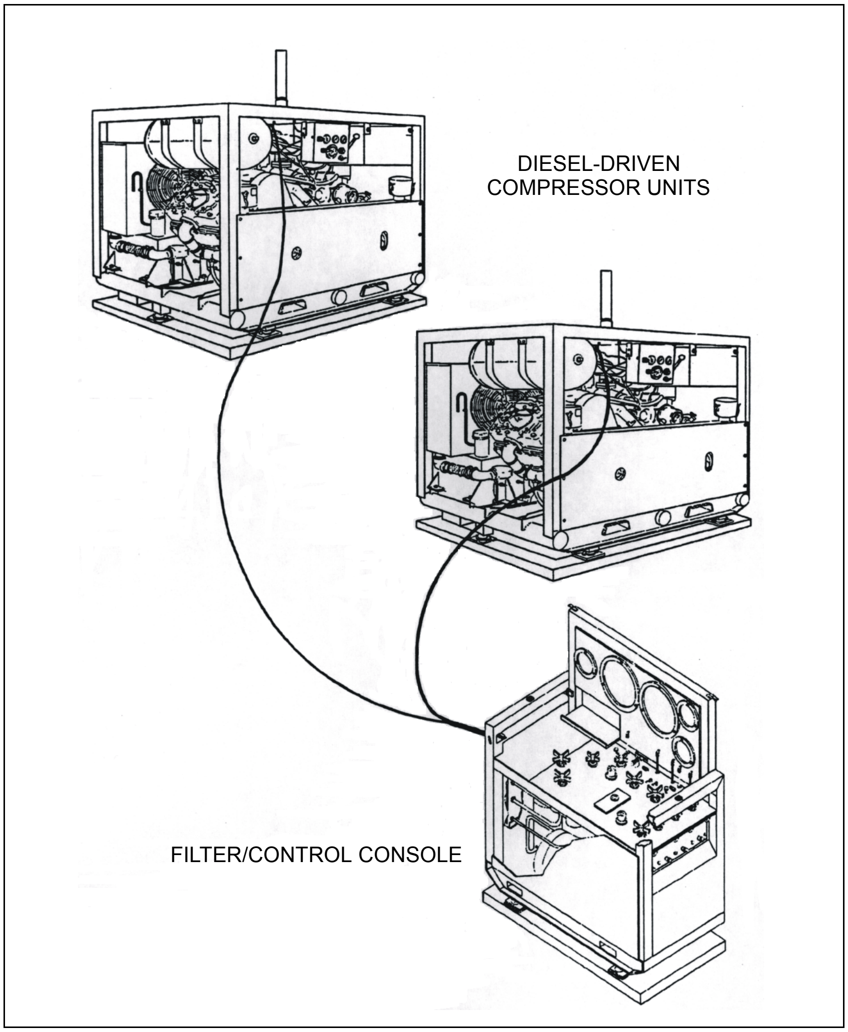


Figure 8-8. Flyaway Air Diving System (FADS) I.

- **Filter control console**. Regulates and filters air from MPAC, HPAC, or HP banks to support four divers, skid-mounted.
- **Suitcase filter control console**. Filters MPAC air to support three divers.
- **Double-lock aluminum recompression chamber**. Standard USN chamber, skid-mounted and designed to interface with filter control console.
- **Two HP air banks**. Two sets of HP banks providing secondary diver and chamber air.
- **HP oxygen tank**. One bank of HP oxygen providing chamber support.
- **5 kW diesel generator**. Provides power for communications, chamber lighting, miscellaneous.

- **5 kW diesel light tower**. Provides power to tripod lights, mast lights, underwater lights.

- **Hydraulic tool package and underwater lights**. As required.

- **Equipment shelter**. Fiberglass container houses filter control console and diving station.

- **Two conex boxes**. Steel containers for equipments storage.

8-5.6 Flyaway Dive System (FADS) III.

The FADS III is a portable, self-contained, surface-supplied diver life-support system designed to support dive missions to 190 fsw (Figure 8-9). Compressed air at 5,000 psi is contained in nine 3.15 cu ft floodable volume composite flasks vertically mounted in an Air Supply Rack Assembly (ASRA). The ASRA will hold 9600 scf of compressed air at 5,000 psi. Compressed air is provided by a 5,000 psi air compressor assembly which includes an air purification system. The FADS III also includes a control console assembly and a volume tank assembly. Three banks of two, three, and four flasks allow the ASRA to provide primary and secondary air to the divers as well as air to support chamber operations. Set-up and operating procedures for the FADS III are found in the *Operating and Maintenance Technical Manual for Fly Away Dive System (FADS) III Air System*, S9592-B1-MMO-010.

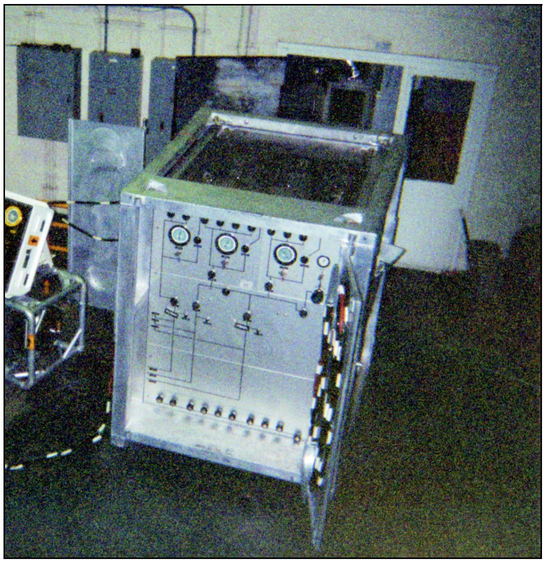


Figure 8-9. Air Supply Rack Assembly (ASRA) of FADS III.

8-6 ACCESSORY EQUIPMENT FOR SURFACE-SUPPLIED DIVING

Accessory equipment that is often useful in surface-supplied diving operations includes the following items:

- **Lead Line**. The lead line is used to measure depth.

- **Descent Line**. The descent line guides the diver to the bottom and is used to pass tools and equipment. A 3-inch double-braid line is recommended, to prevent twisting and to facilitate easy identification by the diver on the bottom. In use, the end of the line may be fastened to a fixed underwater object, or it may be anchored with a weight heavy enough to withstand the current.

- **Circling Line**. The circling line is attached to the bottom end of the descent line. It is used by the diver as a guide in searching and for relocating the descent line.

- **Stage**. Constructed to carry one or more divers, the stage is used to put divers into the water and to bring them to the surface, especially when decompression stops must be made. The stage platform is made in an open grillwork pattern to reduce resistance from the water and may include seats. Guides for the descent line, several eyebolts for attaching tools, and steadying lines or weights are provided. The frames of the stages may be collapsible for easy storage. A safety shackle or screw-pin shackle seized with wire or with a cotter pin must be used to connect the stage to the lifting line when raising or lowering. Stages must be weight tested in accordance with PMS.

- **Stage Line**. Used to raise and lower the stage, the stage line is to be 3-inch double braid, or 3/8-inch wire rope minimum, taken to a capstan or run off a winch and davit.

- **Diving Ladder**. The diving ladder is used to enter the water from a vessel.

- **Weights**. Cast iron or lead weights are used to weight the descent line.

- **Tool Bag**. The tool bag is used to carry tools.

- **Stopwatches**. Stopwatches are used to time the total dive time, decompression stop time, travel time, etc.

8-7 SURFACE AIR SUPPLY SYSTEMS

The diver's air supply may originate from an air compressor, a bank of high-pressure air flasks, or a combination of both.

8-7.1 **Requirements for Air Supply.** Regardless of the source, the air must meet certain established standards of purity, must be supplied in an adequate volume for breathing, and must have a rate of flow that properly ventilates the helmet or mask. The air must also be provided at sufficient pressure to overcome the bottom water pressure and the pressure losses due to flow through the diving hose, fittings, and valves. The air supply requirements depend upon specific factors of each dive such as depth, duration, level of work, number of divers being supported, and type of diving system being used.

8-7.1.1 **Air Purity Standards.** Air taken directly from the atmosphere and pumped to the diver may not meet established purity standards. It may be contaminated by engine exhaust or chemical smog. Initially pure air may become contaminated while passing through a faulty air compressor system. For this reason, all divers' air must be periodically sampled and analyzed to ensure the air meets purity standards. Refer to Table 4-1 for compressed air purity requirements.

To meet these standards, specially designed compressors must be used with the air supplied passed through a highly efficient filtration system. The compressed air found in a shipboard service system usually contains excessive amounts of oil and is not suitable for diving unless filtered. Air taken from any machinery space, or downwind from the exhaust of an engine or boiler, must be considered to be contaminated. For this reason, care must be exercised in the placement and operation of diving air compressors to avoid such conditions. Intake piping or ducting must be provided to bring uncontaminated air to the compressor. The outboard end of this piping must be positioned to eliminate sources of contamination. To ensure that the source of diver's breathing air satisfactorily meets the standards established above, it must be checked at intervals not to exceed 8 months, in accordance with the PMS.

8-7.1.2 **Air Supply Flow Requirements.** The required flow from an air supply depends upon the type of diving apparatus being used. The open-circuit air supply system must have a flow capacity (in acfm) that provides sufficient ventilation at depth to maintain acceptable carbon dioxide levels in the mask or helmet. Carbon dioxide levels must be kept within safe limits during normal work, heavy work, and emergencies.

If demand breathing equipment is used, such as the MK 21 MOD 1 or the MK 20 MOD 0, the supply system must meet the diver's flow requirements. The flow requirements for respiration in a demand system are based upon the average rate of air flow demanded by the divers under normal working conditions. The maximum instantaneous (peak) rate of flow under severe work conditions is not a continuous requirement, but rather the highest rate of airflow attained during the inhalation part of the breathing cycle. The diver's requirement varies with the respiratory demands of the diver's work level.

8-7.1.3 **Supply Pressure Requirements.** In order to supply the diver with an adequate flow of air, the air source must deliver air at sufficient pressure to overcome the bottom seawater pressure and the pressure drop that is introduced as the air flows through the hoses and valves of the system. Table 8-2 shows the values for air consumption and minimum over-bottom pressures required for each of the surface-supplied air diving systems.

Table 8-2. *Primary Air System Requirements.*

System	Minimum Manifold Pressure (MMP)	Air Consumption Average Over Period of Dive (acfm)
MK 21 MOD 1	(Depth in fsw × 0.445) + 90 to 165 psi, depending on the depth of the dive	1.4 (Note 1)
MK 20 MOD 0	(Depth in fsw × 0.445) + 90 psi	1.4

Note 1: The manifold supply pressure requirement is 90 psig over-bottom pressure for depths to 60 fsw, and 135 psig over-bottom pressure for depths from 61-130 fsw. For dives from 131-190 fsw, 165 psig over-bottom pressure shall be used.

8-7.1.4 **Water Vapor Control.** A properly operated air supply system should never permit the air supplied to the diver to reach its dewpoint. Controlling the amount of water vapor (humidity) in the supplied air is normally accomplished by one or both of the following methods:

- **Compression/Expansion**. As high-pressure air expands across a pressure reducing valve, the partial pressure of the water vapor in the air is decreased. Since the expansion takes place at essentially a constant temperature (isothermal), the partial pressure of water vapor required to saturate the air remains unchanged. Therefore, the relative humidity of the air is reduced.

- **Cooling**. Cooling the air prior to expanding it raises its relative humidity, permitting some of the water to condense. The condensed liquid may then be drained from the system.

8-7.1.5 **Standby Diver Air Requirements.** Air supply requirements cannot be based solely on the calculated continuing needs of the divers who are initially engaged in the operation. There must be an adequate reserve to support a standby diver should one be needed.

8-7.2 **Primary and Secondary Air Supply.** All surface-supplied diving systems must include a primary and a secondary air supply in accordance with the *U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual*, SS521-AA-MAN-010. The primary supply must be able to support the air flow and pressure requirements for the diving equipment designated (Table 8-2). The capacity of the primary supply must meet the consumption rate of the designated number of divers for the full duration of the dive (bottom time plus decompression time). The maximum depth of the dive, the number of divers, and the equipment to be used must be taken into account when sizing the supply. The secondary supply must be sized to be able to support recovery of all divers using the equipment and dive profile of the primary supply if the primary supply sustains a casualty at the worst-case time (for example, immediately prior to completion of planned bottom time of maximum dive depth, when decompression obligation is greatest). Primary and secondary supplies may be either high-pressure (HP) bank-supplied or compressor-supplied.

8-7.2.1 **Requirements for Operating Procedures and Emergency Procedures.** Operating procedures (OPs) and emergency procedures (EPs) must be available to support operation of the system and recovery from emergency situations. OPs and EPs are required to be NAVSEA or NAVFAC approved in accordance with paragraph 4-2.6.3. Should the surface-supplied diving system be integrated with a recompression chamber, an air supply allowance for chamber requirements (Volume 5) must be made.

All valves and electrical switches that directly influence the air supply shall be labeled:

“DIVER'S AIR SUPPLY - DO NOT TOUCH”

Banks of flasks and groups of valves require only one central label at the main stop valve.

A volume tank must be part of the air supply system and be located between the supply source and the diver's manifold hose connection. This tank maintains the air supply should the primary supply source fail, providing time to actuate the secondary air supply, and to attenuate the peak air flow demand.

8-7.2.2 **Air Compressors.** Many air supply systems used in Navy diving operations include at least one air compressor as a source of air. To properly select such a compressor, it is essential that the diver have a basic understanding of the principles of gas compression. The NAVSEA/00C ANU list contains guidance for Navy-approved compressors for divers' air systems. See Figure 8-10.

8-7.2.2.1 ***Reciprocating Air Compressors.*** Reciprocating air compressors are the only compressors authorized for use in Navy air diving operations. low pressure (LP) models can provide rates of flow sufficient to support surface-supplied air diving or recompression chamber operations. High-pressure models can charge high-pressure air banks and scuba cylinders.

8-7.2.2.2 ***Compressor Capacity Requirements.*** Air compressors must meet the flow and pressure requirements outlined in paragraph 8-7.1.2 and 8-7.1.3. Normally, reciprocating compressors have their rating (capacity in cubic feet per minute and delivery pressure in psig) stamped on the manufacturer's identification plate. This rating is usually based on inlet conditions of 70°F (21.1°C), 14.7 psia barometric pressure, and 36 percent relative humidity (an air density of 0.075 pound per cubic foot). If inlet conditions vary, the actual capacity either increases or decreases from rated values. If not provided directly, capacity will be provided by conducting a compressor output test (see Topside Tech Notes, Volume II Compressors/Process Instruction NAVSEA-00C4-PI-004, Compressor Capacity Testing). Since the capacity is the volume of air at defined atmospheric conditions, compressed per unit of time, it is affected only by the first stage, as all other stages only increase the pressure and reduce temperature. All industrial compressors are stamped with a code, consisting of at least two, but usually four to five, numbers that specify the bore and stroke.

The actual capacity of the compressor will always be less than the displacement because of the clearance volume of the cylinders. This is the volume above the piston that does not get displaced by the piston during compression. Compressors having a first stage piston diameter of four inches or larger normally have an actual capacity of about 85 percent of their displacement. The smaller the first stage piston, the lower the percentage capacity, because the clearance volume represents a greater percentage of the cylinder volume.

8-7.2.2.3 ***Lubrication.*** Reciprocating piston compressors are either oil lubricated or water lubricated. The majority of the Navy's diving compressors are lubricated by petroleum or synthetic oil. In these compressors, the lubricant:

- Prevents wear between friction surfaces

- Seals close clearances
- Protects against corrosion
- Transfers heat away from heat-producing surfaces
- Transfers minute particles generated from normal system wear to the oil sump or oil filter if so equipped

8-7.2.2.4 ***Lubricant Specifications.*** Unfortunately, the lubricant vaporizes into the air supply and, if not condensed or filtered out, will reach the diver. Lubricants used in air diving compressors must conform to military specifications MIL-L-17331 (2190 TEP) for normal operations, or MIL-H-17672 (2135 TH) for cold weather operations. Where the compressor manufacturer specifically recommends using a synthetic base oil, the recommended oil may be used in lieu of MIL-L-17331 or MIL-H-17672 oil.

8-7.2.2.5 ***Maintaining an Oil-Lubricated Compressor.*** Using an oil-lubricated compressor for diving is contingent upon proper maintenance to limit the amount of oil introduced into the diver's air (see *Topside Tech Notes*, March 1997). When using any lubricated compressor for diving, the air must be checked for oil contamination. Diving operations shall be aborted at the first indication that oil is in the air being delivered to the diver. An immediate air analysis must be conducted to determine whether the amount of oil present exceeds the maximum permissible level in accordance with table Table 4-1.

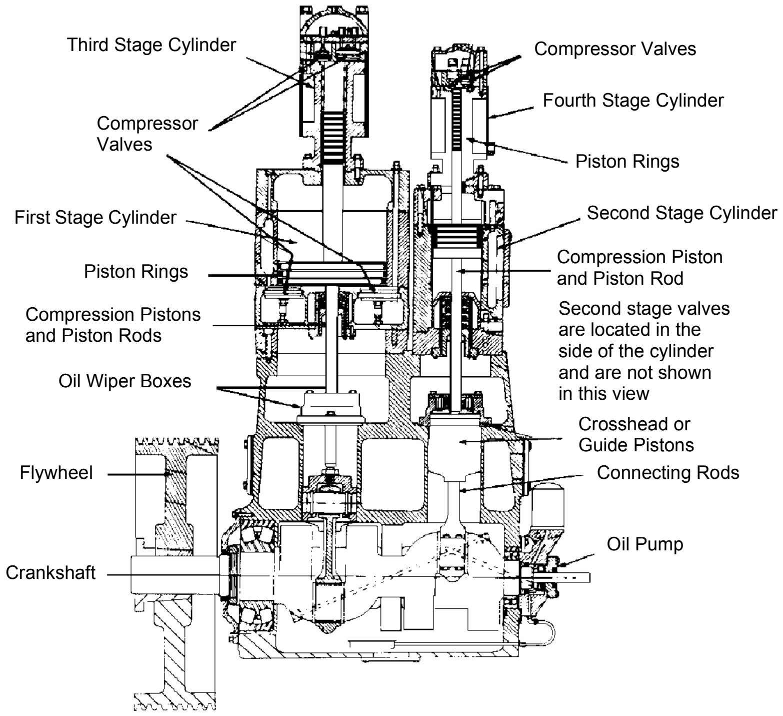
It should be noted that air in the higher stages of a compressor has a greater amount of lubricant injected into it than in the lower stages. It is recommended that the compressor selected for a diving operation provide as close to the required pressure for that operation as possible. A system that provides excessive pressure contributes to the buildup of lubricant in the air supply.

8-7.2.2.6 ***Intercoolers.*** Intercoolers are heat exchangers that are placed between the stages of a compressor to control the air temperature. Water, flowing through the heat exchanger counter to the air flow, serves both to remove heat from the air and to cool the cylinder walls. Intercoolers are frequently air cooled. During the cooling process, water vapor is condensed out of the air into condensate collectors. The condensate must be drained periodically during operation of the compressor, either manually or automatically.

8-7.2.2.7 ***Filters.*** As the air is discharged from the compressor, it passes through a moisture separator and an approved filter to remove lubricant, aerosols, and particulate contamination before it enters the system. Approved filters are listed in the NAVSEA/00C ANU list.

8-7.2.2.8 ***Pressure Regulators.*** A back-pressure regulator will be installed downstream of the compressor discharge. A compressor only compresses air to meet the supply pressure demand. If no demand exists, air is simply pumped through the compressor at atmospheric pressure. Systems within the compressor, such as the

HP Compressor Assembly



MP Compressor Assembly

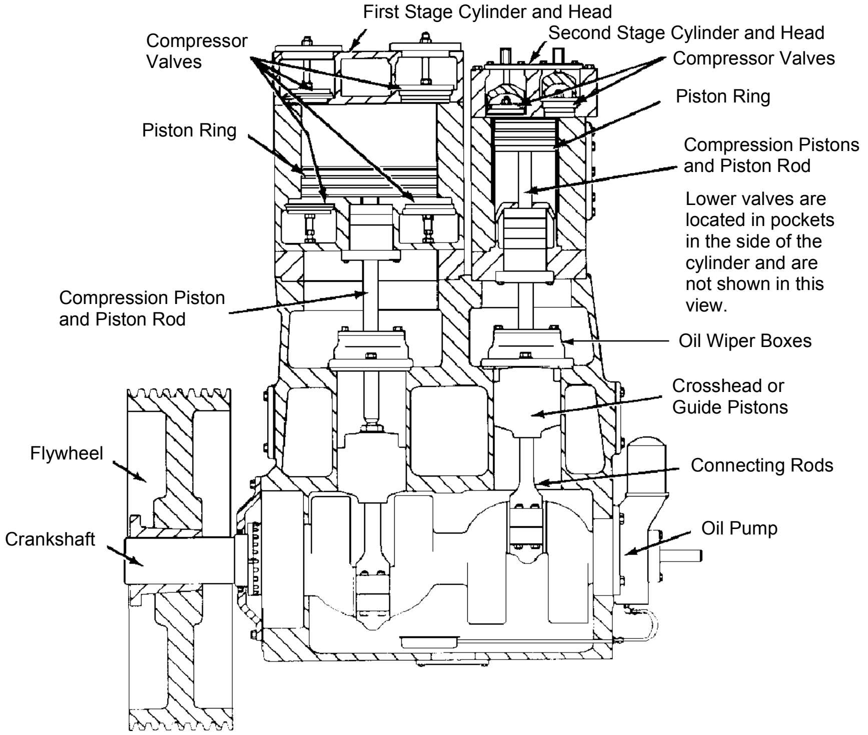


Figure 8-10. HP Compressor Assembly (top); MP Compressor Assembly (bottom).

intercoolers, are designed to perform with maximum efficiency at the rated pressure of the compressor. Operating at any pressure below this rating reduces the efficiency of the unit. Additionally, compression reduces water vapor from the air. Reducing the amount of compression increases the amount of water vapor in the air supplied to the diver.

The air supplied from the compressor expands across the pressure regulator and enters the air banks or volume tank. As the pressure builds up in the air banks or volume tank, it eventually reaches the relief pressure of the compressor, at which time the excess air is simply discharged to the atmosphere. Some electrically-driven compressors are controlled by pressure switches installed in the volume tank or HP flask. When the pressure reaches the upper limit, the electric motor is shut off. When sufficient air has been drawn from the volume tank or HP flask to lower its pressure to some lower limit, the electric motor is restarted.

All piping in the system must be designed to minimize pressure drops. Intake ducting, especially, must be of sufficient diameter so that the rated capacity of the compressor can be fully utilized. All joints and fittings must be checked for leaks using soapy water. Leaks must be repaired. All filters, strainers, and separators must be kept clean. Lubricant, fuel, and coolant levels must be periodically checked.

Any diving air compressor, if not permanently installed, must be firmly secured in place. Most portable compressors are provided with lashing rings for this purpose.

8-7.2.3 **High-Pressure Air Cylinders and Flasks.** HP air cylinders and flasks are vessels designed to hold air at pressures over 600 psi. Convenient and satisfactory diving air supply systems can be provided by using a number of these HP air cylinders or flasks. Any HP vessel to be used as a diving air supply unit must bear appropriate Department of Transportation (DOT) or military symbols certifying that the cylinders or flasks meet high-pressure requirements.

A complete air supply system includes the necessary piping and manifolds, HP filter, pressure reducing valve, and a volume tank. An HP gauge must be located ahead of the reducing valve and an LP gauge must be connected to the volume tank.

In using this type of system, one section must be kept in reserve. The divers take air from the volume tank in which the pressure is regulated to conform to the air supply requirements of the dive. The duration of the dive is limited to the length of time the banks can provide air before being depleted to 200 psi over minimum manifold pressure. This minimum pressure of 200 psi must remain in each flask or cylinder.

As in scuba operations, the quantity of air that can be supplied by a system using cylinders or flasks is determined by the initial capacity of the cylinders or flasks and the depth of the dive. The duration of the air supply must be calculated in advance and must include a provision for decompression.

Sample calculations for dive duration, based on bank air supply, are presented in Sample Problem 1 in paragraph 8-2.2.3 for the MK 21 MOD 1. The sample problems in this chapter do not take the secondary air system requirements into account. The secondary air system must be able to provide air in the event of failure of the primary system per *U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual*, SS521-AA-MAN-010. In the MK 21 sample problem (Sample Problem 2), this would mean decompressing three divers with a 30-minute bottom time using 1.4 acfm per diver. An additional requirement must be considered if the same air system is to support a recompression chamber. Refer to Chapter 22 for information on the additional capacity required to support a recompression chamber.

8-7.2.4 **Shipboard Air Systems.** Many Navy ships have permanently installed shipboard air supply systems that provide either LP or HP air. These systems are used in support of diving operations provided they meet the fundamental requirements of purity, capacity, and pressure.

In operation, a volume source (such as a diesel or electrically driven compressor) pumps air into a volume tank. The compressor automatically keeps the tank full as long as the amount of air being used by the diver does not exceed the capacity of the compressor. The ability of a given unit to support a diving operation may be determined from the capacity of the system.

8-8 DIVER COMMUNICATIONS

The surface-supplied diver has two means of communicating with the surface, depending on the type of equipment used. If the diver is using the MK 21 MOD 1, or the MK 20 MOD 0, both voice communications and line-pull signals are available. Voice communications are used as the primary means of communication. Line-pull signals are used only as a backup. Diver-to-diver communications are available through topside intercom, diver-to-diver hand signals or slate boards.

8-8.1 **Diver Intercommunication Systems.** The major components of the intercommunication system include the diver's earphones and microphone, the communication cable to each diver, the surface control unit, and the tender's speaker and microphone. The system is equipped with an external power cord and can accept 115 VAC or 12 VDC. The internal battery is used for backup power requirements. It should not be used as the primary power source unless an external power source is not available.

The intercom system is operated by a designated phone talker at the diving station. The phone talker monitors voice communications and keeps an accurate log of significant messages. All persons using the intercom system should lower the pitch of their voices and speak slowly and distinctly. The conversation should be kept brief and simple, using standard diving terminology. Divers must repeat verbatim all directions and orders received from topside.

The approved Navy diver communication system is compatible with the MK 21 MOD 1 and the MK 20 MOD 0. This is a surface/underwater system that allows conference communications between the tender and up to three divers. It incorporates voice correction circuitry that compensates for the distortion caused by divers speaking in a helium-oxygen atmosphere.

The divers' voices are continuously monitored on the surface. All communications controls are located at the surface. The topside supervisor speaks with any or all of the divers by exercising the controls on the front panel. It is necessary for a phone talker to monitor and control the underwater communications system at all times.

8-8.2 **Line-Pull Signals.** A line-pull signal consists of one pull or a series of sharp, distinct pulls on the umbilical that are strong enough to be felt by the diver (Figure 8-11). All slack must be taken out of the umbilical before the signal is given.

The line-pull signal code (Table 8-3) has been established through many years of experience. Standard signals are applicable to all diving operations; special signals may be arranged between the divers and Diving Supervisor to meet particular mission requirements. Most signals are acknowledged as soon as they are received. This acknowledgment consists of replying with the same signal. If a signal is not properly returned by the diver, the surface signal is sent again. A continued absence of confirmation is assumed to mean one of three things: the line has become fouled, there is too much slack in the line, or the diver is in trouble.

If communications are lost, the Diving Supervisor must be notified immediately and steps taken to identify the problem. The situation is treated as an emergency (see paragraph 6-12.5.3.2).

There are three line-pull signals that are not answered immediately. Two of these, from diver to tender, are "Haul me up" and "Haul me up immediately." Acknowledgment consists of initiation of the action. The other signal, from the tender to diver, is "Come up." This signal is not acknowledged until the diver is ready to leave the bottom. If for some reason the diver cannot respond to the order, the diver must communicate the reason via the voice intercom system or through the line-pull signal meaning "I understand," followed (if necessary) by an appropriate emergency signal.

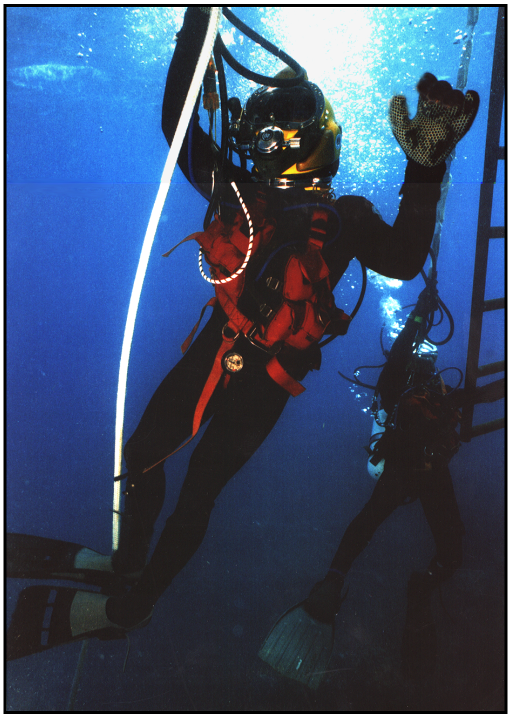


Figure 8-11. Communicating with Line-Pull Signals.

Table 8-3. *Line-Pull Signals.*

From Tender to Diver		**Searching Signals (Without Circling Line)**	
1 Pull	“Are you all right?” When diver is descending, one pull means “Stop.”	7 Pulls	“Go on (or off) searching signals.”
2 Pulls	“Going Down.” During ascent, two pulls mean “You have come up too far; go back down until we stop you.”	1 Pull	“Stop and search where you are.”
3 Pulls	“Stand by to come up.”	2 Pulls	“Move directly away from the tender if given slack; move toward the tender if strain is taken on the life line.”
4 Pulls	“Come up.”	3 Pulls	“Face your umbilical, take a strain, move right.”
2-1 Pulls	“I understand” or “Talk to me.”	4 Pulls	“Face your umbilical, take a strain, move left.”
3-2 Pulls	“Ventilate.”		
4-3 Pulls	“Circulate.”		
From Diver to Tender		**Searching Signals (With Circling Line)**	
1 Pull	“I am all right.” When descending, one pull means “Stop” or “I am on the bottom.”	7 Pulls	“Go on (or off) searching signals.”
2 Pulls	“Lower” or “Give me slack.”	1 Pull	“Stop and search where you are.”
3 Pulls	“Take up my slack.”	2 Pulls	“Move away from the weight.”
4 Pulls	“Haul me up.”	3 Pulls	“Face the weight and go right.”
2-1 Pulls	“I understand” or “Talk to me.”	4 Pulls	“Face the weight and go left.”
3-2 Pulls	“More air.”		
4-3 Pulls	“Less air.”		
Special Signals From the Diver		**Emergency Signals From the Diver**	
1-2-3 Pulls	“Send me a square mark.”	2-2-2 Pulls	“I am fouled and need the assistance of another diver.”
5 Pulls	“Send me a line.”	3-3-3 Pulls	“I am fouled but can clear myself.”
2-1-2 Pulls	“Send me a slate.”	4-4-4 Pulls	“Haul me up immediately.”
ALL EMERGENCY SIGNALS SHALL BE ANSWERED AS GIVEN EXCEPT 4-4-4			

A special group of searching signals is used by the tender to direct a diver in moving along the bottom. These signals are duplicates of standard line-pull signals, but their use is indicated by an initial seven-pull signal to the diver that instructs the diver to interpret succeeding signals as searching signals. When the tender wants to revert to standard signals, another seven-pull signal is sent to the diver which means searching signals are no longer in use. Only the tender uses searching signals; all signals initiated by the diver are standard signals. To be properly oriented for using searching signals, the diver must face the line (either the lifeline or the descent line, if a circling line is being employed).

8-9 PREDIVE PROCEDURES

The predive activities for a surface-supplied diving operation involve many people and include inspecting and assembling the equipment, activating the air supply systems, and dressing the divers.

8-9.1 **Predive Checklist.** A comprehensive predive checklist is developed to suit the requirements of the diving unit and of the particular operation. This is in addition to the general Diver Safety and Planning Checklist (Figure 6-19a) and suggested Predive Checklist (Figure 6-21a).

8-9.2 **Diving Station Preparation.** The diving station is neatly organized with all diving and support equipment placed in an assigned location. Deck space must not be cluttered with gear; items that could be damaged are placed out of the way (preferably off the deck). A standard layout pattern should be established and followed.

8-9.3 **Air Supply Preparation.** The primary and secondary air supply systems are checked to ensure that adequate air is available. Air compressors of the divers' air system are started and checked for proper operation. The pressure in the accumulator tanks is checked. If HP air cylinders are being used, the manifold pressure is checked. If a compressor is being used as a secondary air supply, it is started and kept running throughout the dive. The air supply must meet purity standards (see paragraph 8-7.1.1).

8-9.4 **Line Preparation.** Depth soundings are taken and descent line, stage, stage lines, and connections are checked, with decompression stops properly marked.

8-9.5 **Recompression Chamber Inspection and Preparation.** If available, the recompression chamber is inspected and all necessary equipment and a copy of appropriate recompression treatment tables are placed on hand at the chamber. Two stop watches and the decompression tables are also required. Adequate air supply for immediate pressurization of the chamber is verified and the oxygen supply system is charged and made ready for operation in accordance with Chapter 22.

8-9.6 **Predive Inspection.** When the Diving Supervisor is satisfied that all equipment is on station and in good operating condition, the next step is to dress the divers.

8-9.7 **Donning Gear.** Dressing the divers is the responsibility of the tender.

8-9.8 **Diving Supervisor Predive Checklist.** The Diving Supervisor must always use a predive checklist prior to putting divers in the water. This checklist must be tailored by the unit to the specific equipment and systems being used. Chapter 6 contains typical predive checklists for surface-supplied equipment. Refer to the appropriate operations and maintenance manual for detailed checklists for specific equipment.

8-10 WATER ENTRY AND DESCENT

Once the predive procedures have been completed, the divers are ready to enter the water. There are several ways to enter the water, with the choice usually determined by the nature of the diving platform. Regardless of the method of entry, the divers should look before entering the water. Three methods for entering the water are the:

- Ladder method
- Stage method
- Step-in method

8-10.1 **Predescent Surface Check.** In the water and prior to descending to operating depth, the diver makes a final equipment check.

- The diver immediately checks for leaks in the suit or air connections.
- If two divers are being employed, both divers perform as many checks as possible on their own rigs and then check their dive partner's rig. The tender or another diver can be of assistance by looking for any telltale bubbles.
- A communications check is made and malfunctions or deficiencies not previously noted are reported at this time.

When satisfied that the divers are ready in all respects to begin the dive, they notify the Diving Supervisor and the tenders move the divers to the descent line. When in position for descent, the diver adjusts for negative buoyancy and signals readiness to the Diving Supervisor.

8-10.2 **Descent.** Descent may be accomplished with the aid of a descent line or stage. Topside personnel must ensure that air is being supplied to the diver in sufficient quantity and at a pressure sufficient to offset the effect of the steadily increasing water pressure. The air pressure must also include an overbottom pressure allowance to protect the diver against a serious squeeze if he or she falls.

While descending, the diver adjusts the air supply so that breathing is easy and comfortable. The diver continues to equalize the pressure in the ears as necessary during descent and must be on guard for any pain in the ears or sinuses, or any other warning signals of possible danger. If any such indications are noted, the descent is halted. The difficulty may be resolved by ascending a few feet to regain a pressure balance; if this is not effective, the diver is returned to the surface.

Some specific guidelines for descent are as follows:

- With a descent line, the diver locks the legs around the line and holds on to the line with one hand.
- In a current or tideway, the diver descends with back to the flow in order to be held against the line and not be pulled away. If the current measures more than

1.5 knots, the diver wears additional weights or descends on a weighted stage, so that descent is as nearly vertical as possible.

- When the stage is used for descent, it is lowered with the aid of a winch and guided to the site by a shackle around the descent line. The diver stands in the center of the stage, maintaining balance by holding on to the side bails. Upon reaching the bottom, the diver exits the stage as directed by the Diving Supervisor.

- The maximum allowable rate of descent, by any method, shall not exceed 75 feet per minute (fpm), although such factors as the diver's ability to clear the ears, currents and visibility and the need to approach an unknown bottom with caution may render the actual rate of descent considerably less.

- The diver signals arrival on the bottom and quickly checks bottom conditions. Conditions that are radically different than expected are reported to the Diving Supervisor. If there is any doubt about the safety of the diver or the diver's readiness to operate under the changed conditions, the dive is aborted.

- A diver should thoroughly ventilate when reaching the bottom, at subsequent intervals as the diver feels necessary and as directed from the surface. On dives deeper than 100 fsw, the diver may not notice the CO_2 warning symptoms because of nitrogen narcosis. It is imperative that the Diving Supervisor monitors his or her divers' ventilation.

8-11 UNDERWATER PROCEDURES

8-11.1 Adapting to Underwater Conditions. Through careful and thorough planning, the divers can be properly prepared for the underwater conditions at the diving site. The diver will employ the following techniques to adapt to underwater conditions:

- Upon reaching the bottom and before leaving the area of the stage or descent line, the diver adjusts buoyancy and makes certain that the air supply is adequate.

- The diver becomes oriented to the bottom and the work site using such clues as the lead of the umbilical, natural features on the bottom, the direction of current. However, bottom current may differ from the surface current. The direction of current flow may change significantly during the period of the dive. If the diver has any trouble in orientation, the tender can guide the diver by using the line-pull searching signals.

The diver is now ready to move to the work site and begin the assignment.

8-11.2 Movement on the Bottom. Divers should follow these guidelines for movement on the bottom areas:

- Before leaving the descent line or stage, ensure that the umbilical is not fouled.

- Loop one turn of the lifeline and air hose over an arm; this acts as a buffer against a sudden surge or pull on the lines.

- Proceed slowly and cautiously to increase safety and to conserve energy.

- If obstructions are encountered, adjust buoyancy to pass over the obstruction (not under or around). If you pass around an obstruction, you must return by the same side to avoid fouling lines.

- When using buoyancy adjustments to aid in movement, avoid bouncing along the bottom; all diver movements are controlled.

- If the current is strong, stoop or crawl to reduce body area exposed to the current. Adjust the inflation of the dress to compensate for any change in depth, even if the change is only a few feet.

- When moving on a rocky or coral bottom, make sure lines do not become fouled on outcroppings, guarding against tripping and getting feet caught in crevices. Watch for sharp projections that can cut hoses, diving dress or unprotected hands. The tender is particularly careful to take up any slack in the diver's umbilical to avoid fouling.

- Guard against slipping and falling on gravel bottoms, especially on slopes.

- Avoid unnecessary movements that stir up the bottom and impair visibility.

CAUTION **Avoid overinflation and be aware of the possibility of blowup when breaking loose from mud. It is better to call for aid from the standby diver than to risk blowup.**

- Mud and silt may not be solid enough to support your weight. Many hours may be spent working under mud without unreasonable risk. The primary hazard with mud bottoms comes from the concealment of obstacles and dangerous debris.

8-11.3 **Searching on the Bottom.** If appropriate electronic searching equipment is not available, it may be necessary to use unaided divers to conduct the search. Procedures for searching on the bottom with unaided divers are:

1. A diver search of the bottom can be accomplished with a circling line, using the descent line as the base point of the search. The first sweep is made with the circling line held taut at a point determined by the range of visibility. If possible, the descent line should be in sight or, if visibility is limited, within reach. The starting point is established by a marker, a line orientation with the current or the light, signals from topside, or a wrist compass. After a full 360-degree sweep has been made, the diver moves out along the circling line

another increment (roughly double the first) and makes a second sweep in the opposite direction to avoid twisting or fouling the lifeline and air hose.

2. If the object is not found when the end of the circling line has been reached, the base point (the descent line) is shifted. Each base point in succession should be marked by a buoy to avoid unnecessary duplication in the search. If the search becomes widespread, many of the marker buoys can be removed, leaving only those marking the outer limits of the area.

3. If the diver is unable to make a full circle around the descent line because of excessive current or obstructions, the search patterns are adjusted accordingly.

4. A linear search pattern (Jack-Stay) can be established by laying two large buoys and setting a line between them. A diving launch, with a diver on the bottom, can follow along the line from buoy to buoy, coordinating progress with the diver who is searching to each side of the established base line. These buoys may be readjusted to enlarge search areas.

5. Once the object of a search is located, it is marked. The diver can secure the circling line to the object as an interim measure, while waiting for a float line to be sent down.

8-11.4 **Enclosed Space Diving.** Divers are often required to work in an enclosed or confined space. Enclosed space diving shall be supported by a surface-supplied air system (MK 20 MOD 0, MK 21 MOD 1, and EXO BR MS).

8-11.4.1 **Enclosed Space Hazards.** The interior of sunken ships, barges, submarine ballast tanks, mud tanks, sonar domes, and cofferdams is hazardous due to limited access, poor visibility, and slippery surfaces. Enclosed spaces may be dry or flooded, and dry spaces may contain a contaminated atmosphere.

NOTE **When a diver is working in an enclosed or confined space with the exception of submarine ballast tanks, the Diving Supervisor shall have the diver tended by another diver at the access opening. Ultimately, the number of tending divers deployed depends on the situation and the good judgement of the Diving Officer, Master Diver, or Diving Supervisor on the site.**

8-11.4.2 **Enclosed Space Safety Precautions.** Because of the hazards involved in enclosed space operations, divers must rigorously adhere to the following warnings.

WARNING **During enclosed space diving, all divers shall be outfitted with a MK 21 MOD 1, MK 20 MOD 0, or EXO BR MS that includes a diver-to-diver and diver-to-topside communications system and an EGS for the diver inside the space.**

WARNING **For submarine ballast tanks, the divers shall not remove their diving equipment until the atmosphere has been flushed twice with air from a compressed air source meeting the requirements of Chapter 4, or the submarine L.P. blower, and tests confirm that the atmosphere is safe for**

breathing. Tests of the air in the enclosed space shall be conducted hourly. Testing shall be done in accordance with NSTM 074, Volume 3, Gas Free Engineering (S9086-CH-STM-030/CH-074) for forces afloat, and NAVSEA S-6470-AA-SAF-010 for shore-based facilities. If the divers smell any unusual odors they shall immediately don their EGS.

WARNING **If the diving equipment should fail, the diver shall immediately switch to the EGS and abort the dive.**

8-11.5 **Working Around Corners.** When working around corners where the umbilical is likely to become fouled or line-pull signals may be dissipated, a second diver (tending diver) may be sent down to tend the lines of the first diver at the obstruction and to pass along any line-pull signals. Line-pull signals are used when audio communications are lost, and are passed on the first diver's lines; the tending diver uses his own lines only for signals directly pertaining to his own situation.

8-11.6 **Working Inside a Wreck.** When working inside a wreck, the same procedure of deploying tending divers is followed. This technique applies to the tending divers as well: every diver who penetrates a deck level has another tending diver at that level, or levels, above. Ultimately, the number of tending divers deployed depends on the situation and the good judgment of the Diving Officer, Master Diver, or Diving Supervisor on the site. Obviously, an operation requiring penetration through multiple deck levels requires detailed advanced planning in order to provide for the proper support of the number of divers required. MK 21 MOD 1 and MK 20 MOD 0 are the only equipment approved for working inside a wreck. The diver enters a wreck feet first and never uses force to gain entry through an opening.

8-11.7 **Working With or Near Lines or Moorings.** When working with or near lines or moorings, observe the following rules:

- Stay away from lines under strain.
- Avoid passing under lines or moorings if at all possible; avoid brushing against lines or moorings that have become encrusted with barnacles.
- If a line or mooring is to be shifted, the diver is brought to the surface and, if not removed from the water, moved to a position well clear of any hazard.
- If a diver must work with several lines (messengers, float lines, lifting lines, etc.) each should be distinct in character (size or material) or marking (color codes, tags, wrapping).
- Never cut a line unless the line is positively identified.
- When preparing to lift heavy weights from the bottom, the lines selected must be strong enough and the surface platform must be positioned directly over the object to be raised. Prior to the lift, make sure the diver is clear of the lift area or leaves the water.

8-11.8 **Bottom Checks.** Bottom checks are conducted after returning to the stage or descent line and prior to ascent. The checks are basically the same for each rig.

1. Ensure all tools are ready for ascent.
2. Check that all umbilicals and lines are clear for ascent.
3. Assess and report your condition (level of fatigue, remaining strength, physical aches or pains, etc.) and mental acuity.

8-11.9 **Job Site Procedures.** The range of diving jobs is wide and varied. Many jobs follow detailed work procedures and require specific predive training to ensure familiarity with the work. The *Underwater Ship Husbandry Manual*, S0600-AA-PRO-010, presents guidance for most commonly encountered jobs, such as replacement and repair of propellers, propeller blades, auxiliary propulsion motors, and sonar domes.

8-11.9.1 **Underwater Ship Husbandry Procedures.** Due to the complexity of ships' underwater systems and the sophistication of newly developed repair techniques, specific procedures were developed to provide guidance in the underwater repair and maintenance of U.S. Navy ships. These procedures are located in individually bound chapters of the Underwater Ship Husbandry Manual (S0600-AA-PRO-010). Chapter 1 of the manual is the Index and User Guide, which provides information on the subsequent chapters of the manual.

8-11.9.2 **Working with Tools.** Underwater work requires appropriate tools and materials, such as cement, foam plastic, and patching compounds. Many of these are standard hand tools (preferably corrosion-resistant) and materials; others are specially designed for underwater work. A qualified diver will become familiar with the particular considerations involved in working with these various tools and materials in an underwater environment. Hands-on training experience is the only way to get the necessary skills. Consult the appropriate operations and maintenance manuals for the use techniques of specific underwater tools. In working with tools the following basic rules always apply:

- Never use a tool that is not in good repair. If a cutting tool becomes dulled, return it to the surface for sharpening.
- Do not overburden the worksite with unnecessary tools, but have all tools that may be needed readily available.
- Tools are secured to the diving stage by lanyard, carried in a tool bag looped over the diver's arm, or lowered on the descent line using a riding shackle and a light line for lowering. Prior to ascent or descent, secure power to all tools. Attach lanyards to all tools, connectors, shackles and shackle pins.
- Using the diving stage as a worksite permits organization of tools while providing for security against loss. The stage also gives the diver leverage and

stability when applying force (as to a wrench), or when working with a power tool that transmits a force back through the diver.

- Tying a hogging line to the work also gives the diver leverage while keeping him close to his task without continually having to fight a current.

8-11.10 **Safety Procedures.** The best safety factors are a positive, confident attitude about diving and careful advance planning for emergencies. A diver in trouble underwater should relax, avoid panic, communicate the problem to the surface and carefully think through the possible solutions to the situation. Topside support personnel should implement emergency job-site procedures as indicated in Chapter 6. In all situations, the Diving Supervisor should ensure that common sense and good seamanship prevail to safely resolve each emergency.

Emergency procedures are covered specifically for each equipment in its appropriate operations and maintenance manual and in general in Chapter 6. However, there are a number of situations a diver is likely to encounter in the normal range of activity which, if not promptly solved, can lead to full-scale emergencies. These situations and the appropriate action to be taken follow.

8-11.10.1 **Fouled Umbilical Lines.** As soon as a diver discovers that the umbilical has become fouled, the diver must stop and examine the situation. Pulling or tugging without a plan may only serve to complicate the problem and could lead to a severed hose. The Diving Supervisor is notified if possible (the fouling may prevent transmission of line-pull signals). If the lines are fouled on an obstruction, retracing steps should free them. If the lines cannot be cleared quickly and easily, the standby diver is sent down to assist. The standby diver is sent down as normal procedure, should communications be interrupted and the tender be unable to haul the diver up. The standby diver, using the first diver's umbilical (as a descent line), should be able to trace and release the lines. If it is impossible to free the first diver, the standby diver should signal for a replacement umbilical.

8-11.10.2 **Fouled Descent Lines.** If the diver becomes fouled with the descent line and cannot be easily cleared, it is necessary to haul the diver and the line to the surface, or to cut the weight free of the line and attempt to pull it free from topside. If the descent line is secured to an object or if the weight is too heavy, the diver may have to cut the line before being hauled up. For this reason, a diver should not descend on a line that cannot be cut.

WARNING **If job conditions call for using a steel cable or a chain as a descent line, the Diving Officer must approve such use.**

8-11.10.3 **Falling.** When working at mid-depth in the water column, the diver should keep a hand on the stage or rigging to avoid falling. The diver avoids putting an arm overhead in a dry suit; air leakage around the edges of the cuffs may change the suit buoyancy and increase the possibility of a fall in the water column.

8-11.10.4 **Damage to Helmet and Diving Dress.** If a leak occurs in the helmet, the diver's head is lowered and the air pressure slightly increased to prevent water leakage. A leak in the diving suit only requires remaining in an upright position; water in the suit does not directly endanger breathing.

8-11.11 **Tending the Diver.** Procedures for tending the diver follow.

1. Before the dive, the tender carefully checks the diving dress with particular attention to the nonreturn valve, air control valve, helmet locking device, intercom system, helmet seal and harness.

2. When the diver is ready, the tenders dress and assist the diver to the stage or ladder or waters edge, always keeping a hand on the umbilical.

3. The primary tender and a backup tender as required are always on station to assist the diver. As the diver enters the water, the tenders handle the umbilical, using care to avoid sharp edges. The umbilical must never be allowed to run free or be belayed around a cleat or set of bitts. Pay out of the umbilical is at a steady rate to permit the diver to descend smoothly. If a stage is being used, the descent rate is coordinated with the winch operator or line handlers.

4. Throughout the dive the tender keeps slack out of the line while not holding it too tautly. Two or three feet of slack permits the diver freedom of movement and prevents the diver from being pulled off the bottom by surging of the support craft or the force of current acting on the line. The tender occasionally checks the umbilical to ensure that movement by the diver has not resulted in excessive slack. Excessive slack makes signaling difficult, hinders the tender from catching the diver if falling and increases the possibility of fouling the umbilical.

5. The tender monitors the umbilical by feel and the descent line by sight for any line-pull signals from the diver. If an intercom is not being used, or if the diver is silent, the tender periodically verifies the diver's condition by line-pull signal. If the diver does not answer, the signal is repeated; if still not answered, the Diving Supervisor is notified. If communications are lost, the situation is treated as an emergency (see paragraph 6-12.5.3.2 for loss-of-communication procedures).

8-11.12 **Monitoring the Diver's Movements.** The Diving Supervisor and designated members of the dive team constantly monitor the diver's progress and keep track of his relative position.

- **Supervisor Actions**.

  1. Follow the bubble trail, while considering current(s). If the diver is searching the bottom, bubbles move in a regular pattern. If the diver is working in place, bubbles do not shift position. If the diver has fallen, the bubbles may move rapidly off in a straight line.

  2. Monitor the pneumofathometer pressure gauge to keep track of operating depth. If the diver remains at a constant depth or rises, the gauge provides

a direct reading, without the need to add air. If the diver descends, the hose must be cleared and a new reading made.

- **Tender Actions**. Feel the pull of the umbilical.
- **Additional Personnel Actions**. Monitor the gauges on the supply systems for any powered equipment. For example, the ammeter on an electric welding unit indicates a power drain when the arc is in use; the gas pressure gauges for a gas torch registers the flow of fuel. Additionally, the pop made by a gas torch being lighted will probably be audible over the intercom and bubbles from the torch will break on the surface, giving off small quantities of smoke.

8-12 ASCENT PROCEDURES

Follow these ascent procedures when it is time for the divers to return to the surface:

1. To prepare for a normal ascent, the diver clears the job site of tools and equipment. These can be returned to the surface by special messenger lines sent down the descent line. If the diver cannot find the descent line and needs a special line, this can be bent onto his umbilical and pulled down by the diver. The diver must be careful not to foul the line as it is laid down. The tender then pulls up the slack. This technique is useful in shallow water, but not practical in deep dives.
2. If possible, the diving stage is positioned on the bottom. If some malfunction such as fouling of the descent line prevents lowering the stage to the bottom, the stage should be positioned below the first decompression stop if possible. Readings from the pneumofathometer are the primary depth measurements.
3. If ascent is being made using the descent line or the stage has been positioned below the first decompression stop, the tender signals the diver “Standby to come up” when all tools and extra lines have been cleared away. The diver acknowledges the signal. The diver, however, does not pull up. The tender lifts the diver off the bottom when the diver signals “Ready to come up,” and the tender signals “Coming up. Report when you leave the bottom.” The diver so reports.
4. If, during the ascent, while using a descent line, the diver becomes too buoyant and rises too quickly, the diver checks the ascent by clamping his legs on the descent line.
5. The rate of ascent is a critical factor in decompressing the diver. Ascent must be carefully controlled at 30 feet per minute by the tender. The ascent is monitored with the pneumofathometer. As the diver reaches the stage and climbs aboard, topside is notified of arrival. The stage is then brought up to the first decompression stop. Refer to Chapter 9 for decompression procedures, including an explanation of the tables.

6. While ascending and during the decompression stops, the diver must be satisfied that no symptoms of physical problems have developed. If the diver feels any pain, dizziness, or numbness, the diver immediately notifies topside. During this often lengthy period of ascent, the diver also checks to ensure that his umbilical is not becoming fouled on the stage line, the descent line, or by any steadying weights hanging from the stage platform.

7. Upon arrival at the surface, topside personnel, timing the movement as dictated by any surface wave action, coordinate bringing the stage and umbilical up and over the side.

8. If the diver exits the water via the ladder, the tenders provide assistance. The diver will be tired, and a fall back into the water could result in serious injury. Under no conditions is any of the diver's gear to be removed before the diver is firmly on deck.

8-13 SURFACE DECOMPRESSION

8-13.1 Disadvantages of In-Water Decompression. Decompression in the water column is time consuming, uncomfortable, and inhibits the ability of the support vessel to get underway. Delay could also present other problems for the support vessel: weather, threatened enemy action or operating schedule constraints. In-water decompression delays medical treatment, when needed, and increases the possibility of severe chilling and accident. For these reasons, decompression is often accomplished in a recompression chamber on the support ship (Figure 8-12). Refer to Chapter 9 for surface decompression procedures.

Figure 8-12. Surface Decompression.

8-13.2 **Transferring a Diver to the Chamber.** When transferring a diver from the water to the chamber, the tenders are allowed no more than 3½ minutes to undress the diver. A tender or diving medical personnel, as required by the nature of the dive or the condition of the diver, must be in the chamber with any necessary supplies prior to arrival of the diver. The time factor is critical and delays cannot be tolerated. Undressing a diver for surface decompression should be practiced until a smooth, coordinated procedure is developed.

8-14 POSTDIVE PROCEDURES

Postdive procedures are planned in advance to ensure personnel are carefully examined for any possible injury or adverse effects and equipment is inspected, maintained and stowed in good order.

8-14.1 **Personnel and Reporting.** Immediate postdive activities include any required medical treatment for the diver and the recording of mandatory reports.

- Medical treatment is administered for cuts or abrasions. The general condition of the diver is monitored until problems are unlikely to develop. The Diving Supervisor resets the stopwatch after the diver reaches the surface and remains alert for irregularities in the diver’s actions or mental state. The diver must remain within 30 minutes’ travel time of the diving unit for at least 2 hours after surfacing.

- Mandatory records and reports are covered in Chapter 5. Certain information is logged as soon as the diving operations are completed, while other record keeping is scheduled when convenient. The Diving Supervisor is responsible for the diving log, which is kept as a running account of the dive. The diver is responsible for making appropriate entries in the personal diving record. Other personnel, as assigned, are responsible for maintaining equipment usage logs.

8-14.2 **Equipment.** A postdive checklist, tailored to the equipment used, is followed to ensure equipment receives proper maintenance prior to storage. Postdive maintenance procedures are contained in the equipment operation and maintenance manual and the planned maintenance system package.

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9-3.7 **Equivalent Single Dive Bottom Time.** The *equivalent single dive bottom time* is the time used to select a schedule for a single repetitive dive. This time is expressed in minutes.

9-3.8 **Unlimited/No-Decompression (No “D”) Limit.** The maximum time that can be spent at a given depth that safe ascent can be made directly to the surface at a prescribed travel rate with no decompression stops is the *unlimited/no-decompression* or *No “D” limit* (Table 9-6).

9-3.9 **Repetitive Dive.** A *repetitive dive is* any dive conducted within 12 hours of a previous dive.

9-3.10 **Repetitive Group Designation.** The *repetitive group designation* is a letter used to indicate the amount of residual nitrogen remaining in a diver’s body following a previous dive.

9-3.11 **Residual Nitrogen.** *Residual nitrogen* is the nitrogen gas still dissolved in a diver’s tissues after surfacing.

9-3.12 **Residual Nitrogen Time.** *Residual nitrogen time* is the time that must be added to the bottom time of a repetitive dive to compensate for the nitrogen still in solution in a diver’s tissues from a previous dive. Residual nitrogen time is expressed in minutes.

9-3.13 **Single Dive.** A *single dive* refers to any dive conducted more than 12 hours after a previous dive.

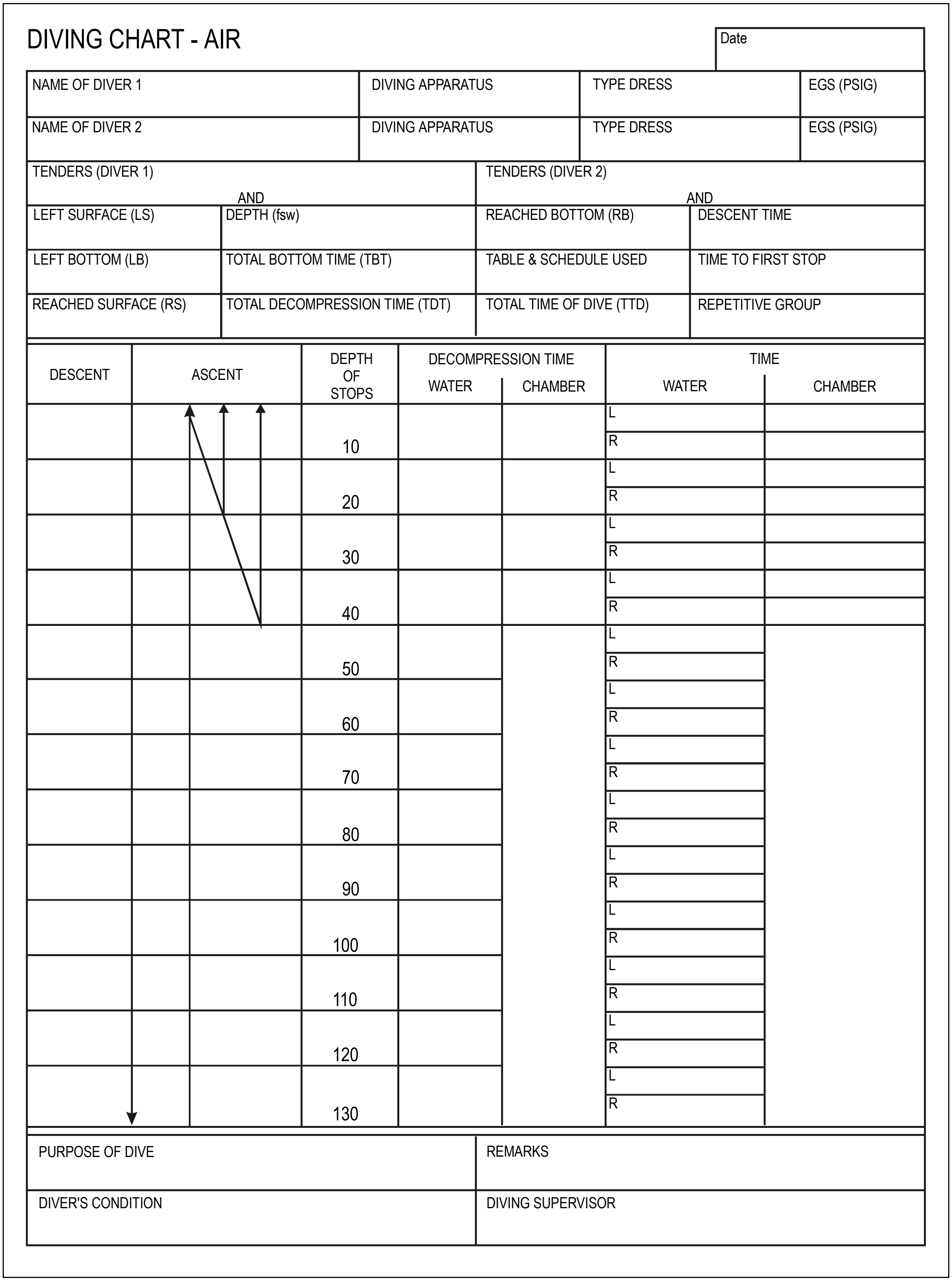
9-3.14 **Single Repetitive Dive.** A *single repetitive dive is* a dive for which the bottom time used to select the decompression schedule is the sum of the residual nitrogen time and the actual bottom time of the dive.

9-3.15 **Surface Interval.** The *surface interval is* the time a diver has spent on the surface following a dive. It begins as soon as the diver surfaces and ends as soon as he starts his next descent.

9-4 DIVE RECORDING

Chapter 5 provides information for maintaining a Command Diving Log and personal diving log and reporting individual dives to the Naval Safety Center. In addition to these records, every Navy air dive may be recorded on a diving chart similar to Figure 9-1. The diving chart is a convenient means of collecting the dive data, which in turn will be transcribed in the dive log. Diving Record abbreviations that may be used in the Command Diving Log are:

- LS - Left Surface
- RB - Reached Bottom
- LB - Left Bottom



DIVING CHART - AIR

Date

NAME OF DIVER 1	DIVING APPARATUS	TYPE DRESS	EGS (PSIG)
NAME OF DIVER 2	DIVING APPARATUS	TYPE DRESS	EGS (PSIG)
TENDERS (DIVER 1) AND		TENDERS (DIVER 2) AND	
LEFT SURFACE (LS)	DEPTH (fsw)	REACHED BOTTOM (RB)	DESCENT TIME
LEFT BOTTOM (LB)	TOTAL BOTTOM TIME (TBT)	TABLE & SCHEDULE USED	TIME TO FIRST STOP
REACHED SURFACE (RS)	TOTAL DECOMPRESSION TIME (TDT)	TOTAL TIME OF DIVE (TTD)	REPETITIVE GROUP

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
		10			L	
					R	
		20			L	
					R	
		30			L	
					R	
		40			L	
					R	
		50			L	
					R	
		60			L	
					R	
		70			L	
					R	
		80			L	
					R	
		90			L	
					R	
		100			L	
					R	
		110			L	
					R	
		120			L	
					R	
		130			L	
					R	

PURPOSE OF DIVE	REMARKS
DIVER'S CONDITION	DIVING SUPERVISOR

Figure 9-1. Air Diving Chart.

9-6.2.2 **Travel Rate Exceeded.** On a Standard Air Dive, if the rate of ascent is greater than 30 fpm, STOP THE ASCENT, allow the watches to catch up, and then continue ascent. If the stop is arrived at early, start the stop time after the watches catch up.

9-7 UNLIMITED/NO-DECOMPRESSION LIMITS AND REPETITIVE GROUP DESIGNATION TABLE FOR UNLIMITED/NO-DECOMPRESSION AIR DIVES

The Unlimited/No-Decompression Table (Table 9-6) serves three purposes. First, the table identifies that on a dive with the depth 20 fsw and shallower, unlimited bottom time may be achieved. Second, it summarizes all the depth and bottom time combinations for which no decompression is required. Third, it provides the repetitive group designation for each unlimited/no-decompression dive. Even though decompression is not required, there is still an amount of nitrogen remaining in the diver’s tissues for up to 12 hours following a dive. If they dive again within a 12-hour period, divers must consider this residual nitrogen when calculating decompression from the repetitive dive. Any dive deeper than 25 fsw that has a bottom time greater than the no-decompression limit given in this table is a decompression dive and must be conducted per the Standard Air Decompression Table.

Each depth listed in the Unlimited/No-Decompression Table has a corresponding no-decompression limit listed in minutes. This limit is the maximum bottom time that divers may spend at that depth without requiring decompression. Use the columns to the right of the no-decompression limits column to obtain the repetitive group designation. This designation must be assigned to a diver subsequent to every dive.

To find the repetitive group designation:

1. Enter the table at the depth equal to, or next greater than, the maximum depth of the dive.

2. Follow that row to the right to the bottom time equal to, or just greater than, the actual bottom time of the dive.

3. Follow the column up to the repetitive group designation.

9-7.1 **Example.** In planning a dive, the Dive Supervisor wants the divers to conduct a brief inspection of the work site, located at a depth of 152 fsw. Determine the maximum no-decompression limit and repetitive group designation.

9-7.2 **Solution.** The maximum bottom time that may be used without requiring decompression and the repetitive group designation after the dive can be found in either the Unlimited/No-Decompression Table or the Standard Air Decompression Table.

- **Using the Unlimited/No-Decompression Table**.

1. Locate the dive depth in the Depth column. Because there is no entry for 154 (152 +2) fsw, round the depth up to the next greater depth of 160 fsw.

2. Move vertically across the table to locate the no-decompression limit in the Unlimited/No-Decompression Limits column. The no-decompression limit is 5 minutes. To avoid having to make decompression stops, the divers must descend to 152 fsw, make the inspection and begin ascent within 5 minutes of leaving the surface.

3. To find the repetitive group designation, follow the 160-fsw entry to the right to the 5-minute bottom time entry and then follow it vertically to the top of the column. This shows the repetitive group designation to be D.

- **Using the Standard Air Decompression Table**.

1. Locate the schedule for the dive depth. Because there is no schedule for 154 (152 +2) fsw, round the depth up to the next greater depth of 160 fsw.

2. Follow the 5-minute bottom time row all the way horizontally to the right. There is a “0” listed in the decompression stops column and D is depicted in the Repetitive Group column.

Figure 9-5 is a diving chart for this dive.

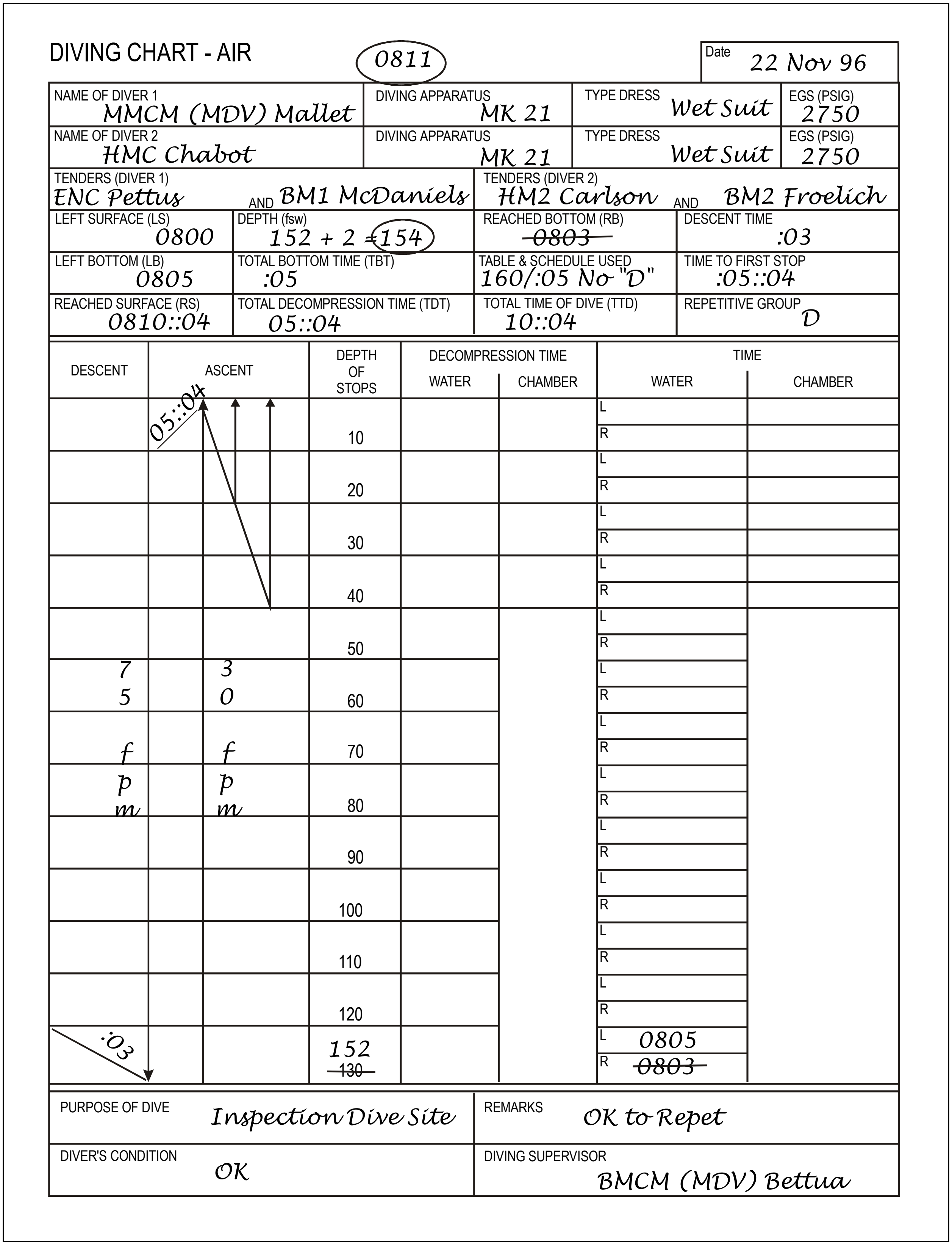
9-8 U.S. NAVY STANDARD AIR DECOMPRESSION TABLE

This manual combines the Standard Air Decompression Schedules and Exceptional Exposure Air Schedules into one table (see Table 9-5). To clearly distinguish between the standard (normal) and exceptional exposure decompression schedules, the exceptional exposure schedules have been separated by a bold line.

NOTE **The Commanding Officer must have CNO approval to conduct planned exceptional exposure dives.**

If the bottom time of a dive is less than the first bottom time listed for its depth, decompression is not required. The divers may ascend directly to the surface at a rate of 30 feet per minute (fpm). The repetitive group designation for a no-decompression dive is given in the Unlimited/No-Decompression Table. As noted in the Standard Air Decompression Table, there are no repetitive group designations for exceptional exposure dives. Repetitive dives are not permitted following an exceptional exposure dive.

9-8.1 **Example.** Divers complete a salvage dive to a depth of 140 fsw for 37 minutes. They were not unusually cold or fatigued during the dive. Determine the decompression schedule and the repetitive group designation at the end of the decompression.



DIVING CHART - AIR 0811

Date 22 Nov 96

NAME OF DIVER 1 MMCM (MDV) Mallet	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2750
NAME OF DIVER 2 HMC Chabot	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2750

TENDERS (DIVER 1) ENC Pettus AND BM1 McDaniels

TENDERS (DIVER 2) HM2 Carlson AND BM2 Froelich

LEFT SURFACE (LS) 0800	DEPTH (fsw) 152 + 2 = 154	REACHED BOTTOM (RB) ~~0803~~	DESCENT TIME :03
LEFT BOTTOM (LB) 0805	TOTAL BOTTOM TIME (TBT) :05	TABLE & SCHEDULE USED 160/:05 No "D"	TIME TO FIRST STOP :05::04
REACHED SURFACE (RS) 0810::04	TOTAL DECOMPRESSION TIME (TDT) 05::04	TOTAL TIME OF DIVE (TTD) 10::04	REPETITIVE GROUP D

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME WATER	DECOMPRESSION TIME CHAMBER	TIME WATER	TIME CHAMBER
	05::04	10			L R	
		20			L R	
		30			L R	
		40			L R	
		50			L R	
7 5	3 0	60			L R	
f p	f p	70			L R	
m	m	80			L R	
		90			L R	
		100			L R	
		110			L R	
		120			L R	
:03		152 ~~130~~			L 0805 R ~~0803~~	

PURPOSE OF DIVE Inspection Dive Site	REMARKS OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR BMCM (MDV) Bettua

Figure 9-5. Completed Air Diving Chart.

9-8.2 **Solution.** Select the equal or next deeper depth and the equal or next longer bottom time (140 + 2 = 142 fsw). This would be the 150/40 schedule, repetitive group designator N (see Figure 9-6).

9-9 REPETITIVE DIVES

During the 12-hour period after an air dive, the quantity of residual nitrogen in divers' bodies will gradually be reduced to its normal level. If the divers are to make a second dive within this period (repetitive dive), they must consider their residual nitrogen level when planning for the dive.

The procedures for conducting a repetitive dive are summarized in Figure 9-7. Upon completing the first dive, the divers are assigned a repetitive group designation from either the Standard Air Decompression Table or the Unlimited/No-Decompression Table. This designation relates directly to the residual nitrogen level upon surfacing. As nitrogen passes out of the diver's tissues and blood, their repetitive group designation changes. By using the Residual Nitrogen Timetable (Table 9-7), this designation may be determined at any time during the surface interval.

To determine the decompression schedule for a repetitive dive using either the unlimited/no-decompression, standard air, or surface decompression table:

1. Determine the residual nitrogen level just prior to leaving the surface of the of the repetitive dive (based on the repetitive dive depth), using the Residual Nitrogen Timetable. This level is expressed as residual nitrogen time, in minutes.

2. Add this time to the actual bottom time of the repetitive dive to get the Equivalent Single Dive Time (ESDT).

3. Conduct decompression from the repetitive dive using the max depth (MD) and the equivalent single dive time to select the appropriate decompression schedule. Avoid equivalent single dives requiring the use of Exceptional Exposure decompression schedules.

Always use a systematic Repetitive Dive Worksheet, shown in Figure 9-8, when determining the decompression schedule for a repetitive dive.

9-9.1 **Residual Nitrogen Timetable for Repetitive Air Dives.** The quantity of residual nitrogen in a diver's body immediately after a dive is expressed by the repetitive group designation assigned from either the Standard Air Decompression Schedule or the Unlimited/No-Decompression Table. The upper portion of the Residual Nitrogen Timetable is composed of various intervals between 10 minutes and 12 hours. These are expressed in hours and minutes (2:21 = 2 hours, 21 minutes). Each interval has a minimum time (top limit) and a maximum time (bottom limit).

REPETITIVE DIVE WORKSHEET

Date:

1st DIVE							
Max Depth							
Bottom Time							
Table & Schedule						**REPET Group**	
Surface Interval						**New Group**	
2nd DIVE							
Max Depth			**MD + ESDT = Table & Schedule**				
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		
Ensure the RNT Exception Rule does not apply							
Surface Interval						**New Group**	
3rd DIVE							
Max Depth			**MD + ESDT = Table & Schedule**				
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		
Ensure the RNT Exception Rule does not apply							
Surface Interval						**New Group**	
4th DIVE							
Max Depth			**MD + ESDT = Table & Schedule**				
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		
Ensure the RNT Exception Rule does not apply							
Surface Interval						**New Group**	

Figure 9-8. Repetitive Dive Worksheet.

Residual nitrogen times corresponding to the depth of the repetitive dive are given in the body of the lower portion of the table. To determine the residual nitrogen time for a repetitive dive:

1. Locate the diver's repetitive group designation from the previous dive along the diagonal line above the table.

2. Read horizontally to the interval where the diver's surface interval lies. The time spent on the surface must be between or equal to the limits of the selected interval.

3. Read vertically down to the new repetitive group designation. This corresponds to the present quantity of residual nitrogen in the diver's body.

4. Continue down in this same column to the row representing the depth of the repetitive dive. The time given at the intersection is the residual nitrogen time, in minutes, to be applied to the bottom time of the repetitive dive.

9-9.1.1 **Example.** A repetitive dive is planned to 98 fsw for an estimated bottom time of 15 minutes. The previous dive was to a depth of 100 (100+1=101) fsw with a bottom time of 48 minutes. The diver's surface interval is 6 hours 26 minutes (6:26). Determine the proper decompression schedule.

1. Use the 110/50 schedule of the Standard Air Decompression Table to find the residual nitrogen time of the previous dive. Read across the 50-minute bottom time row to find the repetitive group designator of M.

2. Move to the Residual Nitrogen Timetable for Repetitive Air Dives.

3. Enter the table on the diagonal line at M.

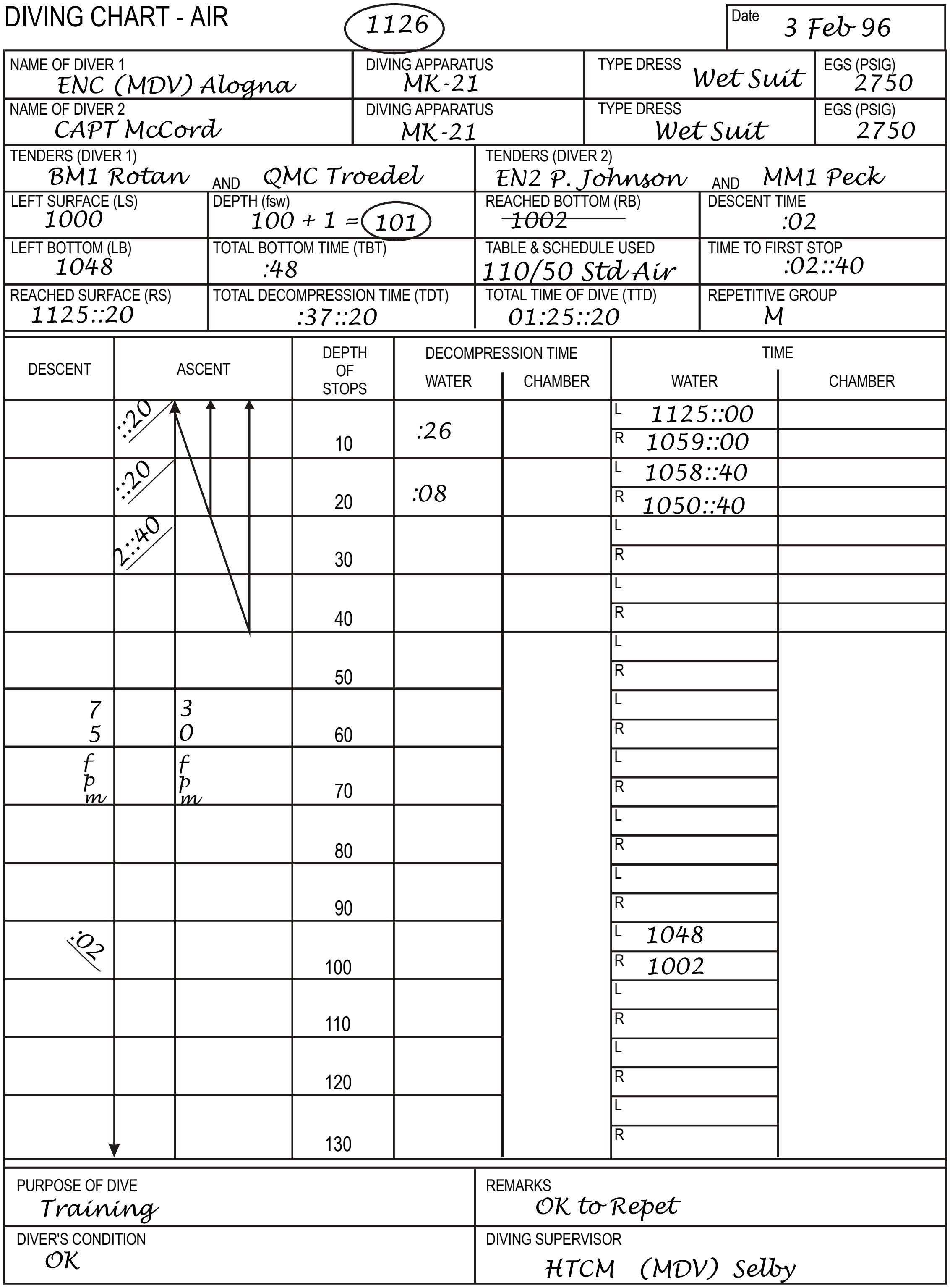
4. Read horizontally across the line until reaching the surface interval coinciding with the diver's surface interval of 6 hours 26 minutes. The diver's surface interval falls within the limits of the 6:19/9:28 column.

5. Read vertically down the 6:19/9:28 column until reaching the depth coinciding with the repetitive dive depth of 100 fsw to find the residual nitrogen time of 7 minutes.

6. Add the 7 minutes of residual nitrogen time to the estimated bottom time of 15 minutes to obtain the single equivalent dive time of 22 minutes.

7. The diver will be decompressed on the 100/22 No-Decompression schedule.

Figure 9-9 depicts the dive profile for the first dive, Figure 9-10 shows the Repetitive Dive Worksheet, and Figure 9-11 shows the dive profile for the repetitive dive.



DIVING CHART - AIR 1126

Date 3 Feb 96

NAME OF DIVER 1 ENC (MDV) Alogna	DIVING APPARATUS MK-21	TYPE DRESS Wet Suit	EGS (PSIG) 2750
NAME OF DIVER 2 CAPT McCord	DIVING APPARATUS MK-21	TYPE DRESS Wet Suit	EGS (PSIG) 2750

TENDERS (DIVER 1) BM1 Rotan AND QMC Troedel

TENDERS (DIVER 2) EN2 P. Johnson AND MM1 Peck

LEFT SURFACE (LS) 1000	DEPTH (fsw) 100 + 1 = 101	REACHED BOTTOM (RB) ~~1002~~	DESCENT TIME :02
LEFT BOTTOM (LB) 1048	TOTAL BOTTOM TIME (TBT) :48	TABLE & SCHEDULE USED 110/50 Std Air	TIME TO FIRST STOP :02::40
REACHED SURFACE (RS) 1125::20	TOTAL DECOMPRESSION TIME (TDT) :37::20	TOTAL TIME OF DIVE (TTD) 01:25::20	REPETITIVE GROUP M

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
	::20	10	:26		L 1125::00 R 1059::00	
	::20	20	:08		L 1058::40 R 1050::40	
	2::40	30			L R	
		40			L R	
		50			L R	
7 5	3 0	60			L R	
f p m	f p m	70			L R	
		80			L R	
		90			L R	
:02		100			L 1048 R 1002	
		110			L R	
		120			L R	
		130			L R	

PURPOSE OF DIVE Training	REMARKS OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR HTCM (MDV) Selby

Figure 9-9. Dive Profile.

REPETITIVE DIVE WORKSHEET

Date:
3 FEB 96

1st DIVE

Max Depth	100 + 1 = 100		
Bottom Time	:48		
Table & Schedule	110/50 Std Air	**REPET Group**	M
Surface Interval	6:26	**New Group**	B

2nd DIVE

Max Depth			**MD + ESDT = Table & Schedule**				
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
:15	**+**	:07	**=**	:22	**=**	100/22 No "D"	G

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

3rd DIVE

Max Depth			**MD + ESDT = Table & Schedule**				
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

4th DIVE

Max Depth			**MD + ESDT = Table & Schedule**				
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

Figure 9-10. Repetitive Dive Worksheet.

Once the divers are on the surface, the tenders have three and a half (:03:30) minutes to remove the breathing apparatus and diving dress and assist the divers into the recompression chamber.

Pressurizing the recompression chamber with air to 40 fsw should take approximately 30 seconds (descent rate not to exceed 80 fpm). The total elapsed time from when the divers leave the 30 foot stop (or 30 fsw if no water stops are required) to when they reach the 40 foot recompression chamber stop **must not exceed 5 minutes**. During descent in the recompression chamber, if a diver cannot clear and the chamber is at a depth of at least 20 fsw, stop, then breathe oxygen at 20 fsw for twice the 40 fsw chamber stop time. Ascend to 10 fsw and breathe oxygen again for twice the 40 fsw chamber stop time. Then ascend to the surface. This “safe way out” procedure is not intended to be used in place of normal Sur D O_2 procedures.

If the prescribed surface interval is exceeded and the divers are asymptomatic, treat them as if they have Type I decompression sickness (Treatment Table 5, Chapter 21). If the divers are symptomatic, they are treated as if they have Type II decompression sickness (Treatment Table 6, Chapter 21), even if they are only displaying Type I symptoms. Symptoms occurring during the chamber stops are treated as recurrences (Chapter 21).

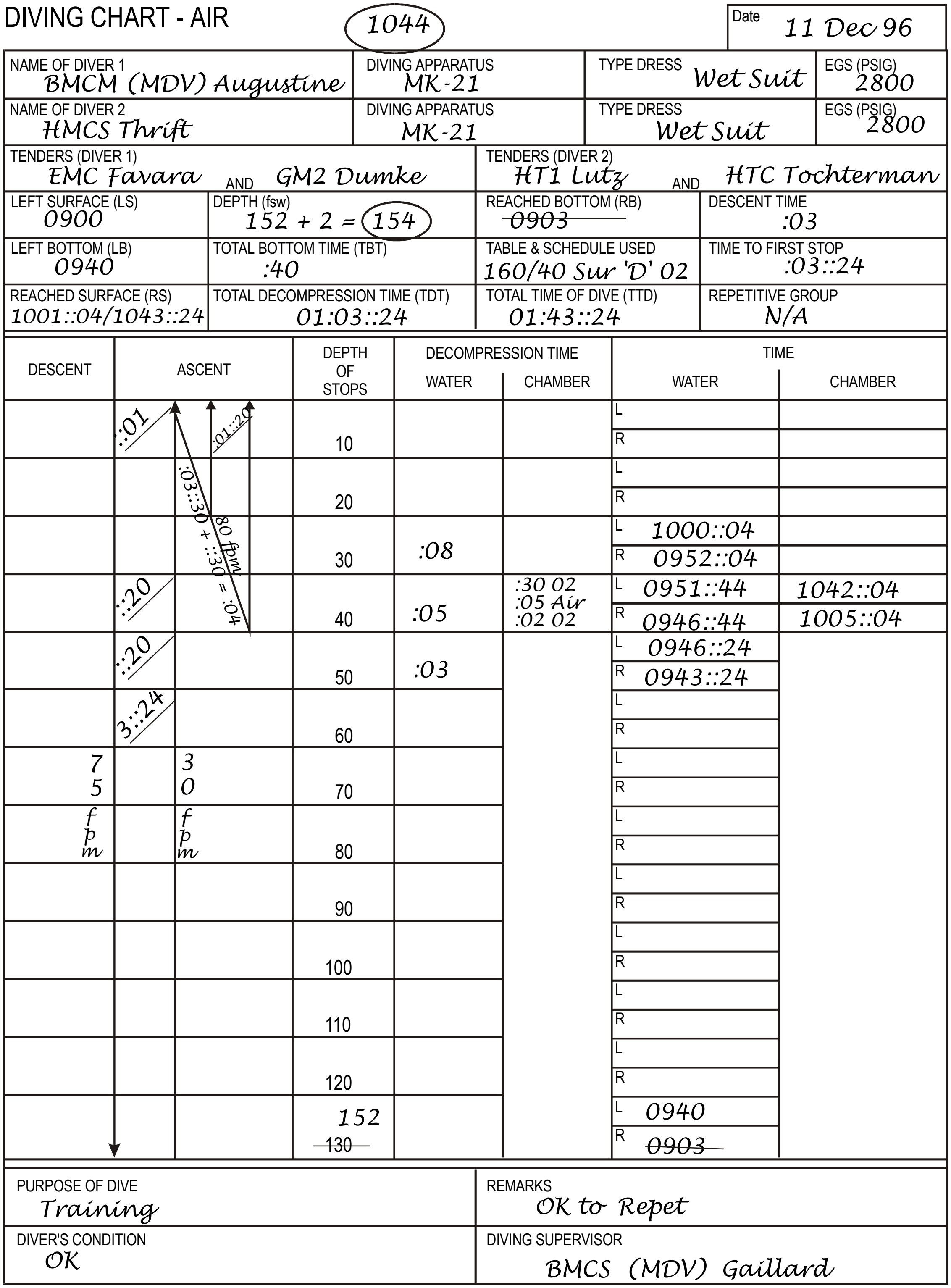
Upon arrival at 40 fsw in the recompression chamber, the divers are placed on the Built-in Breathing System (BIBS) mask breathing pure oxygen. The mask should be strapped on both divers to ensure a good oxygen seal. The designated 40 foot stop time commences once the divers are breathing oxygen. The divers breathe oxygen throughout the 40 foot stop, interrupting oxygen breathing after each 30 minutes with a 5 minute period of breathing chamber air (referred to as an “air break”). Count the air breaks as “dead time” and not part of the oxygen stop time. If the air break interval falls on time to travel, remove oxygen and commence traveling to the surface at 30 fpm. This procedure simplifies time keeping and should be used whenever using the Surface Decompression Table Using Oxygen. Remove the O_2 mask prior to leaving the 40 fsw stop for the surface.

9-10.1.1 **Example.** A dive is planned to approximately 160 fsw for 40 minutes. The dive is to be conducted using Sur D O_2 procedures. Figure 9-12 shows this dive profile.

In the event of oxygen system failure, it is important to be familiar with the appropriate air decompression schedules. If the oxygen system fails while the divers are in the water, the divers are shifted to the Standard Air Decompression Table or the Surface Decompression Table Using Air. During the chamber phase, use the procedures listed below in the event of oxygen system failure or CNS oxygen toxicity.

9-10.1.2 **Loss of Oxygen Supply in the Chamber (40 fsw Chamber Stop).** If the oxygen supply in the chamber is lost at the 40 fsw chamber stop, have the diver breathe chamber air.

- **Temporary Loss**. Return the diver to oxygen breathing. Consider any time on air as dead time.



DIVING CHART - AIR 1044

Date 11 Dec 96

NAME OF DIVER 1 BMCM (MDV) Augustine	DIVING APPARATUS MK-21	TYPE DRESS Wet Suit	EGS (PSIG) 2800
NAME OF DIVER 2 HMCS Thrift	DIVING APPARATUS MK-21	TYPE DRESS Wet Suit	EGS (PSIG) 2800
TENDERS (DIVER 1) EMC Favara AND GM2 Dumke		TENDERS (DIVER 2) HT1 Lutz AND HTC Tochterman	
LEFT SURFACE (LS) 0900	DEPTH (fsw) 152 + 2 = 154	REACHED BOTTOM (RB) ~~0903~~	DESCENT TIME :03
LEFT BOTTOM (LB) 0940	TOTAL BOTTOM TIME (TBT) :40	TABLE & SCHEDULE USED 160/40 Sur 'D' 02	TIME TO FIRST STOP :03::24
REACHED SURFACE (RS) 1001::04/1043::24	TOTAL DECOMPRESSION TIME (TDT) 01:03::24	TOTAL TIME OF DIVE (TTD) 01:43::24	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
	::01 :01::20	10			L R	
	:03::30 + ::30 = :04 80 fpm	20			L R	
		30	:08		L 1000::04 R 0952::04	
	::20	40	:05	:30 02 :05 Air :02 02	L 0951::44 R 0946::44	1042::04 1005::04
	::20	50	:03		L 0946::24 R 0943::24	
	3::24	60			L R	
75	30	70			L R	
fpm	fpm	80			L R	
		90			L R	
		100			L R	
		110			L R	
		120			L R	
		152 ~~130~~			L 0940 R ~~0903~~	

PURPOSE OF DIVE Training	REMARKS OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR BMCS (MDV) Gaillard

Figure 9-12. Dive Profile.

- **Permanent Loss**. Multiply the remaining oxygen time by three to obtain the equivalent chamber decompression time on air. If 50% helium 50% oxygen or 50% nitrogen 50% oxygen is available, multiply the remaining oxygen time by two to obtain the equivalent chamber decompression time on 50/50. Allocate 10% of the equivalent air or 50/50 time to the 40-fsw stop, 20% to the 30 fsw stop, and 70% to the 20 fsw stop. Round the stop times up to the next whole minute. Surface upon completion of the 20 fsw stop.

Example. The oxygen supply to the chamber is lost at 10 minutes and 50/50 is not available. The original surface decompression using oxygen schedule called for a 20-min. oxygen stop.

Solution. The remaining oxygen time is 10 minutes (20-10). The equivalent chamber decompression time on air is 30 minutes (3 x 10). The 30 minutes of air stop time should be allocated as follows: Three minutes at 40 fsw (30 x 0.1), 6 minutes at 30 fsw (30 x 0.2), and 21 minutes at 20 fsw (30 x 0.7).

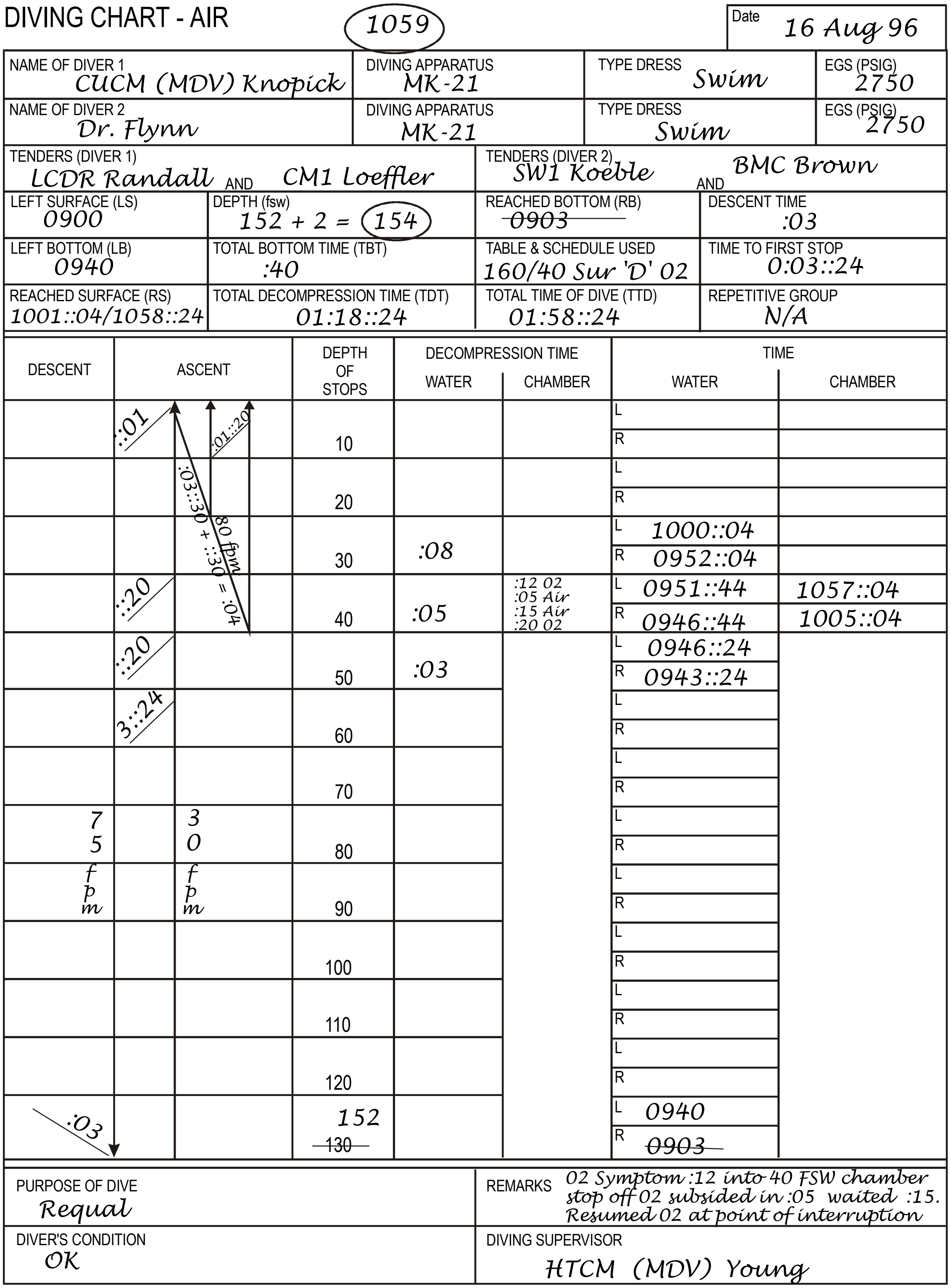
9-10.1.3 **CNS Oxygen Toxicity (40 fsw Chamber Stop).** At the first sign of CNS toxicity, the patient should be removed from oxygen and allowed to breathe chamber air. Fifteen minutes after all symptoms have completely subsided, resume oxygen breathing at the point of interruption. If symptoms of CNS oxygen toxicity develop again or if the first symptom is a convulsion, take the following action:

1. Remove the mask.
2. After all symptoms have completely subsided, decompress 10 feet at a rate of 1 fsw/min. For a convulsion, begin travel when the patient is fully relaxed and breathing normally.
3. Resume oxygen breathing at the shallower depth at the point of interruption.
4. If another oxygen symptom occurs, complete decompression time on air. Multiply the remaining oxygen time by three to obtain the equivalent chamber decompression time on air. Allocate 30% of the equivalent air to the 30 fsw stop and 70% to the 20 fsw stop. Surface upon completion of the 20 fsw stop.

9-10.1.3.1 ***Example.*** The diver has a third oxygen symptom after completing 28 minutes of the required decompression. The diver is at 30 fsw based on the second oxygen symptom protocol. The original surface decompression using oxygen schedule called for a 38 min. oxygen stop.

9-10.1.3.2 ***Solution.*** The remaining oxygen time is 10 minutes (38-28). The equivalent chamber decompression time on air is 30 minutes (3 x 10). The 30 minutes of air stop time should be allocated as follows: Three minutes at 30 fsw (30 x 0.3) and seven minutes at 20 fsw (30 x 0.7).

9-10.1.4 **Repetitive Dives.** There are no repetitive diving tables or surface interval tables for surface decompression dives. If another surface decompression dive using



DIVING CHART - AIR (1059)

Date 16 Aug 96

NAME OF DIVER 1 CUCM (MDV) Knopick	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2750
NAME OF DIVER 2 Dr. Flynn	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2750

TENDERS (DIVER 1) LCDR Randall AND CM1 Loeffler	TENDERS (DIVER 2) SW1 Koeble AND BMC Brown

LEFT SURFACE (LS) 0900	DEPTH (fsw) 152 + 2 = (154)	REACHED BOTTOM (RB) ~~0903~~	DESCENT TIME :03
LEFT BOTTOM (LB) 0940	TOTAL BOTTOM TIME (TBT) :40	TABLE & SCHEDULE USED 160/40 Sur 'D' 02	TIME TO FIRST STOP 0:03::24
REACHED SURFACE (RS) 1001::04/1058::24	TOTAL DECOMPRESSION TIME (TDT) 01:18::24	TOTAL TIME OF DIVE (TTD) 01:58::24	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME		
			WATER	CHAMBER		WATER	CHAMBER
	::01 :01::20	10			L R		
		20			L R		
	:03::30 + ::30 = :04 80 fpm	30	:08		L R	1000::04 0952::04	
	::20	40	:05	:12 02 :05 Air :15 Air :20 02	L R	0951::44 0946::44	1057::04 1005::04
	::20	50	:03		L R	0946::24 0943::24	
	3::24	60			L R		
		70			L R		
7 5	3 0	80			L R		
f p m	f p m	90			L R		
		100			L R		
		110			L R		
		120			L R		
:03		152 ~~130~~			L R	0940 ~~0903~~	

PURPOSE OF DIVE Requal	REMARKS 02 Symptom :12 into 40 FSW chamber stop off 02 subsided in :05 waited :15. Resumed 02 at point of interruption
DIVER'S CONDITION OK	DIVING SUPERVISOR HTCM (MDV) Young

Figure 9-13. Dive Profile.

oxygen is planned within a 12-hour period, select the appropriate decompression schedule by:

1. Adding the bottom times of all dives made in the previous 12 hours to get an adjusted bottom time, and

2. Using the maximum depth obtained in the previous 12 hours.

3. The equivalent single dive shall not exceed 170/40 for Sur D O_2 or 190/60 for Sur D Air.

9-10.1.4.1 ***Example.*** A dive is conducted to 165 fsw for 25 minutes, followed by a surface interval of 3 hours 42 minutes, and a repetitive dive to 133 fsw for 15 minutes. The Surface Decompression Table Using Oxygen is used for both dives. Determine the correct decompression schedules.

9-10.1.4.2 ***Solution.*** The correct decompression schedule is 170/25 for the first dive and 170/40 for the second dive. Even though the second dive was to a maximum depth of 138 fsw for 15 minutes, the divers must be decompressed for the maximum depth attained in the previous 12 hours, which was 170 fsw, and a total of all bottom times, which was 40 minutes. Figure 9-14, Figure 9-15, and Figure 9-16 chart this example.

Even if the second dive is to be a Standard Air dive, combine all bottom times in the previous 12 hours to get an adjusted bottom time and decompression schedule from the maximum depth attained in the previous 12 hours.

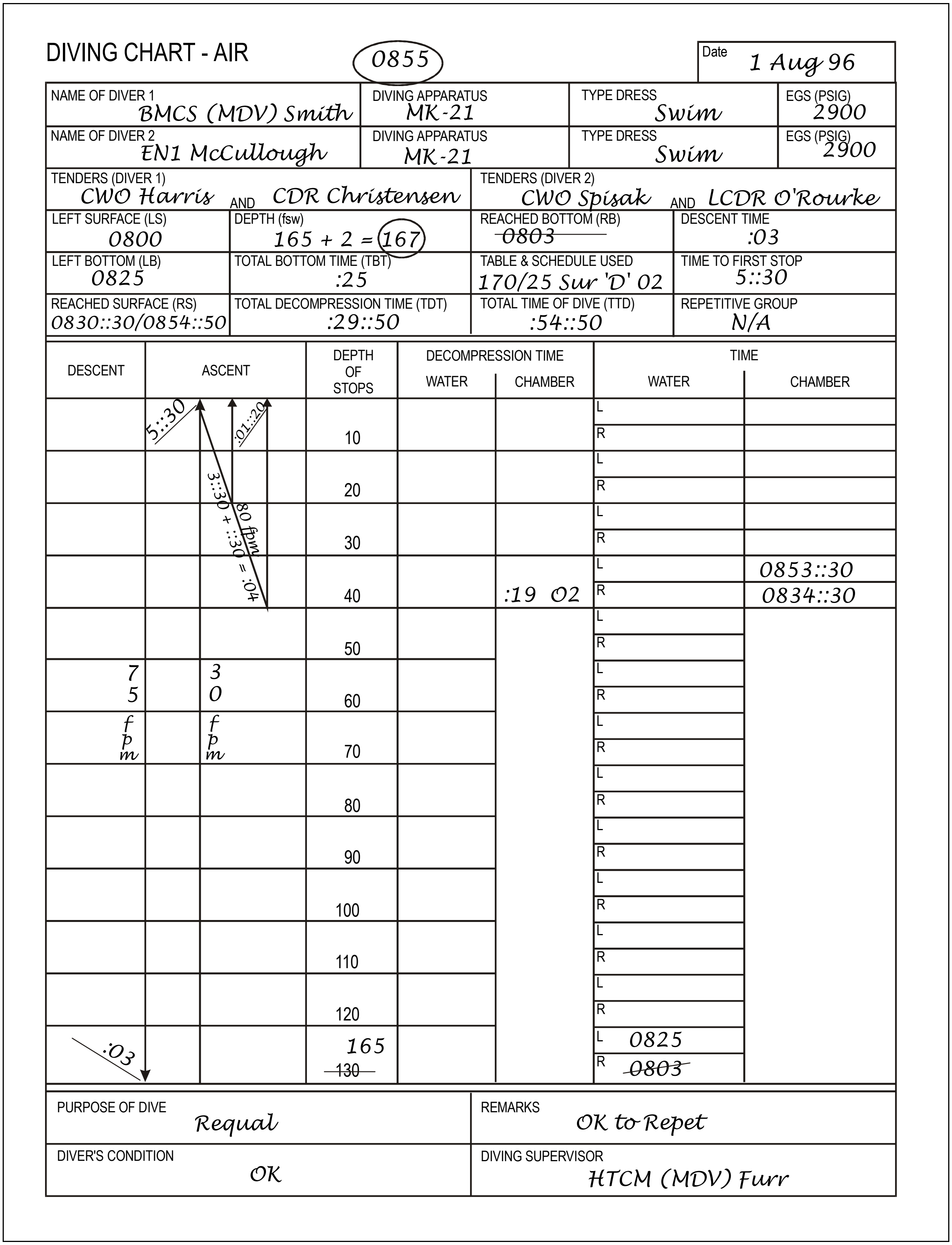
9-10.2 Surface Decompression Table Using Air.

The Surface Decompression Table Using Air (referred to as Sur D Air) should be used for surface decompression following an air dive when a recompression chamber without an oxygen breathing system is all that is available.

The total ascent times of the Surface Decompression Table Using Air exceed those of the Standard Air Decompression Table; the only advantages surface decompression using air are getting the divers out of the water sooner and maintaining the divers in a controlled, closely observed environment during decompression.

When using the Sur D Air table, all ascents are made at 30 fpm. This includes the ascent rate from the last water stop. The time spent on the surface should not exceed 3½ minutes and the rate of descent to the first recompression chamber stop should not exceed 60 fpm. The total elapsed time for these three procedures must not exceed 5 minutes.

If the prescribed surface interval is exceeded and the divers are asymptomatic, they are treated as if they had Type I Decompression Sickness (Treatment Table 5 or 1A, Chapter 21). If the divers are symptomatic, they are treated as if they had Type II Decompression Sickness (Treatment Table 6 or 2A, Chapter 21), even if



DIVING CHART - AIR 0855

Date 1 Aug 96

NAME OF DIVER 1 BMCS (MDV) Smith	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2900
NAME OF DIVER 2 EN1 McCullough	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2900

TENDERS (DIVER 1) CWO Harris AND CDR Christensen

TENDERS (DIVER 2) CWO Spisak AND LCDR O'Rourke

LEFT SURFACE (LS) 0800	DEPTH (fsw) 165 + 2 = 167	REACHED BOTTOM (RB) ~~0803~~	DESCENT TIME :03
LEFT BOTTOM (LB) 0825	TOTAL BOTTOM TIME (TBT) :25	TABLE & SCHEDULE USED 170/25 Sur 'D' 02	TIME TO FIRST STOP 5::30
REACHED SURFACE (RS) 0830::30/0854::50	TOTAL DECOMPRESSION TIME (TDT) :29::50	TOTAL TIME OF DIVE (TTD) :54::50	REPETITIVE GROUP N/A

DESCENT	ASCENT		DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
				WATER	CHAMBER	WATER	CHAMBER
	5::30	:01::20	10			L	
						R	
	3::30 + ::30 = :04	80 fpm	20			L	
						R	
			30			L	
						R	
			40		:19 O2	L	0853::30
						R	0834::30
			50			L	
						R	
7 5		3 0	60			L	
						R	
f p m		f p m	70			L	
						R	
			80			L	
						R	
			90			L	
						R	
			100			L	
						R	
			110			L	
						R	
			120			L	
						R	
:03			165 ~~130~~			L 0825	
						R ~~0803~~	

PURPOSE OF DIVE Requal	REMARKS OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR HTCM (MDV) Furr

Figure 9-14. Dive Profile.

REPETITIVE DIVE WORKSHEET

Date: 1 Aug 96

1st DIVE

Max Depth	165 + 2 = 167		
Bottom Time	:25		
Table & Schedule	170/25 Sur "D" O2	**REPET Group**	N/A
Surface Interval		**New Group**	N/A

2nd DIVE

Max Depth		**MD + ESDT = Table & Schedule**					
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
:15	+	:25	=	:40	=	170/14 Sur "D" O2	N/A

Ensure the RNT Exception Rule does not apply (diver "maxed out" on Sur "D"O2)

Surface Interval		**New Group**	

3rd DIVE

Max Depth		**MD + ESDT = Table & Schedule**					
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		=		=		

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

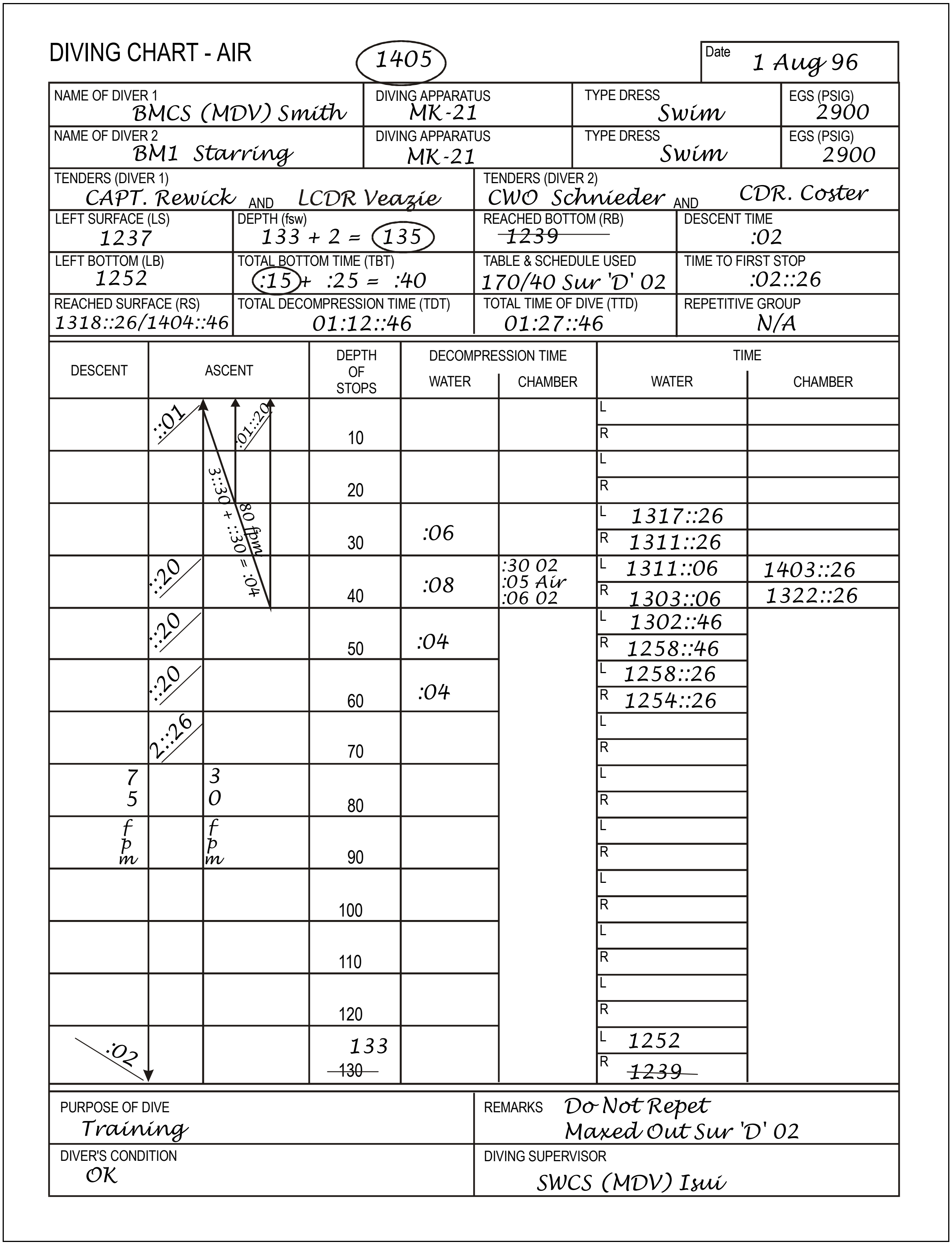
4th DIVE

Max Depth		**MD + ESDT = Table & Schedule**					
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		=		=		

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

Figure 9-15. Repetitive Dive Worksheet.



DIVING CHART - AIR 1405

Date 1 Aug 96

NAME OF DIVER 1 BMCS (MDV) Smith	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2900
NAME OF DIVER 2 BM1 Starring	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2900

TENDERS (DIVER 1) CAPT. Rewick AND LCDR Veazie

TENDERS (DIVER 2) CWO Schnieder AND CDR. Coster

LEFT SURFACE (LS) 1237	DEPTH (fsw) 133 + 2 = 135	REACHED BOTTOM (RB) ~~1239~~	DESCENT TIME :02
LEFT BOTTOM (LB) 1252	TOTAL BOTTOM TIME (TBT) :15 + :25 = :40	TABLE & SCHEDULE USED 170/40 Sur 'D' 02	TIME TO FIRST STOP :02::26
REACHED SURFACE (RS) 1318::26/1404::46	TOTAL DECOMPRESSION TIME (TDT) 01:12::46	TOTAL TIME OF DIVE (TTD) 01:27::46	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME		
			WATER	CHAMBER		WATER	CHAMBER
	::01 :01::20	10			L		
					R		
		20			L		
					R		
	3::30 + ::30 = :04 80 fpm	30	:06		L	1317::26	
					R	1311::26	
	::20	40	:08	:30 02 :05 Air :06 02	L	1311::06	1403::26
					R	1303::06	1322::26
	::20	50	:04		L	1302::46	
					R	1258::46	
	::20	60	:04		L	1258::26	
					R	1254::26	
	2::26	70			L		
					R		
7 5	3 0	80			L		
					R		
f p m	f p m	90			L		
					R		
		100			L		
					R		
		110			L		
					R		
		120			L		
					R		
:02		133 ~~130~~			L	1252	
					R	~~1239~~	

PURPOSE OF DIVE Training	REMARKS Do Not Repet Maxed Out Sur 'D' 02
DIVER'S CONDITION OK	DIVING SUPERVISOR SWCS (MDV) Isui

Figure 9-16. Dive Profile.

they are only displaying Type I symptoms. Symptoms occurring during the chamber stops are treated as recurrences (Chapter 21).

9-10.2.1 **Example.** A dive is conducted to 123 fsw for 48 minutes using the Surface Decompression Table Using Air. Determine the correct decompression schedule.

9-10.2.2 **Solution.** The correct decompression schedule for a dive conducted to 123 fsw for 48 minutes is the 130/50 schedule. The decompression chart is shown in Figure 9-17.

9-10.2.3 **Repetitive Dives.** If a second surface decompression air dive is planned within a 12-hour period, the same rule applies as for making a second Sur D O_2 dive (paragraph 9-10.1.4).

9-10.2.3.1 ***Example.*** A repetitive Sur D Air dive is planned for 138 fsw for 20 minutes. The previous dive was to 167 fsw for 30 minutes. The surface interval was 4 hours 27 minutes. Determine the correct decompression schedules.

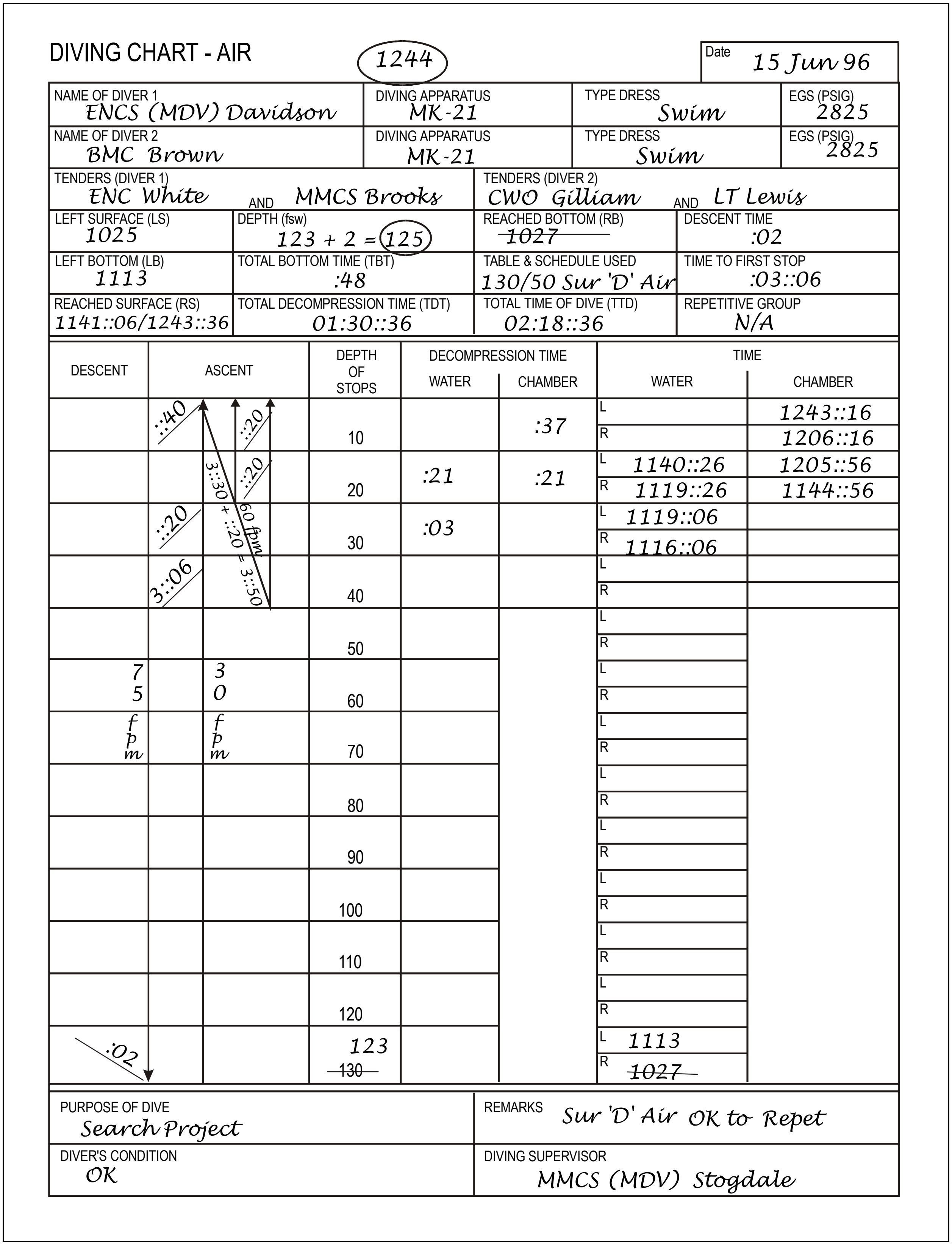
9-10.2.3.2 ***Solution.*** The correct schedule for the first dive is 180/30. The correct schedule for the second dive is 180/50. As explained in the Sur D O_2 procedure, the correct procedure is to decompress the divers on a schedule for the maximum depth attained and the total of bottom times of all dives made in the previous 12 hours. Figure 9-18 illustrate the first dive, the repetitive dive worksheet is shown in Figure 9-19 and the repetitive dive for the example above is shown in Figure 9-20.

9-11 EXCEPTIONAL EXPOSURE DIVES

Exceptional exposure dives are those dives in which the risk of decompression sickness, oxygen toxicity, and/or exposure to the elements is substantially greater than on normal working dives. Decompression schedules for exceptional exposure dives are contained in the Standard Air Decompression Table. These exceptional exposure schedules are intended to be used only in emergencies, such as diver entrapment. Exceptional exposure dives should not be planned in advance except under the most unusual operational circumstances. The Commanding Officer must carefully assess the need for planned exceptional exposure diving and prior CNO approval for such diving is required. Selected exceptional exposure dives have been proven safe in controlled conditions and are authorized at the Naval Diving and Salvage Training Center during certain phases of diver training.

9-11.1 Surface Decompression Procedures for Exceptional Exposure Dives.

The long decompressions times associated with exceptional exposure dives impose unusual demands on a diver’s endurance. There is also limited assurance that the dive will be completed without decompression sickness. These two risks can be reduced by using surface decompression techniques rather than completing decompression entirely in the water.



DIVING CHART - AIR 1244

Date 15 Jun 96

NAME OF DIVER 1 ENCS (MDV) Davidson	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2825
NAME OF DIVER 2 BMC Brown	DIVING APPARATUS MK-21	TYPE DRESS Swim	EGS (PSIG) 2825

TENDERS (DIVER 1) ENC White AND MMCS Brooks

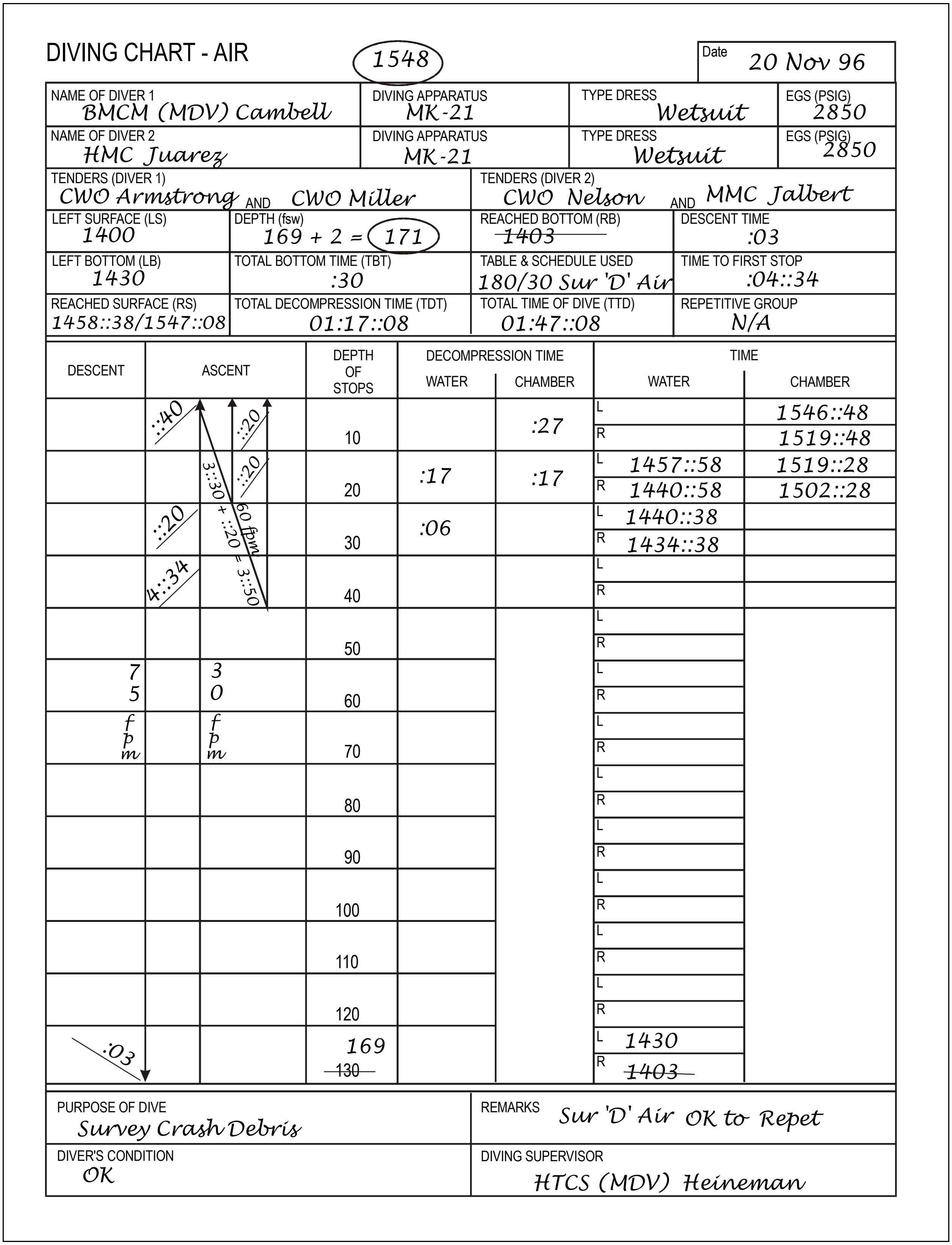
TENDERS (DIVER 2) CWO Gilliam AND LT Lewis

LEFT SURFACE (LS) 1025	DEPTH (fsw) 123 + 2 = 125	REACHED BOTTOM (RB) ~~1027~~	DESCENT TIME :02
LEFT BOTTOM (LB) 1113	TOTAL BOTTOM TIME (TBT) :48	TABLE & SCHEDULE USED 130/50 Sur 'D' Air	TIME TO FIRST STOP :03::06
REACHED SURFACE (RS) 1141::06/1243::36	TOTAL DECOMPRESSION TIME (TDT) 01:30::36	TOTAL TIME OF DIVE (TTD) 02:18::36	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME WATER	DECOMPRESSION TIME CHAMBER	TIME WATER	TIME CHAMBER
	::40 ::20	10		:37	L	1243::16
					R	1206::16
	::20 3::30 + ::20 = 3::50	20	:21	:21	L 1140::26	1205::56
					R 1119::26	1144::56
	::20 60 fpm	30	:03		L 1119::06	
					R 1116::06	
	3::06	40			L	
					R	
		50			L	
					R	
75	30	60			L	
					R	
fpm	fpm	70			L	
					R	
		80			L	
					R	
		90			L	
					R	
		100			L	
					R	
		110			L	
					R	
		120			L	
					R	
:02		123 ~~130~~			L 1113	
					R ~~1027~~	

PURPOSE OF DIVE Search Project	REMARKS Sur 'D' Air OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR MMCS (MDV) Stogdale

Figure 9-17. Dive Profile.



DIVING CHART - AIR 1548

Date 20 Nov 96

NAME OF DIVER 1 BMCM (MDV) Cambell | DIVING APPARATUS MK-21 | TYPE DRESS Wetsuit | EGS (PSIG) 2850

NAME OF DIVER 2 HMC Juarez | DIVING APPARATUS MK-21 | TYPE DRESS Wetsuit | EGS (PSIG) 2850

TENDERS (DIVER 1) CWO Armstrong AND CWO Miller | TENDERS (DIVER 2) CWO Nelson AND MMC Jalbert

LEFT SURFACE (LS) 1400 | DEPTH (fsw) 169 + 2 = 171 | REACHED BOTTOM (RB) ~~1403~~ | DESCENT TIME :03

LEFT BOTTOM (LB) 1430 | TOTAL BOTTOM TIME (TBT) :30 | TABLE & SCHEDULE USED 180/30 Sur 'D' Air | TIME TO FIRST STOP :04::34

REACHED SURFACE (RS) 1458::38/1547::08 | TOTAL DECOMPRESSION TIME (TDT) 01:17::08 | TOTAL TIME OF DIVE (TTD) 01:47::08 | REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME		
			WATER	CHAMBER		WATER	CHAMBER
	::40 ::20	10		:27	L		1546::48
					R		1519::48
	::20 3::30 + ::20 = 3::50 60 fpm	20	:17	:17	L	1457::58	1519::28
					R	1440::58	1502::28
	::20	30	:06		L	1440::38	
					R	1434::38	
	4::34	40			L		
					R		
		50			L		
					R		
7 5	3 0	60			L		
					R		
f p m	f p m	70			L		
					R		
		80			L		
					R		
		90			L		
					R		
		100			L		
					R		
		110			L		
					R		
		120			L		
					R		
:03		169 ~~130~~			L	1430	
					R	~~1403~~	

PURPOSE OF DIVE Survey Crash Debris | REMARKS Sur 'D' Air OK to Repet

DIVER'S CONDITION OK | DIVING SUPERVISOR HTCS (MDV) Heineman

Figure 9-18. Dive Profile.

REPETITIVE DIVE WORKSHEET

Date:
20 Nov 96

1st DIVE

Max Depth	169 + 2 = 171		
Bottom Time	:30		
Table & Schedule	180/30 Sur “D” Air	**REPET Group**	N/A
Surface Interval	4:27	**New Group**	N/A

2nd DIVE

Max Depth		**MD + ESDT = Table & Schedule**					
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
:20	**+**	:30	**=**	:50	**=**	180/50 Sur “D” Air	N/A

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

3rd DIVE

Max Depth		**MD + ESDT = Table & Schedule**					
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

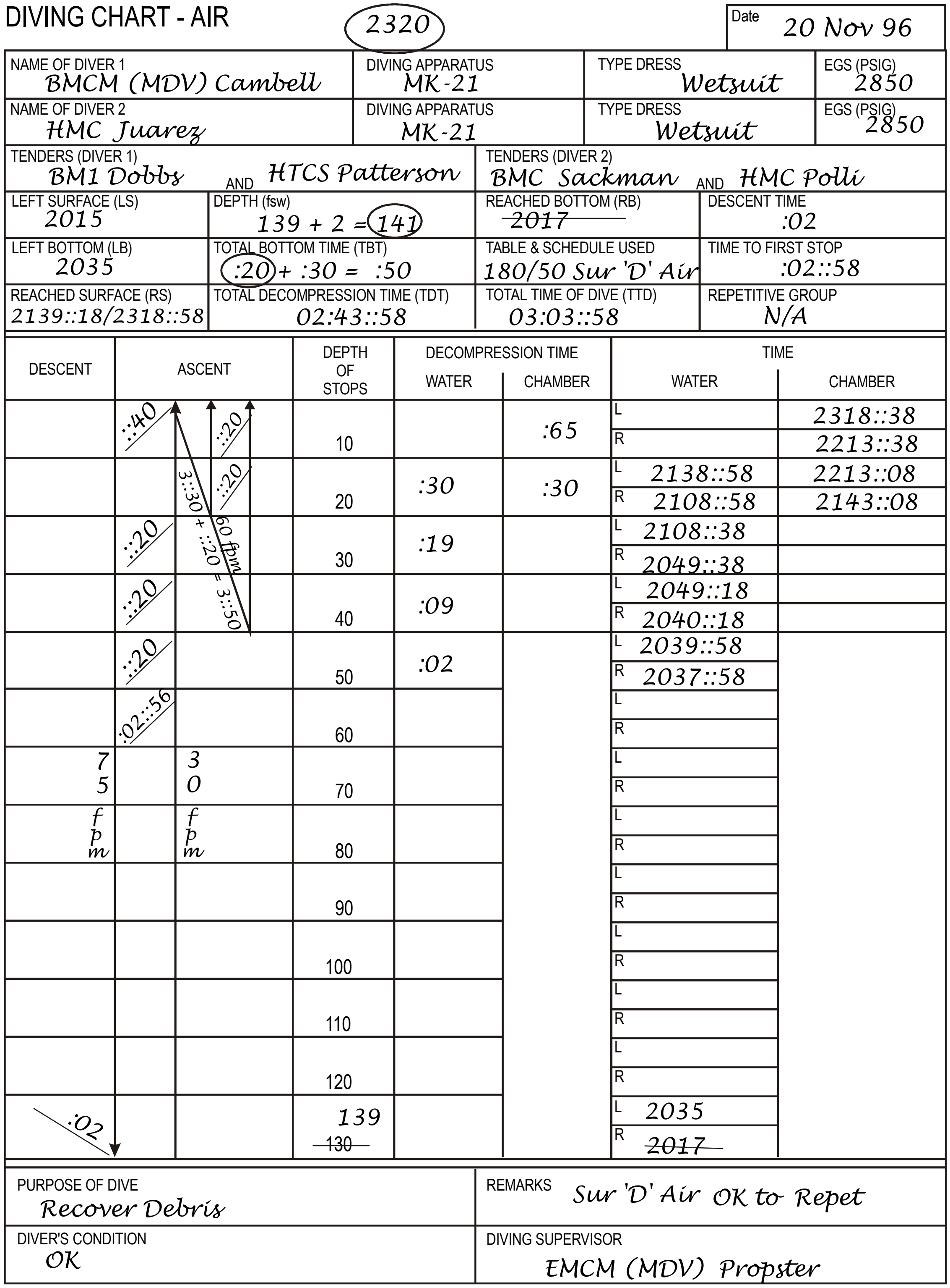
4th DIVE

Max Depth		**MD + ESDT = Table & Schedule**					
Bottom Time	**+**	**RNT**	**=**	**ESDT**	**=**	**Table & Schedule**	**REPET Group**
	+		**=**		**=**		

Ensure the RNT Exception Rule does not apply

Surface Interval		**New Group**	

Figure 9-19. Repetitive Dive Worksheet.



DIVING CHART - AIR 2320

Date 20 Nov 96

NAME OF DIVER 1 BMCM (MDV) Cambell	DIVING APPARATUS MK-21	TYPE DRESS Wetsuit	EGS (PSIG) 2850
NAME OF DIVER 2 HMC Juarez	DIVING APPARATUS MK-21	TYPE DRESS Wetsuit	EGS (PSIG) 2850

TENDERS (DIVER 1) BM1 Dobbs AND HTCS Patterson	TENDERS (DIVER 2) BMC Sackman AND HMC Polli

LEFT SURFACE (LS) 2015	DEPTH (fsw) 139 + 2 = 141	REACHED BOTTOM (RB) ~~2017~~	DESCENT TIME :02
LEFT BOTTOM (LB) 2035	TOTAL BOTTOM TIME (TBT) :20 + :30 = :50	TABLE & SCHEDULE USED 180/50 Sur 'D' Air	TIME TO FIRST STOP :02::58
REACHED SURFACE (RS) 2139::18/2318::58	TOTAL DECOMPRESSION TIME (TDT) 02:43::58	TOTAL TIME OF DIVE (TTD) 03:03::58	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
	::40 ::20	10		:65	L R	2318::38 2213::38
	3::30 ::20	20	:30	:30	L 2138::58 R 2108::58	2213::08 2143::08
	::20 + ::20 60 fpm	30	:19		L 2108::38 R 2049::38	
	::20 = 3::50	40	:09		L 2049::18 R 2040::18	
	::20	50	:02		L 2039::58 R 2037::58	
	:02::56	60			L R	
75	30	70			L R	
fpm	fpm	80			L R	
		90			L R	
		100			L R	
		110			L R	
		120			L R	
:02		139 ~~130~~			L 2035 R ~~2017~~	

PURPOSE OF DIVE Recover Debris	REMARKS Sur 'D' Air OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR EMCM (MDV) Propster

Figure 9-20. Dive Profile.

9-11.1.1 **If oxygen is available at the 30 fsw stop in the water:**

1. Complete the entire 30 fsw in water stop on oxygen, interrupting oxygen breathing after each 30 minutes with a 5 minute air break. The air breaks count as part of the stop time.
2. Ascend to the surface at 30 fpm. Minor variations in the rate of travel between 20 and 40 fpm are acceptable.
3. Once on the surface, the tenders have three and a half (:03:30) minutes to remove the breathing apparatus and diving dress and assist the divers into the recompression chamber.
4. Pressurize the recompression chamber with air to 30 fsw at a travel rate of 60 fpm.
5. Upon arrival at 30 fsw in the recompression chamber, the divers are placed on the Built-in Breathing System (BIBS) mask breathing 100% oxygen.
6. The 30 foot stop time commences once the divers are breathing oxygen. Repeat the 30 fsw in-water stop time.
7. The divers breathe oxygen throughout the 30-foot stop, interrupting oxygen breathing after each 30 minutes with a 5 minute air break. The air breaks count as part of the stop time.
8. Ascend to 20 fsw at 30 fpm. Complete the 20 fsw in-water stop time. The divers breathe oxygen throughout the 20-foot stop, interrupting oxygen breathing after each 30 minutes with a 5 minute air break. The air breaks count as part of the stop time.
9. Ascend to 10 fsw at 30 fpm. Complete the 10 fsw in-water stop time. The divers breathe oxygen throughout the 10-foot stop, interrupting oxygen breathing after each 30 minutes with a 5 minute air break. The air breaks count as part of the stop time.
10. Ascent to the surface at 30 fpm.

9-11.1.2 **If no oxygen is available at the 30 fsw stop in the water:**

1. Complete the entire 20 fsw in the water.
2. Ascend to the surface at 30 fpm. Minor variations in the rate of travel between 20 and 40 fpm are acceptable.
3. Once on the surface, the tenders have three and a half (:03:30) minutes to remove the breathing apparatus and diving dress and assist the divers into the recompression chamber.

4. Pressurize the recompression chamber with air to 20 fsw at a travel rate of 60 fpm.

5. Upon arrival at 20 fsw in the recompression chamber, the divers are placed on the Built-in Breathing System (BIBS) mask breathing 100% oxygen.

6. The 20 foot stop time commences once the divers are breathing oxygen. Repeat the 20 fsw in-water stop time.

7. The divers breathe oxygen throughout the 20-foot stop, interrupting oxygen breathing after each 30 minutes with a 5 minute air break. The air breaks count as part of the stop time.

8. Ascend to 10 fsw at 30 fpm. Complete the 10 fsw in-water stop time. The divers breathe oxygen throughout the 10-foot stop, interrupting oxygen breathing after each 30 minutes with a 5 minute air break. The air breaks count as part of the stop time.

9. Ascent to the surface at 30 fpm.

9-11.2 **Oxygen System Failure (Chamber Stop).** If the oxygen systems fails during a chamber stop, complete the remaining decompression time on air.

9-12 DIVING AT HIGH ALTITUDES

Because of the reduced atmospheric pressure, dives conducted at altitude require more decompression than identical dives conducted at sea level. Standard air decompression tables, therefore, cannot be used as written. Some organizations calculate specific decompression tables for use at each altitude. An alternative approach is to correct the altitude dive to obtain an equivalent sea level dive, then determine the decompression requirement using standard tables. This procedure is commonly known as the "Cross Correction" technique and always yields a sea level dive that is deeper than the actual dive at altitude. A deeper sea level equivalent dive provides the extra decompression needed to offset effects of diving at altitude.

9-12.1 **Altitude Correction Procedure.** To apply the “Cross Correction” technique, two corrections must be made for altitude diving. First, the actual dive depth must be corrected to determine the sea level equivalent depth. Second, the decompression stops in the sea level equivalent depth table must be corrected for use at altitude. Strictly speaking, ascent rate should also be corrected, but this third correction can safely be ignored.

9-12.1.1 **Correction of Depth of Dive.** Depth of a sea level equivalent dive is determined by multiplying the depth of the dive at altitude by a ratio of atmospheric pressure at sea level to atmospheric pressure at altitude. Using millibars (mb) as a unit for expressing atmospheric pressure at altitude equivalent depth is then:

$$\text{Equivalent Depth (fsw)} = \text{Altitude Depth (fsw)} \times \frac{\text{Pressure at Sea Level (mb)}}{\text{Pressure at Altitude (mb)}}$$

Example: A diver makes a dive to 60 fsw at an altitude of 5000 ft. The atmospheric pressure measured at 5000 ft is 843 millibars (0.832 ATA). Atmospheric pressure at sea level is assumed to be 1013 millibars (1.000 ATA). Sea level equivalent depth is then:

$$\text{Equivalent Depth (fsw)} = 60\text{ fsw} \times \frac{1013\text{ mb}}{843\text{ mb}} = 72.1\text{ fsw}$$

9-12.1.2 **Correction for Decompression Stop Depths.** Depth of the corrected stop at altitude is calculated by multiplying depth of a sea level equivalent stop by a ratio of atmospheric pressure at altitude to atmospheric pressure at sea level. [Note: this ratio is inverse to the ratio in the formula above.

$$\text{Altitude Stop Depth (fsw)} = \text{Sea Level Stop Depth (fsw)} \times \frac{\text{Pressure at Altitude (mb)}}{\text{Pressure at Sea Level (mb)}}$$

Example: A diver makes a dive at an altitude of 5000 ft. An equivalent sea level dive requires a decompression stop at 20 fsw. Stop depth used at altitude is then:

$$\text{Altitude Stop Depth (fsw)} = 20\text{ fsw} \times \frac{843\text{ mb}}{1013\text{ mb}} = 16.6\text{ fsw}$$

To simplify calculations, Table 9-3 gives corrected sea level equivalent depths and equivalent stops depths for dives from 10-190 ft and for altitudes from 1,000 to 10,000 ft in 1000 ft increments.

WARNING Table 9-3 **cannot be used with constant ppO$_2$ diving equipment, such as the MK 16.**

9-12.2 **Need for Correction.** No correction is required for dives conducted at altitudes between sea level and 300 ft. The additional risk associated with these dives is minimal. At altitudes between 300 and 1000 feet, correction is required for dives

Table 9-3. *Sea Level Equivalent Depth (fsw).*

Actual Depth	Altitude (feet)									
(fsw)	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
10	10	15	15	15	15	15	15	15	15	15
15	15	20	20	20	20	20	20	25	25	25
20	20	25	25	25	25	25	30	30	30	30
25	25	30	30	30	35	35	35	35	35	40
30	30	35	35	35	40	40	40	50	50	50
35	35	40	40	50	50	50	50	50	50	60
40	40	50	50	50	50	50	60	60	60	60
45	45	50	60	60	60	60	60	70	70	70
50	50	60	60	60	70	70	70	70	70	80
55	55	60	70	70	70	70	80	80	80	80
60	60	70	70	70	80	80	80	90	90	90
65	65	70	80	80	80	90	90	90	100	100
70	70	80	80	90	90	90	100	100	100	110
75	75	90	90	90	100	100	100	110	110	110
80	80	90	90	100	100	100	110	110	120	120
85	85	100	100	100	110	110	120	120	120	130
90	90	100	110	110	110	120	120	130	130	140
95	95	110	110	110	120	120	130	130	140	140
100	100	110	120	120	130	130	130	140	140	150
105	105	120	120	130	130	140	140	150	150	160
110	110	120	130	130	140	140	150	150	160	160
115	115	130	130	140	140	150	150	160	170	170
120	120	130	140	140	150	150	160	170	170	180
125	125	140	140	150	160	160	170	170	180	190
130	130	140	150	160	160	170	170	180	190	190
135	135	150	160	160	170	170	180	190	190	200
140	140	160	160	170	170	180	190	190	200	210
145	145	160	170	170	180	190	190	200	210	
150	160	170	170	180	190	190	200	210		
155	170	170	180	180	190	200	210			
160	170	180	180	190	200	200				
165	180	180	190	200	200					
170	180	190	190	200						
175	190	190	200							
180	190	200	210							
185	200	200								
190	200									
Table Water Stops	**Equivalent Stop Depths (fsw)**									
10	10	9	9	9	8	8	8	7	7	7
20	19	19	18	17	17	16	15	15	14	14
30	29	28	27	26	25	24	23	22	21	21
40	39	37	36	35	33	32	31	30	29	28
50	48	47	45	43	42	40	39	37	36	34
60	58	56	54	52	50	48	46	45	43	41

Note: ━━ = Exceptional Exposure Limit

deeper than 145 fsw (actual depth). At altitudes above 1000 ft., correction is required for all dives.

9-12.3 **Depth Measurement at Altitude.** The preferred method for measuring depth at altitude is a mechanical or electronic gauge that can be re-zeroed at the dive site. Once re-zeroed, no further correction of the reading is required.

When using a recompression chamber for decompression, zero the chamber depth gauges before conducting surface decompression.

Most mechanical depth gauges carried by divers have a sealed one atmosphere reference and cannot be adjusted for altitude, thus they will read low throughout a dive at altitude. A correction factor of 1 fsw for every 1000 ft of altitude should be added to the reading of a sealed reference gauge before entering Table 9-3.

Pneumofathometers can be used at altitude. Add the pneumofathometer correction factor (Table 9-1) to the depth reading before entering Table 9-3. The pneumofathometer correction factors are unchanged at altitude.

A sounding line or fathometer may be used to measure the depth if a suitable depth gauge is not available. These devices measure the linear distance below the surface of the water, not the water pressure. Though fresh water is less dense than sea water, all dives will be assumed to be conducted in sea water, thus no corrections will be made based on water salinity. Enter Table 9-3 directly with the depth indicated on the line or fathometer.

9-12.4 **Equilibration at Altitude.** Upon ascent to altitude, two things happen. The body off-gases excess nitrogen to come into equilibrium with the lower partial pressure of nitrogen in the atmosphere. It also begins a series of complicated adjustments to the lower partial pressure of oxygen. The first process is called equilibration; the second is called acclimatization. Twelve hours at altitude is required for equilibration. A longer period is required for full acclimatization.

If a diver begins a dive at altitude within 12 hours of arrival, the residual nitrogen left over from sea level must be taken into account. In effect, the initial dive at altitude can be considered a repetitive dive, with the first dive being the ascent from sea level to altitude. Table 9-4 gives the repetitive group associated with an initial ascent to altitude. Using this group and the time at altitude before diving, enter the Residual Nitrogen Timetable for Repetitive Air Dives (Table 9-7) to determine a new repetitive group designator associated with that period of equilibration. Determine sea level equivalent depth for your planned dive using Table 9-3. From your new repetitive group and sea level equivalent depth, determine the residual nitrogen time associated with the dive. Add this time to the actual bottom time of the dive.

Example: A diver ascends rapidly to 6000 feet in a helicopter and begins a dive to 100 fsw 90 minutes later. How much residual nitrogen time should be added to the dive?

From Table 9-4, repetitive group upon arrival at 6000 feet is Group E. During 90 minutes at altitude, the diver will desaturate to Group D. From Table 9-3, sea level equivalent depth for a 100 fsw dive is 130 fsw. From Table 9-7, residual nitrogen time for a 130 fsw dive in Group D is 11 minutes. The diver should add 11 minutes to bottom time.

Table 9-4 can also be used when a diver who is fully equilibrated at one altitude ascends to and dives at a higher altitude. Enter Table 9-4 with the difference between the two altitudes to determine an initial repetitive group.

Example: Divers equilibrated at a base camp altitude of 6000 feet, fly by helicopter to the dive site at 10,000 feet. The difference between the altitudes is 4000 feet. From Table 9-4, the initial repetitive group to be used at 10,000 feet is Group C.

WARNING **Altitudes above 10,000 feet can impose serious stress on the body resulting in significant medical problems while the acclimatization process takes place. Ascents to these altitudes must be slow to allow acclimatization to occur and prophylactic drugs may be required. These exposures should always be planned in consultation with a Diving Medical Officer. Commands conducting diving operations above 10,000 feet may obtain the appropriate decompression procedures from NAVSEA 00C.**

Table 9-4. *Repetitive Groups Associated with Initial Ascent to Altitude.*

Altitude (feet)	Repetitive Group
1000	A
2000	B
3000	B
4000	C
5000	D
6000	E
7000	E
8000	F
9000	G
10000	H

9-12.5 **Diving At Altitude Worksheet.** Figure 9-21 is a worksheet for altitude diving. To determine Sea Level Equivalent Depth (SLED) and corrected decompression stops for an altitude dive, follow these steps:

9-12.5.1 **Corrections for Depth of Dive at Altitude and In-Water Stops.**

DIVING AT ALTITUDE WORKSHEET

DATE

Actual Dive Site Altitude ________ feet

1. Altitude from Table 9-3. ________ feet

2. Actual Depth of Dive (corrected per section 9-12.3) ________ fsw

3. Sea Level Equivalent Depth from Table 9-3 ________ SLED

4. Repetitive Group from Table 9-4 ________

5. Time at Altitude ________ hrs ________ min

6. New Repetitive Group Designation from Table 9-7 ________

7. Residual Nitrogen Time ________ min

8. Planned Bottom Time + ________ min

9. Equivalent Single Dive Time = ________ min

10. Decompression Table

☐ Standard Air Table
☐ Surface Table Using Oxygen
☐ Unlimited/No-Decompression Table
☐ Surface Table Using Air

11. Table/Schedule ____/____

12. Decompression Schedule

Sea Level Stop Depth	Altitude Stop Depth	Stop Time (Water/Chamber)
10 fsw	________ fsw	____/____ min
20 fsw	________ fsw	____/____ min
30 fsw	________ fsw	____/____ min
40 fsw	________ fsw	____/____ min*
50 fsw	________ fsw	________ min
60 fsw	________ fsw	________ min

13. Repetitive Group Letter Designation ________

*Chamber stop on SUR D O_2 will be at 40 fsw.

Figure 9-21. Worksheet for Diving at Altitude.

Line 1. Determine dive site altitude by referring to a map. From Table 9-3, enter the altitude in feet that is equal to, or next greater than the altitude at the dive site.

Line 2. Enter the actual depth of the dive in feet of seawater.

NOTE **Refer to paragraph 9-12.3 to correct divers' depth gauge readings to actual depths at altitude.**

Line 3. Read Table 9-3 vertically down the Actual Depth column. Select a depth that is equal to or next greater than the actual depth. Reading horizontally, select the Sea Level Equivalent Depth corresponding to an altitude equal or next greater than that of your dive site.

9-12.5.2 Corrections for Equilibration.

Line 4. Enter the Repetitive Group upon arrival at altitude from Table 9-4 for the altitude listed on Line 1.

Line 5. Record time in hours and minutes spent equilibrating at altitude prior to the dive. If time at altitude is greater than 12 hours, proceed to step 7 and enter zero.

Line 6. Using Table 9-7, determine the Repetitive Group at the end of the predive equilibration interval.

Line 7. Using Table 9-7, determine the Residual Nitrogen Time for the new repetitive group designation from line 6 and the Sea Level Equivalent Depth from line 3.

Line 8. Enter the planned bottom time.

Line 9. Add the bottom time and the residual nitrogen time to obtain the equivalent Single Dive Time.

Line 10. Select the Decompression Table to be used.

Line 11. Enter the Schedule from the Decompression Table using the Sea Level Equivalent Depth from line 3 and equivalent Single Dive Time from line 9.

Line 12. Using the lower section of Table 9-3, read down the Table Water Stops column on the left to the decompression stop(s) given in the Sea Level Equivalent Depth Table/Schedule. Read horizontally to the altitude column. Record the corresponding altitude stop depths on the worksheet.

NOTE **For surface decompression dives on oxygen, the chamber stops are not adjusted for altitude. Enter the same depths as at sea level. Keeping chamber stop depths the same as sea level provides an extra decom-**

pression benefit for the diver on oxygen. For surface decompression on air, stops must be adjusted. (See the example below and Figure 9-22.)

Line 13. Record the Repetitive Group Designator at the end of the dive.

NOTE **Follow all decompression table procedures for ascent and descent**

Example: Five hours after arriving at an altitude of 7750 feet, divers make a 60 min air dive to a gauge depth of 75 fsw. Depth is measured with a pneumofathometer having a non-adjustable gauge with a fixed reference pressure of one atmosphere. The Surface Decompression Table Using Oxygen will be used for decompression. What is the proper decompression schedule?

The altitude is first rounded up to 8000 feet. A depth correction of +8 fsw must be added to the maximum depth recorded on the fixed reference gauge. A pneumofathometer correction factor of + 1 fsw must also be added. The divers' actual depth is 84 fsw. Table 9-3 is entered at an actual depth of 85 fsw. The Sea Level Equivalent Depth for 8000 feet of altitude is 120 fsw. The repetitive group upon arrival at altitude is Group F. This decays to Group B during the five hours at altitude pre-dive. The residual nitrogen time for Group B at 120 fsw is 6 minutes. The Equivalent Single Dive Time therefore is 66 minutes. The appropriate decompression schedule from the Surface Decompression Table Using Oxygen is 120 fsw for 70 minutes. By the schedule, a 4-minute stop at 30 fsw in the water and a 39-minute stop at 40 fsw in the chamber are required. The water stop is taken at a depth of 22 fsw. The chamber stop is taken at a depth of 40 fsw.

Figure 9-22 shows the filled-out Diving at Altitude Worksheet for this dive. Figure 9-23 shows the filled-out Diving Chart.

9-12.6 **Repetitive Dives.** Repetitive dives may be conducted at altitude. The procedure is identical to that a sea level, with the exception that the sea level equivalent dive depth is always used to replace the actual dive depth. Figure 9-24 (on page 9-48) is a Repetitive Dive at Altitude Worksheet.

Example: Fourteen hours after ascending to an altitude of 7750 feet, divers make a 82 fsw 60 min MK 21 dive using the Standard Air Table. Depth is measured with a pneumofathometer having a depth gauge adjustable for altitude. After two hours and 10 min on the surface, they make a second dive to 79 fsw for 30 min and decompress on the Surface Decompression Table Using Oxygen. What is the proper decompression schedule for the second dive?

The altitude is first rounded up to 8000 feet. For the first dive, a depth correction of +1 fsw must be added to the 82 fsw pneumofathometer reading. The divers actual depth on the first dive is 83 fsw. Table 9-3 is entered at an actual depth of 85 fsw. The Sea Level Equivalent Depth for the first dive is 120 fsw. The repetitive group designation upon completion of the 60 min dive is Group O. This decays to Group H during the 2 hour 10 min surface interval.

The actual depth of the second dive is 80 fsw (79 fsw plus a 1 fsw pneumofathometer correction). Table 9-3 is entered at an actual depth of 80 fsw. The Sea Level

Equivalent Depth for the second dive is 110 fsw. The residual nitrogen time for Group H at 110 fsw is 27 min. The equivalent single dive time therefore is 57 min. The appropriate decompression schedule from the Surface Decompression Table Using Oxygen is 110 fsw for 60 min. A 26 min stop at 40 fsw in the chamber is required by the schedule. This stop is taken at a chamber depth of 40 fsw.

Figure 9-25 shows the filled-out Repetitive Dive at Altitude Worksheet for these two dives. Figure 9-26 and Figure 9-28 shows the filled out Diving Charts for the first and second dives.

9-13 ASCENT TO ALTITUDE AFTER DIVING/FLYING AFTER DIVING.

Leaving the dive site may require temporary ascent to a higher altitude. For example, divers may drive over a mountain pass at higher altitude or leave the dive site by air. Ascent to altitude after diving increases the risk of decompression sickness because of the additional reduction in atmospheric pressure. The higher the altitude, the greater the risk. (Pressurized commercial airline flights are addressed in Note 3 of Table 9-5.)

Table 9-5 gives the surface interval (hours:minutes) required before making a further ascent to altitude. The surface interval depends on the planned increase in altitude and the highest repetitive group designator obtained in the previous 24-hour period. Enter the table with the highest repetitive group designator obtained in the previous 24-hour period. Read the required surface interval from the column for the planned change in altitude.

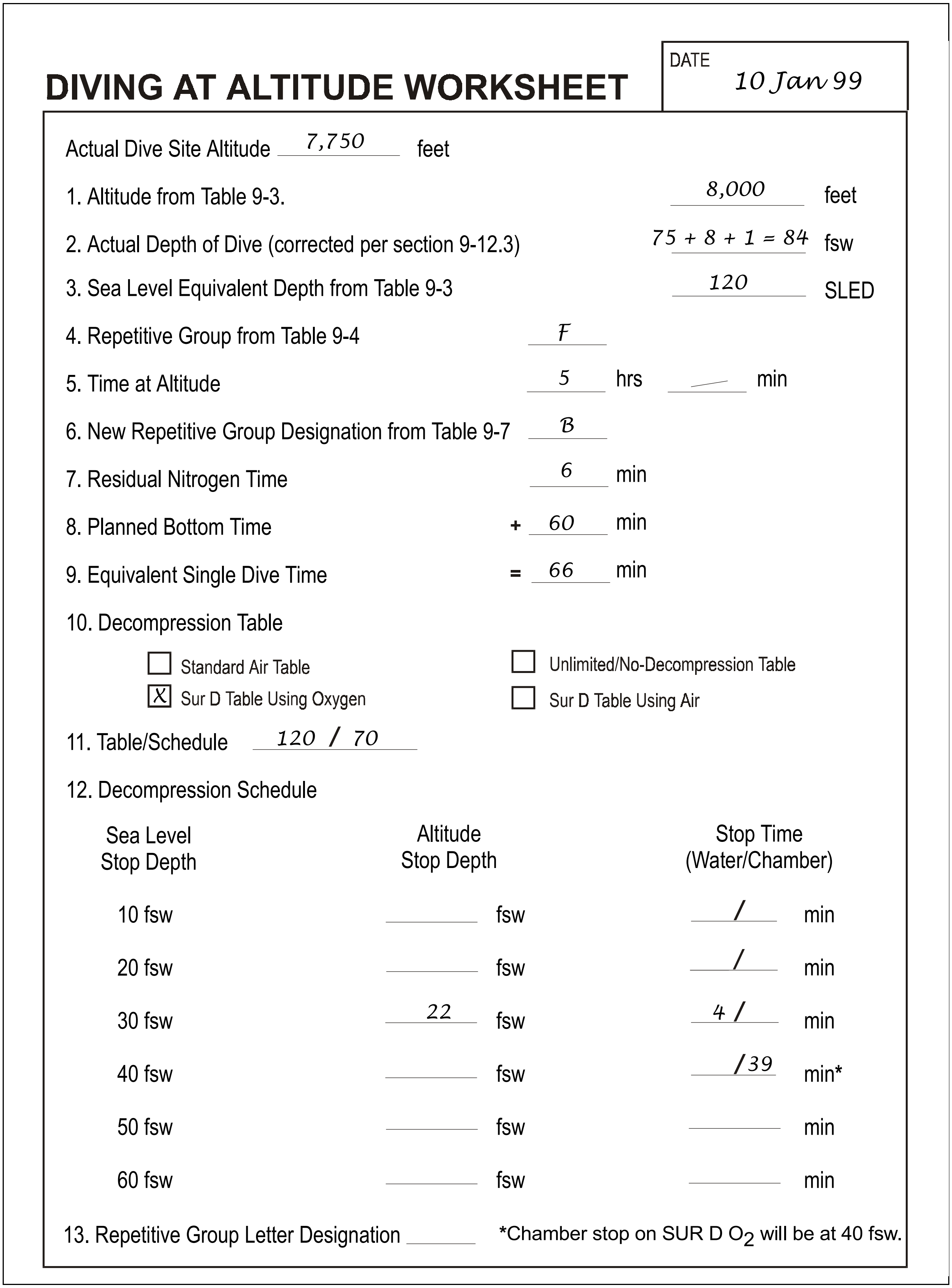
Example: A diver surfaces from a 60 fsw for 60 minutes no-decompression dive at sea level in Repetitive Group J. After a surface interval of 6 hours 10 minutes, the diver makes a second dive to 30 fsw for 20 minutes placing him in Repetitive Group C. He plans to fly home in a commercial aircraft in which the cabin pressure is controlled at 8000 feet. What is the required surface interval before flying?

The planned increase in altitude is 8000 feet. Because the diver has made two dives in the previous 24-hour period, you must use the highest Repetitive Group Designator of the two dives. Enter Table 9-5 at 8000 feet and read down to Repetitive Group J. The diver must wait 17 hours and 35 minutes after completion of the second dive before flying.

Example: Upon completion of a dive at an altitude of 4000 feet, the diver plans to ascend to 7500 feet in order to cross a mountain pass. The diver's repetitive group upon surfacing is Group G. What is the required surface interval before crossing the pass?

The planned increase in altitude is 3500 feet. Enter Table 9-5 at 4000 feet and read down to Repetitive Group G. The diver must delay 1 hour and 23 minutes before crossing the pass.

Example: Upon completion of a dive at 2000 feet, the diver plans to fly home in an unpressurized aircraft at 5000 feet. The diver's repetitive group designator upon surfacing is Group K. What is the required surface interval before flying?



DIVING AT ALTITUDE WORKSHEET

DATE 10 Jan 99

Actual Dive Site Altitude 7,750 feet

1. Altitude from Table 9-3. 8,000 feet
2. Actual Depth of Dive (corrected per section 9-12.3) 75 + 8 + 1 = 84 fsw
3. Sea Level Equivalent Depth from Table 9-3 120 SLED
4. Repetitive Group from Table 9-4 F
5. Time at Altitude 5 hrs — min
6. New Repetitive Group Designation from Table 9-7 B
7. Residual Nitrogen Time 6 min
8. Planned Bottom Time + 60 min
9. Equivalent Single Dive Time = 66 min
10. Decompression Table

☐ Standard Air Table
☒ Sur D Table Using Oxygen
☐ Unlimited/No-Decompression Table
☐ Sur D Table Using Air

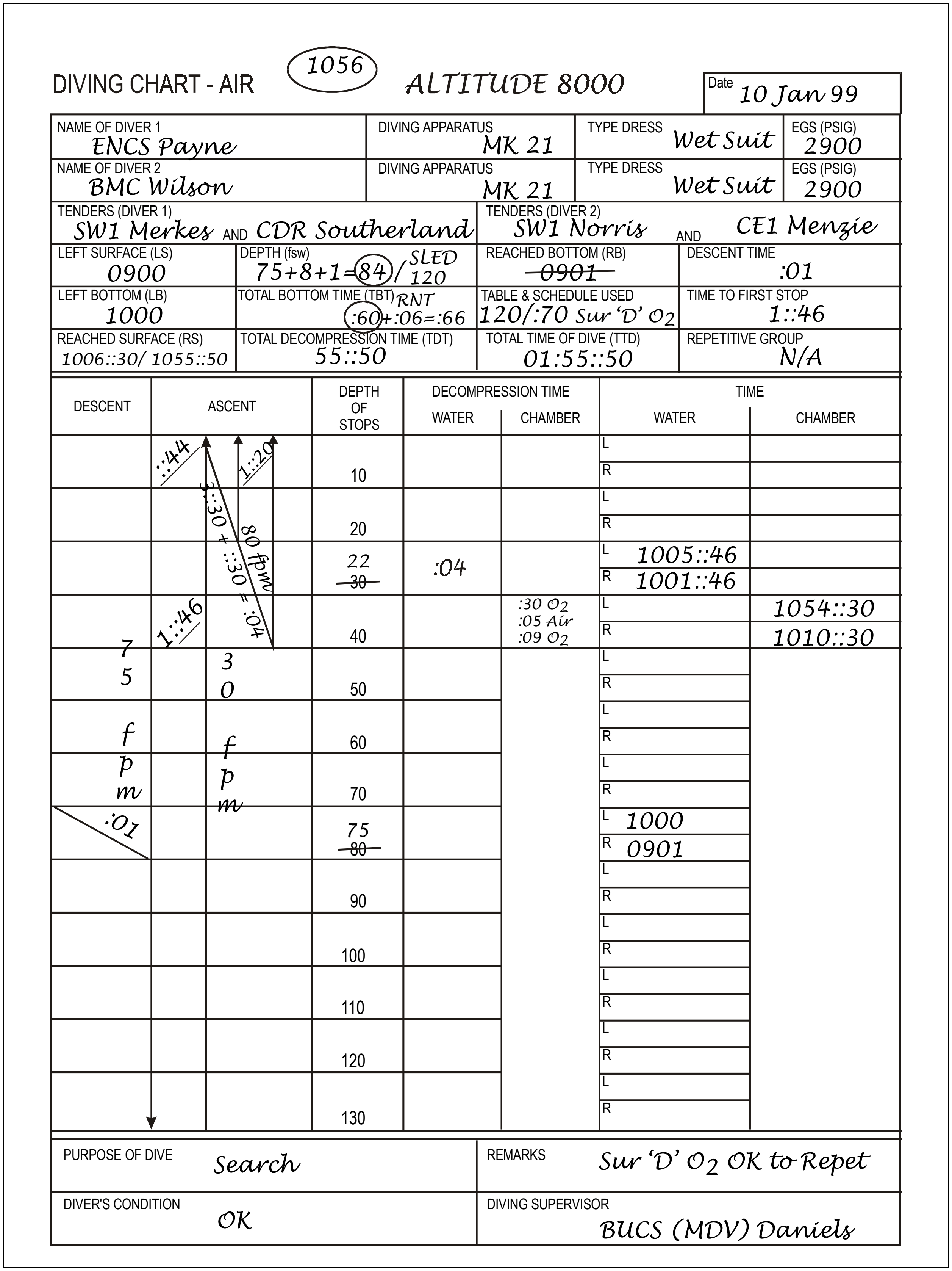
11. Table/Schedule 120 / 70
12. Decompression Schedule

Sea Level Stop Depth	Altitude Stop Depth	Stop Time (Water/Chamber)
10 fsw	fsw	/ min
20 fsw	fsw	/ min
30 fsw	22 fsw	4 / min
40 fsw	fsw	/39 min*
50 fsw	fsw	min
60 fsw	fsw	min

13. Repetitive Group Letter Designation ______

*Chamber stop on SUR D O_2 will be at 40 fsw.

Figure 9-22. Completed Worksheet for Diving at Altitude



DIVING CHART - AIR 1056 ALTITUDE 8000

Date 10 Jan 99

NAME OF DIVER 1 ENCS Payne	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2900
NAME OF DIVER 2 BMC Wilson	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2900

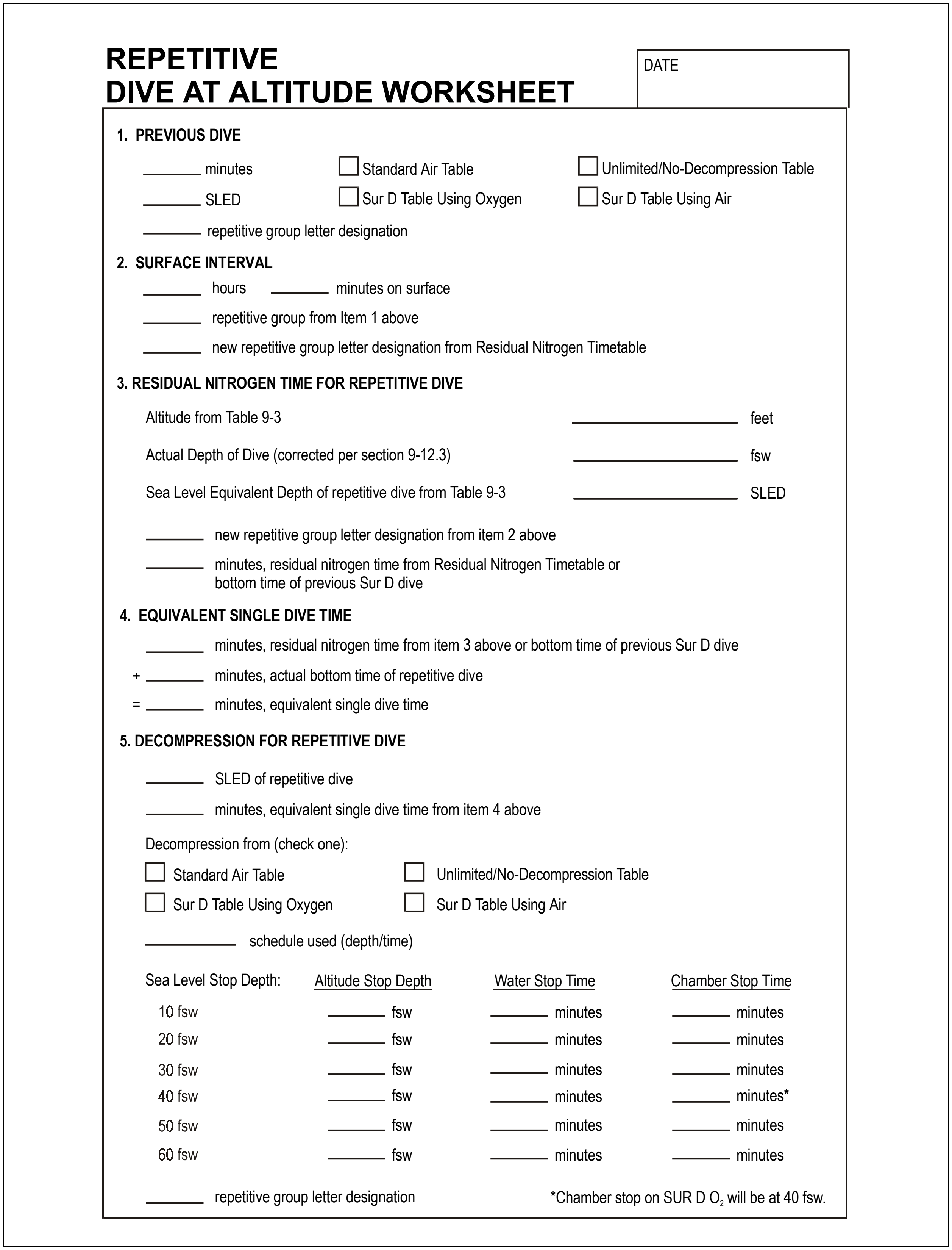
TENDERS (DIVER 1) SW1 Merkes AND CDR Southerland	TENDERS (DIVER 2) SW1 Norris AND CE1 Menzie

LEFT SURFACE (LS) 0900	DEPTH (fsw) 75+8+1=84/ SLED 120	REACHED BOTTOM (RB) ~~0901~~	DESCENT TIME :01
LEFT BOTTOM (LB) 1000	TOTAL BOTTOM TIME (TBT) :60+:06=:66 RNT	TABLE & SCHEDULE USED 120/:70 Sur 'D' O_2	TIME TO FIRST STOP 1::46
REACHED SURFACE (RS) 1006::30/ 1055::50	TOTAL DECOMPRESSION TIME (TDT) 55::50	TOTAL TIME OF DIVE (TTD) 01:55::50	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME WATER	DECOMPRESSION TIME CHAMBER		TIME WATER	TIME CHAMBER
		10			L		
					R		
		20			L		
					R		
		22 ~~30~~	:04		L	1005::46	
					R	1001::46	
		40		:30 O_2 :05 Air :09 O_2	L		1054::30
					R		1010::30
		50			L		
					R		
		60			L		
					R		
		70			L		
					R		
:01		75 ~~80~~			L	1000	
					R	0901	
		90			L		
					R		
		100			L		
					R		
		110			L		
					R		
		120			L		
					R		
		130			L		
					R		

PURPOSE OF DIVE Search	REMARKS Sur 'D' O_2 OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR BUCS (MDV) Daniels

Figure 9-23. Completed Chart for Dive at Altitude.



REPETITIVE
DIVE AT ALTITUDE WORKSHEET

DATE

1. PREVIOUS DIVE

_______ minutes ☐ Standard Air Table ☐ Unlimited/No-Decompression Table

_______ SLED ☐ Sur D Table Using Oxygen ☐ Sur D Table Using Air

_______ repetitive group letter designation

2. SURFACE INTERVAL

_______ hours _______ minutes on surface

_______ repetitive group from Item 1 above

_______ new repetitive group letter designation from Residual Nitrogen Timetable

3. RESIDUAL NITROGEN TIME FOR REPETITIVE DIVE

Altitude from Table 9-3 _________________ feet

Actual Depth of Dive (corrected per section 9-12.3) _________________ fsw

Sea Level Equivalent Depth of repetitive dive from Table 9-3 _________________ SLED

_______ new repetitive group letter designation from item 2 above

_______ minutes, residual nitrogen time from Residual Nitrogen Timetable or bottom time of previous Sur D dive

4. EQUIVALENT SINGLE DIVE TIME

_______ minutes, residual nitrogen time from item 3 above or bottom time of previous Sur D dive

\+ _______ minutes, actual bottom time of repetitive dive

= _______ minutes, equivalent single dive time

5. DECOMPRESSION FOR REPETITIVE DIVE

_______ SLED of repetitive dive

_______ minutes, equivalent single dive time from item 4 above

Decompression from (check one):

☐ Standard Air Table ☐ Unlimited/No-Decompression Table

☐ Sur D Table Using Oxygen ☐ Sur D Table Using Air

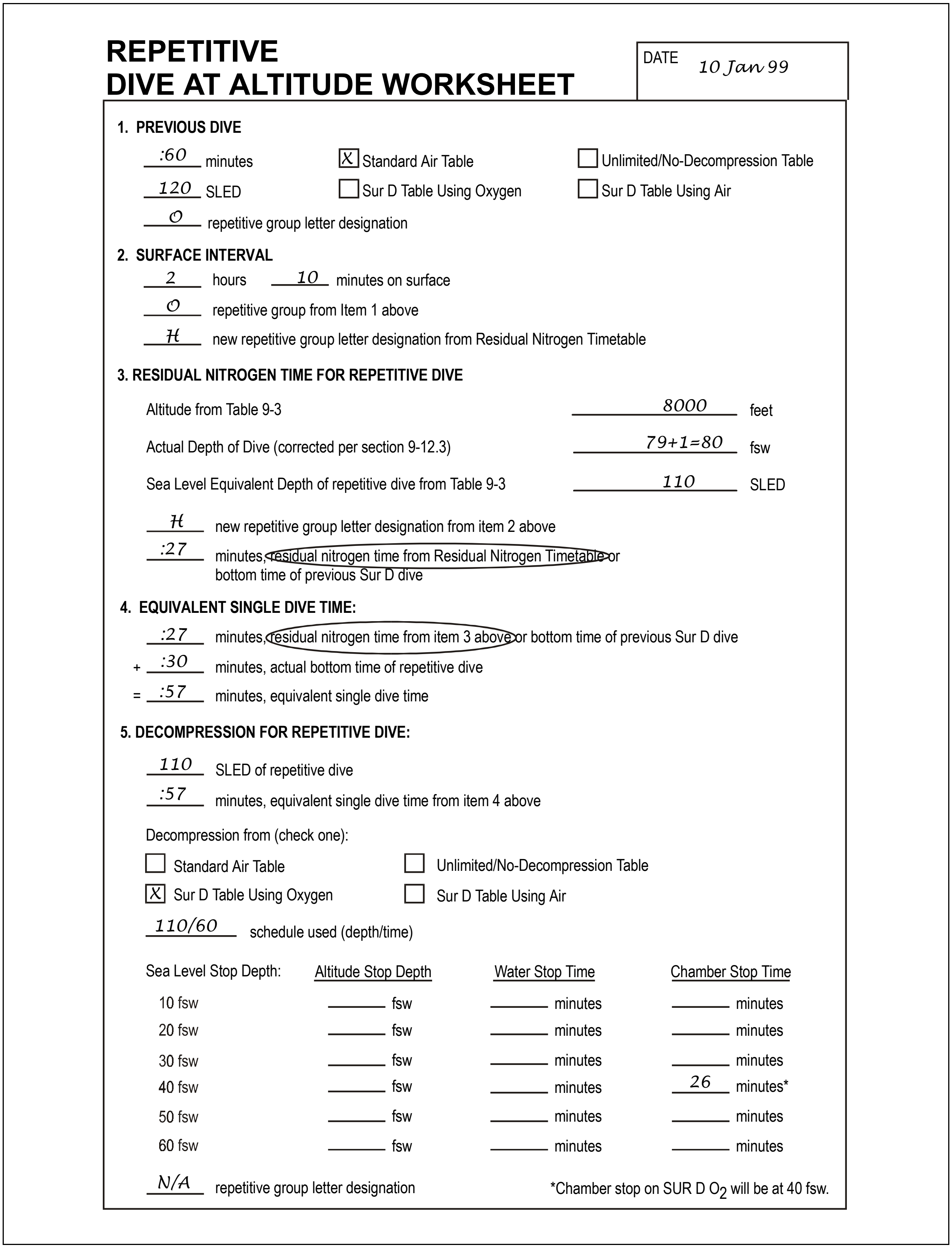
__________ schedule used (depth/time)

Sea Level Stop Depth:	Altitude Stop Depth	Water Stop Time	Chamber Stop Time
10 fsw	_______ fsw	_______ minutes	_______ minutes
20 fsw	_______ fsw	_______ minutes	_______ minutes
30 fsw	_______ fsw	_______ minutes	_______ minutes
40 fsw	_______ fsw	_______ minutes	_______ minutes*
50 fsw	_______ fsw	_______ minutes	_______ minutes
60 fsw	_______ fsw	_______ minutes	_______ minutes

_______ repetitive group letter designation

*Chamber stop on SUR D O_2 will be at 40 fsw.

Figure 9-24. Worksheet for Repetitive Dive at Altitude.



REPETITIVE
DIVE AT ALTITUDE WORKSHEET

DATE 10 Jan 99

1. PREVIOUS DIVE

:60 minutes ☒ Standard Air Table ☐ Unlimited/No-Decompression Table

120 SLED ☐ Sur D Table Using Oxygen ☐ Sur D Table Using Air

O repetitive group letter designation

2. SURFACE INTERVAL

2 hours 10 minutes on surface

O repetitive group from Item 1 above

H new repetitive group letter designation from Residual Nitrogen Timetable

3. RESIDUAL NITROGEN TIME FOR REPETITIVE DIVE

Altitude from Table 9-3 8000 feet

Actual Depth of Dive (corrected per section 9-12.3) 79+1=80 fsw

Sea Level Equivalent Depth of repetitive dive from Table 9-3 110 SLED

H new repetitive group letter designation from item 2 above

:27 minutes, [✓ residual nitrogen time from Residual Nitrogen Timetable] or bottom time of previous Sur D dive

4. EQUIVALENT SINGLE DIVE TIME:

:27 minutes, [✓ residual nitrogen time from item 3 above] or bottom time of previous Sur D dive

\+ :30 minutes, actual bottom time of repetitive dive

= :57 minutes, equivalent single dive time

5. DECOMPRESSION FOR REPETITIVE DIVE:

110 SLED of repetitive dive

:57 minutes, equivalent single dive time from item 4 above

Decompression from (check one):

☐ Standard Air Table ☐ Unlimited/No-Decompression Table

☒ Sur D Table Using Oxygen ☐ Sur D Table Using Air

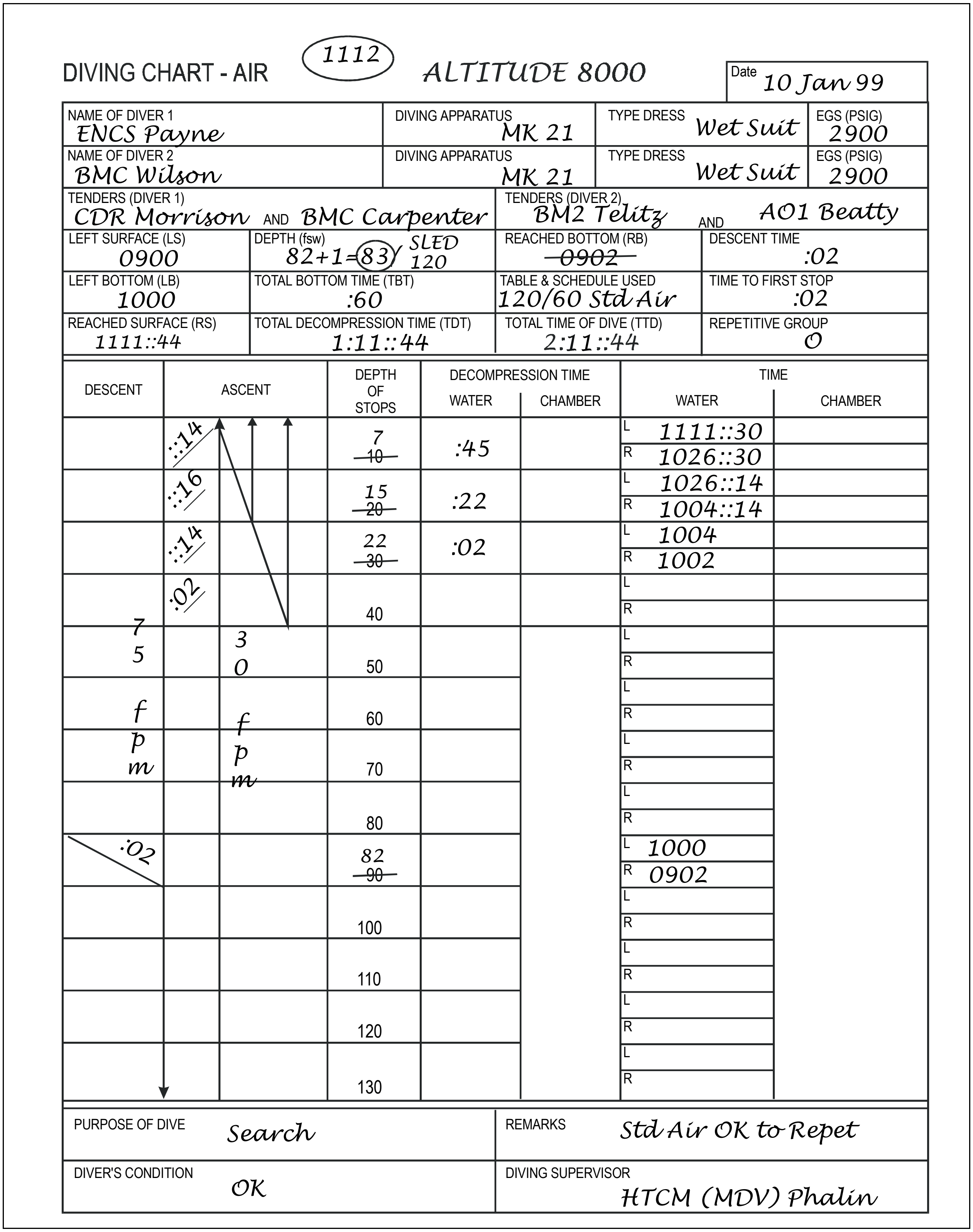
110/60 schedule used (depth/time)

Sea Level Stop Depth:	Altitude Stop Depth	Water Stop Time	Chamber Stop Time
10 fsw	fsw	minutes	minutes
20 fsw	fsw	minutes	minutes
30 fsw	fsw	minutes	minutes
40 fsw	fsw	minutes	26 minutes*
50 fsw	fsw	minutes	minutes
60 fsw	fsw	minutes	minutes

N/A repetitive group letter designation

*Chamber stop on SUR D O_2 will be at 40 fsw.

Figure 9-25. Completed Worksheet for Repetitive Dive at Altitude.



DIVING CHART - AIR 1112 ALTITUDE 8000

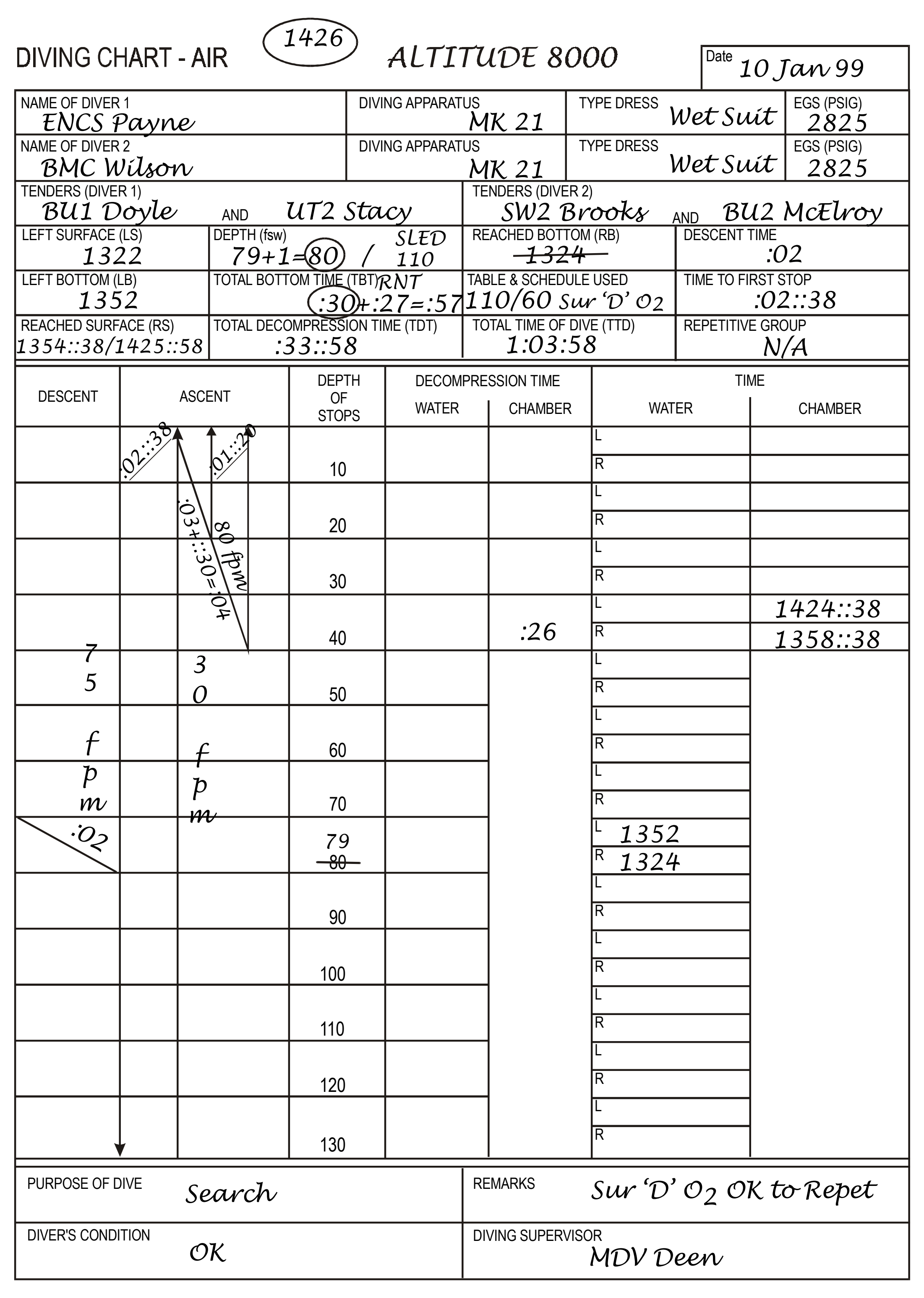
Date 10 Jan 99

NAME OF DIVER 1 ENCS Payne	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2900
NAME OF DIVER 2 BMC Wilson	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2900
TENDERS (DIVER 1) CDR Morrison AND BMC Carpenter		TENDERS (DIVER 2) BM2 Telitz AND AO1 Beatty	
LEFT SURFACE (LS) 0900	DEPTH (fsw) 82+1=83 SLED 120	REACHED BOTTOM (RB) ~~0902~~	DESCENT TIME :02
LEFT BOTTOM (LB) 1000	TOTAL BOTTOM TIME (TBT) :60	TABLE & SCHEDULE USED 120/60 Std Air	TIME TO FIRST STOP :02
REACHED SURFACE (RS) 1111::44	TOTAL DECOMPRESSION TIME (TDT) 1:11::44	TOTAL TIME OF DIVE (TTD) 2:11::44	REPETITIVE GROUP O

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
	::14	7 ~~10~~	:45		L 1111::30 R 1026::30	
	::16	15 ~~20~~	:22		L 1026::14 R 1004::14	
	::14	22 ~~30~~	:02		L 1004 R 1002	
	:02	40			L R	
75	30	50			L R	
f		60			L R	
p m	f p m	70			L R	
		80			L R	
:02		82 ~~90~~			L 1000 R 0902	
		100			L R	
		110			L R	
		120			L R	
		130			L R	

PURPOSE OF DIVE Search	REMARKS Std Air OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR HTCM (MDV) Phalin

Figure 9-26. Completed Chart for Dive at Altitude.



DIVING CHART - AIR 1426 ALTITUDE 8000

Date 10 Jan 99

NAME OF DIVER 1 ENCS Payne	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2825
NAME OF DIVER 2 BMC Wilson	DIVING APPARATUS MK 21	TYPE DRESS Wet Suit	EGS (PSIG) 2825

TENDERS (DIVER 1) BU1 Doyle AND UT2 Stacy	TENDERS (DIVER 2) SW2 Brooks AND BU2 McElroy

LEFT SURFACE (LS) 1322	DEPTH (fsw) 79+1=80 / SLED 110	REACHED BOTTOM (RB) ~~1324~~	DESCENT TIME :02
LEFT BOTTOM (LB) 1352	TOTAL BOTTOM TIME (TBT) RNT :30+:27=:57	TABLE & SCHEDULE USED 110/60 Sur 'D' O_2	TIME TO FIRST STOP :02::38
REACHED SURFACE (RS) 1354::38/1425::58	TOTAL DECOMPRESSION TIME (TDT) :33::58	TOTAL TIME OF DIVE (TTD) 1:03:58	REPETITIVE GROUP N/A

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
		10			L R	
		20			L R	
		30			L R	
		40		:26	L R	1424::38 1358::38
		50			L R	
		60			L R	
		70			L R	
		79 ~~80~~			L 1352 R 1324	
		90			L R	
		100			L R	
		110			L R	
		120			L R	
		130			L R	

PURPOSE OF DIVE Search	REMARKS Sur 'D' O_2 OK to Repet
DIVER'S CONDITION OK	DIVING SUPERVISOR MDV Deen

Figure 9-27. Completed Chart for Repetitive Dive at Altitude.

***Table 9-5.** Required Surface Interval Before Ascent to Altitude After Diving.*

Repetitive Group Designator	Increase in Altitude									
	1000	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
A	0:00	0:00	0:00	0:00	0:00	0:00	0:00	**0:00**	0:00	0:00
B	0:00	0:00	0:00	0:00	0:00	0:00	0:00	**0:00**	0:00	2:11
C	0:00	0:00	0:00	0:00	0:00	0:00	0:00	**0:00**	3:06	8:26
D	0:00	0:00	0:00	0:00	0:00	0:00	0:09	**3:28**	7:33	12:52
E	0:00	0:00	0:00	0:00	0:00	0:51	3:35	**6:54**	10:59	16:18
F	0:00	0:00	0:00	0:00	1:12	3:40	6:23	**9:43**	13:47	19:07
G	0:00	0:00	0:00	1:23	3:34	6:02	8:46	**12:05**	16:10	21:29
H	0:00	0:00	1:31	3:26	5:37	8:05	10:49	**14:09**	18:13	23:33
I	0:00	1:32	3:20	5:15	7:26	9:54	12:38	**15:58**	20:02	24:00
J	1:32	3:09	4:57	6:52	9:04	11:32	14:16	**17:35**	21:39	24:00
K	3:00	4:37	6:25	8:20	10:32	13:00	15:44	**19:03**	23:07	24:00
L	4:21	5:57	7:46	9:41	11:52	14:20	17:04	**20:23**	24:00	24:00
M	5:35	7:11	9:00	10:55	13:06	15:34	18:18	**21:37**	24:00	24:00
N	6:43	8:20	10:08	12:03	14:14	16:42	19:26	**22:46**	24:00	24:00
O	7:47	9:24	11:12	13:07	15:18	17:46	20:30	**23:49**	24:00	24:00
Z	8:17	9:54	11:42	13:37	15:49	18:17	21:01	**24:00**	24:00	24:00
Exceptional Exposure	Wait 48 hours before flying									

NOTE 1 When using Table 9-5, use the highest repetitive group designator obtained in the previous 24-hour period.

NOTE 2 Table 9-5 may only be used when the maximum altitude achieved is 10,000 feet or less. For ascents above 10,000 feet, consult NAVSEA 00C for guidance.

NOTE 3 The cabin pressure in commercial aircraft is maintained at a constant value regardless of the actual altitude of the flight. Though cabin pressure varies somewhat with aircraft type, the nominal value is 8,000 feet. For commercial flights, use a final altitude of 8000 feet to compute the required surface interval before flying.

NOTE 4 No surface interval is required before taking a commercial flight if the dive site is at 8000 feet or higher. In this case, flying results in an increase in atmospheric pressure rather than a decrease.

NOTE 5 No repetitive group is given for air dives with surface decompression on oxygen or air. For these surface decompression dives, enter the standard air table with the sea level equivalent depth and bottom time of the dive to obtain the appropriate repetitive group designator to be used.

NOTE 6 For ascent to altitude following a non-saturation helium-oxygen dive, wait 12 hours if the dive was a no-decompression dive. Wait 24 hours if the dive was a decompression dive.

The planned increase in altitude is 3000 feet. Enter Table 9-5 at 3000 feet and read down to Repetitive Group K. The diver must delay 6 hours and 25 minutes before taking the flight.

Table 9-6. *Unlimited/No-Decompression Limits and Repetitive Group Designation Table for Unlimited/No-Decompression Air Dives.*

Depth (feet/meters)		No-Decompression Limits (min)	Group Designation														
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10	3.0	unlimited	60	120	210	300	797	*									
15	4.6	unlimited	35	70	110	160	225	350	452	*							
20	6.1	unlimited	25	50	75	100	135	180	240	325	390	917	*				
25	7.6	595	20	35	55	75	100	125	160	195	245	315	361	540	595		
30	9.1	405	15	30	45	60	75	95	120	145	170	205	250	310	344	405	
35	10.7	310	5	15	25	40	50	60	80	100	120	140	160	190	220	270	310
40	12.2	200	5	15	25	30	40	50	70	80	100	110	130	150	170	200	
50	15.2	100		10	15	25	30	40	50	60	70	80	90	100			
60	18.2	60		10	15	20	25	30	40	50	55	60					
70	21.3	50		5	10	15	20	30	35	40	45	50					
80	24.4	40		5	10	15	20	25	30	35	40						
90	27.4	30		5	10	12	15	20	25	30							
100	30.5	25		5	7	10	15	20	22	25							
110	33.5	20			5	10	13	15	20								
120	36.6	15			5	10	12	15									
130	39.6	10			5	8	10										
140	42.7	10			5	7	10										
150	45.7	5			5												
160	48.8	5				5											
170	51.8	5				5											
180	54.8	5				5											
190	59.9	5				5											

* Highest repetitive group that can be achieved at this depth regardless of bottom time.

*Table 9-7. **Residual Nitrogen Timetable for Repetitive Air Dives.***

Locate the diver's repetitive group designation from his previous dive along the diagonal line above the table. Read horizontally to the interval in which the diver's surface interval lies.

Next, read vertically downward to the new repetitive group designation. Continue downward in this same column to the row that represents the depth of the repetitive dive. The time given at the intersection is residual nitrogen time, in minutes, to be applied to the repetitive dive.

* Dives following surface intervals of more than 12 hours are not repetitive dives. Use actual bottom times in the Standard Air Decompression Tables to compute decompression for such dives.

** If no Residual Nitrogen Time is given, then the repetitive group does not change.

Repetitive group at the beginning of the surface interval

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

New Repetitive Group Designation

Repetitive Dive Depth feet/meters		Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
10	3.0	**	**	**	**	**	**	**	**	**	**	**	797	279	159	88	39
20	6.1	**	**	**	**	**	**	917	399	279	208	159	120	88	62	39	18
30	9.1	†	†	†	349	279	229	190	159	132	109	88	70	54	39	25	12
40	12.2	257	241	213	187	161	138	116	101	87	73	61	49	37	25	17	7
50	15.2	169	160	142	124	111	99	87	76	66	56	47	38	29	21	13	6
60	16.2	122	117	107	97	88	79	70	61	52	44	36	30	24	17	11	5
70	21.3	100	96	87	80	72	64	57	50	43	37	31	26	20	15	9	4
80	24.4	84	80	73	68	61	54	48	43	38	32	28	23	18	13	8	4
90	27.4	73	70	64	58	53	47	43	38	33	29	24	20	16	11	7	3
100	30.5	64	62	57	52	48	43	38	34	30	26	22	18	14	10	7	3
110	33.5	57	55	51	47	42	38	34	31	27	24	20	16	13	10	6	3
120	36.6	52	50	46	43	39	35	32	28	25	21	18	15	12	9	6	3
130	39.6	46	44	40	38	35	31	28	25	22	19	16	13	11	8	6	3
140	42.7	42	40	38	35	32	29	26	23	20	18	15	12	10	7	5	2
150	45.7	40	38	35	32	30	27	24	22	19	17	14	12	9	7	5	2
160	48.8	37	36	33	31	28	26	23	20	18	16	13	11	9	6	4	2
170	51.8	35	34	31	29	26	24	22	19	17	15	12	10	8	6	4	2
180	54.8	32	31	29	27	25	22	20	18	16	14	11	10	8	6	4	2
190	59.9	31	30	28	26	24	21	19	17	15	13	10	10	8	6	4	2

Residual Nitrogen Times (MInutes)

† Read vertically downward to the 40/12.2 (feet/meter) repetitive dive depth. Use the corresponding residual nitrogen times (minutes) to compute the equivalent single dive time. Decompress using the 40/12.2 (feet/meter) standard air decompression table.

Table 9-8. U.S. Navy Standard Air Decompression Table.

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	**Decompression stops** (feet/meters)					Total decompression time (min:sec)	Repetitive group
			50 15.2	40 12.1	30 9.1	20 6.0	10 3.0		
40 12.1	200						0	1:20	*
	210	1:00					2	3:20	N
	230	1:00					7	8:20	N
	250	1:00					11	12:20	O
	270	1:00					15	16:20	O
	300	1:00					19	20:20	Z
	Exceptional Exposure								
	360	1:00					23	24:20	**
	480	1:00					41	42:20	**
	720	1:00					69	70:20	**
50 15.2	100						0	1:40	*
	110	1:20					3	4:40	L
	120	1:20					5	6:40	M
	140	1:20					10	11:40	M
	160	1:20					21	22:40	N
	180	1:20					29	30:40	O
	200	1:20					35	36:40	O
	220	1:20					40	41:40	Z
	240	1:20					47	48:40	Z
60 18.2	60						0	2:00	*
	70	1:40					2	4:00	K
	80	1:40					7	9:00	L
	100	1:40					14	16:00	M
	120	1:40					26	28:00	N
	140	1:40					39	41:00	O
	160	1:40					48	50:00	Z
	180	1:40					56	58:00	Z
	200	1:20				1	69	72:00	Z
	Exceptional Exposure								
	240	1:20				2	79	83:00	**
	360	1:20				20	119	141:00	**
	480	1:20				44	148	194:00	**
	720	1:20				78	187	267:00	**
70 21.3	50						0	2:20	*
	60	2:00					8	10:20	K
	70	2:00					14	16:20	L
	80	2:00					18	20:20	M
	90	2:00					23	25:20	N
	100	2:00					33	35:20	N
	110	1:40				2	41	45:20	O
	120	1:40				4	47	53:20	O
	130	1:40				6	52	60:20	O
	140	1:40				8	56	66:20	Z
	150	1:40				9	61	72:20	Z
	160	1:40				13	72	87:20	Z
	170	1:40				19	79	100:20	Z

* See No Decompression Table for repetitive groups

** Repetitive dives may not follow exceptional exposure dives

Table 9-8. *U.S. Navy Standard Air Decompression Table (Continued).*

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters) 50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	Total decompression time (min:sec)	Repetitive group
80 24.3	40						0	2:40	*
	50	2:20					10	12:40	K
	60	2:20					17	19:40	L
	70	2:20					23	25:40	M
	80	2:00				2	31	35:40	N
	90	2:00				7	39	48:40	N
	100	2:00				11	46	59:40	O
	110	2:00				13	53	68:40	O
	120	2:00				17	56	75:40	Z
	130	2:00				19	63	83:40	Z
	140	2:00				26	69	97:40	Z
	150	2:00				32	77	111:40	Z
	Exceptional Exposure								
	180	2:00				35	85	122:40	**
	240	1:40			6	52	120	180:40	**
	360	1:40			29	90	160	281:40	**
	480	1:40			59	107	187	355:40	**
	720	1:20		17	108	142	187	456:40	**
90 28.7	30						0	3:00	*
	40	2:40					7	10:00	J
	50	2:40					18	21:00	L
	60	2:40					25	28:00	M
	70	2:20				7	30	40:00	N
	80	2:20				13	40	56:00	N
	90	2:20				18	48	69:00	O
	100	2:20				21	54	78:00	Z
	110	2:20				24	61	88:00	Z
	120	2:20				32	68	103:00	Z
	130	2:00			5	36	74	118:00	Z
100 30.4	25						0	3:20	*
	30	3:00					3	6:20	I
	40	3:00					15	18:20	K
	50	2:40				2	24	29:20	L
	60	2:40				9	28	40:20	N
	70	2:40				17	39	59:20	O
	80	2:40				23	48	74:20	O
	90	2:20			3	23	57	86:20	Z
	100	2:20			7	23	66	99:20	Z
	110	2:20			10	34	72	119:20	Z
	120	2:20			12	41	78	134:20	Z
	Exceptional Exposure								
	180	2:00		1	29	53	118	204:20	**
	240	2:00		14	42	84	142	285:20	**
	360	1:40	2	42	73	111	187	418:20	**
	480	1:40	21	61	91	142	187	505:20	**
	720	1:40	55	106	122	142	187	615:20	**

* See No Decompression Table for repetitive groups

** Repetitive dives may not follow exceptional exposure dives

Table 9-8. *U.S. Navy Standard Air Decompression Table (Continued).*

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters)					Total decompression time (min:sec)	Repetitive group
			50 15.2	40 12.1	30 9.1	20 6.0	10 3.0		
110 **33.1**	20						0	3:40	*
	25	3:20					3	6:40	H
	30	3:20					7	10:40	J
	40	3:00				2	21	26:40	L
	50	3:00				8	26	37:40	M
	60	3:00				18	36	57:40	N
	70	2:40			1	23	48	75:40	O
	80	2:40			7	23	57	90:40	Z
	90	2:40			12	30	64	109:40	Z
	100	2:40			15	37	72	127:40	Z

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters)							Total decompression time (min:sec)	Repetitive group
			70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0		
120 **36.5**	15								0	4:00	*
	20	3:40							2	6:00	H
	25	3:40							6	10:00	I
	30	3:40							14	18:00	J
	40	3:20						5	25	34:00	L
	50	3:20						15	31	50:00	N
	60	3:00					2	22	45	73:00	O
	70	3:00					9	23	55	91:00	O
	80	3:00					15	27	63	109:00	Z
	90	3:00					19	37	74	134:00	Z
	100	3:00					23	45	80	152:00	Z
	Exceptional Exposure										
	120	2:40				10	19	47	98	178:00	**
	180	2:20			5	27	37	76	137	286:00	**
	240	2:20			23	35	60	97	179	398:00	**
	360	2:00		18	45	64	93	142	187	553:00	**
	480	1:40	3	41	64	93	122	142	187	656:00	**
	720	1:40	32	74	100	114	122	142	187	775:00	**
130 **39.6**	10								0	4:20	*
	15	4:00							1	5:20	F
	20	4:00							4	8:20	H
	25	4:00							10	14:20	J
	30	3:40						3	18	25:20	M
	40	3:40						10	25	39:20	N
	50	3:20					3	21	37	65:20	O
	60	3:20					9	23	52	88:20	Z
	70	3:20					16	24	61	105:20	Z
	80	3:00				3	19	35	72	133:20	Z
	90	3:00				8	19	45	80	156:20	Z

* See No Decompression Table for repetitive groups

** Repetitive dives may not follow exceptional exposure dives

Table 9-8. *U.S. Navy Standard Air Decompression Table (Continued).*

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters)									Total decompression time (min:sec)	Repetitive group
			90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0		
140 42.6	10										0	4:40	*
	15	4:20									2	6:40	G
	20	4:20									6	10:40	I
	25	4:00								2	14	20:40	J
	30	4:00								5	21	30:40	K
	40	3:40							2	16	26	48:40	N
	50	3:40							6	24	44	78:40	O
	60	3:40							16	23	56	99:40	Z
	70	3:20						4	19	32	68	127:40	Z
	80	3:20						10	23	41	79	157:40	Z
	Exceptional Exposure												
	90	3:00					2	14	18	42	88	168:40	**
	120	3:00					12	14	36	56	120	242:40	**
	180	2:40				10	26	32	54	94	168	388:40	**
	240	2:20			8	28	34	50	78	124	187	513:40	**
	360	2:00		9	32	42	64	84	122	142	187	686:40	**
	480	2:00		31	44	59	100	114	122	142	187	803:40	**
	720	1:40	16	56	88	97	100	114	122	142	187	926:40	**
150 45.7	5										0	5:00	C
	10	4:40									1	6:00	E
	15	4:40									3	8:00	G
	20	4:20								2	7	14:00	H
	25	4:20								4	17	26:00	K
	30	4:20								8	24	37:00	L
	40	4:00							5	19	33	62:00	N
	50	4:00							12	23	51	91:00	O
	60	3:40						3	19	26	62	115:00	Z
	70	3:40						11	19	39	75	149:00	Z
	80	3:20					1	17	19	50	84	176:00	Z
160 48.7	5										0	5:20	D
	10	5:00									1	6:20	F
	15	4:40								1	4	10:20	H
	20	4:40								3	11	19:20	J
	25	4:40								7	20	32:20	K
	30	4:20							2	11	25	43:20	M
	40	4:20							7	23	39	74:20	N
	50	4:00						2	16	23	55	101:20	Z
	60	4:00						9	19	33	69	135:20	Z
	Exceptional Exposure												
	70	3:40					1	17	22	44	80	169:20	**

* See No Decompression Table for repetitive groups

** Repetitive dives may not follow exceptional exposure dives

Table 9-8. *U.S. Navy Standard Air Decompression Table (Continued).*

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	**Decompression stops** (feet/meters)											Total decompression time (min:sec)	Repetitive group
			110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0		
170 51.8	5												0	5:40	D
	10	5:20											2	7:40	F
	15	5:00										2	5	12:40	H
	20	5:00										4	15	24:40	J
	25	4:40									2	7	23	37:40	L
	30	4:40									4	13	26	48:40	M
	40	4:20								1	10	23	45	84:40	O
	50	4:20								5	18	23	61	112:40	Z
	60	4:00							2	15	22	37	74	155:40	Z
	Exceptional Exposure														
	70	4:00							8	17	19	51	86	186:40	**
	90	3:40						12	12	14	34	52	120	249:40	**
	120	3:00				2	10	12	18	32	42	82	156	359:40	**
	180	2:40			4	10	22	28	34	50	78	120	187	538:40	**
	240	2:40			18	24	30	42	50	70	116	142	187	684:40	**
	360	2:20		22	34	40	52	60	98	114	122	142	187	876:40	**
	480	2:00	14	40	42	56	91	97	100	114	122	142	187	1010:40	**
180 54.8	5												0	6:00	D
	10	5:40											3	9:00	F
	15	5:20										3	6	15:00	I
	20	5:00									1	5	17	29:00	J
	25	5:00									3	10	24	43:00	L
	30	5:00									6	17	27	56:00	N
	40	4:40								3	14	23	50	96:00	O
	50	4:20							2	9	19	30	65	131:00	Z
	60	4:20							5	16	19	44	81	171:00	Z
190 57.9	5	5:40											0	6:20	D
	10	5:40										1	3	10:20	G
	15	5:40										6	7	17:20	I
	20	5:20									2	6	20	34:20	K
	25	:5:20									5	11	25	47:20	M
	30	5:00								1	8	19	32	66:20	N
	40	5:00								8	14	23	55	106:20	O
	Exceptional Exposure														
	50	4:40							4	13	22	33	72	150:20	**
	60	4:40							10	17	19	50	84	186:20	**

* See No Decompression Table for repetitive groups

** Repetitive dives may not follow exceptional exposure dives

Table 9-8. U.S. Navy Standard Air Decompression Table (Continued).

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters)													Total decompression time (min:sec)
			130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	
200 **60.9**	Exceptional Exposure															
	5	6:20													1	7:40
	10	6:00												1	4	11:40
	15	5:40											1	4	10	21:40
	20	5:40											3	7	27	43:40
	25	5:40											7	14	25	52:40
	30	5:20										2	9	22	37	76:40
	40	5:00									2	8	17	23	59	115:40
	50	5:00									6	16	22	39	75	164:40
	60	4:40								2	13	17	24	51	89	202:40
	90	3:40					1	10	10	12	12	30	38	74	134	327:40
	120	3:20				6	10	10	10	24	28	40	64	98	180	476:40
	180	2:40		1	10	10	18	24	24	42	48	70	106	142	187	688:40
	240	2:40		6	20	24	24	36	42	54	68	114	122	142	187	845::40
	360	2:20	12	22	36	40	44	56	82	98	100	114	122	142	187	1061:40
210 **64.0**	Exceptional Exposure															
	5	6:40													1	8:00
	10	6:20												2	4	13:00
	15	6:00											1	5	13	26:00
	20	6:00											4	10	23	44:00
	25	5:40										2	7	17	27	60:00
	30	5:40										4	9	24	41	85:00
	40	5:20									4	9	19	26	63	128:00
	50	5:20								1	9	17	19	45	80	178:00
220 **67.0**	Exceptional Exposure															
	5	7:00													1	8:20
	10	6:40												2	5	14:20
	15	6:20											2	5	16	30:20
	20	6:00										1	3	11	24	46:20
	25	6:00										3	8	19	33	70:20
	30	5:40									1	7	10	23	47	95:20
	40	5:40									6	12	22	29	68	144:20
	50	5:20								3	12	17	18	51	86	194:20
230 **70.1**	Exceptional Exposure															
	5	7:20													2	9:40
	10	6:20											1	2	6	16:40
	15	6:20											3	6	18	34:40
	20	6:20										2	5	12	26	52:40
	25	6:20										4	8	22	37	78:40
	30	6:00									2	8	12	23	51	103:40
	40	5:40								1	7	15	22	34	74	160:40
	50	5:40								5	14	16	24	51	89	206:40

Table 9-8. *U.S. Navy Standard Air Decompression Table (Continued).*

Exceptional Exposure

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters) 130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	Total decompression time (min:sec)
240 **73.1**	5	7:40													2	10:00
	10	7:00											1	3	6	18:00
	15	7:00											4	6	21	39:00
	20	6:40										3	6	15	25	57:00
	25	6:20									1	4	9	24	40	86:00
	30	6:20									4	8	15	22	56	113:00
	40	6:00								3	7	17	22	39	75	171:00
	50	5:40							1	8	15	16	29	51	94	222:00

Exceptional Exposure

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	Decompression stops (feet/meters) 200 60.9	190 57.9	180 54.8	170 51.8	160 48.7	150 45.7	140 42.6	130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	Total decompression time (min:sec)
250 **76.2**	5	7:40																			1	2	11:20
	10	7:20																		1	4	7	20:20
	15	7:00																	1	4	7	22	42:20
	20	7:00																	4	7	17	27	63:20
	25	6:40																2	7	10	24	45	96:20
	30	6:40																6	7	17	23	59	120:20
	40	6:20															5	9	17	19	45	79	182:20
	60	5:20												4	10	10	10	12	22	36	64	164	302:20
	90	4:20									8	10	10	10	10	10	28	28	44	68	98	186	518:20
	120	3:40							5	10	10	10	10	16	24	24	36	48	64	94	142	187	688:20
	180	3:00					4	8	8	10	22	24	24	32	42	44	60	84	114	122	142	187	935:20
	240	3:00					9	14	21	22	22	40	40	42	56	76	98	100	114	122	142	187	1113:20

Exceptional Exposure

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	200 60.9	190 57.9	180 54.8	170 51.8	160 48.7	150 45.7	140 42.6	130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	Total decompression time (min:sec)
260 **79.2**	5	8:00																			1	2	11:40
	10	7:40																		2	4	9	23:40
	15	7:20																	2	4	10	22	46:40
	20	7:00																1	4	7	20	31	71:40
	25	7:00																3	8	11	23	50	103:40
	30	6:40															2	6	8	19	26	61	130:40
	40	6:20														1	6	11	16	19	49	84	194:40

Exceptional Exposure

Depth feet/meters	Bottom time (min)	Time first stop (min:sec)	200 60.9	190 57.9	180 54.8	170 51.8	160 48.7	150 45.7	140 42.6	130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	Total decompression time (min:sec)
270 **82.3**	5	8:20																			1	3	13:00
	10	8:00																		2	5	11	27:00
	15	7:40																	3	4	11	24	51:00
	20	7:20																2	3	9	21	35	79:00
	25	7:00															2	3	8	13	23	53	111:00
	30	7:00															3	6	12	22	27	64	143:00
	40	6:40														5	6	11	17	22	51	88	209:00

Table 9-8. U.S. Navy Standard Air Decompression Table (Continued).

Depth feet/meters	Bottom time (min)	Time first stop (min: sec)	Decompression stops (feet/meters)																				Total decompression time (min:sec)
			200 60.9	190 57.9	180 54.8	170 51.8	160 48.7	150 45.7	140 42.6	130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	
	Exceptional Exposure																						
280 85.3	5	8:40																			2	2	13:20
	10	8:00																	1	2	5	13	30:20
	15	7:40																1	3	4	11	26	54:20
	20	7:40																3	4	8	23	39	86:20
	25	7:20															2	5	7	16	23	56	118:20
	30	7:00														1	3	7	13	22	30	70	155:20
	40	6:40													1	6	6	13	17	27	51	93	223:20
	Exceptional Exposure																						
290 88.4	5	9:00																			2	3	14:40
	10	8:20																	1	3	5	16	34:40
	15	8:00																1	3	6	12	26	57:40
	20	8:00																3	7	9	23	43	94:40
	25	7:40															3	5	8	17	23	60	125:40
	30	7:20														1	5	6	16	22	36	72	167:40
	40	7:00													3	5	7	15	16	32	51	95	233:40

Depth feet/meters	Bottom time (min)	Time first stop (min: sec)	Decompression stops (feet/meters)																				Total decompression time (min:sec)
			200 60.9	190 57.9	180 54.8	170 51.8	160 48.7	150 45.7	140 42.6	130 39.6	120 36.5	110 33.5	100 30.4	90 27.4	80 24.3	70 21.3	60 18.2	50 15.2	40 12.1	30 9.1	20 6.0	10 3.0	
	Exceptional Exposure																						
300 91.4	5	9:20																			3	3	16:00
	10	8:40																	1	3	6	17	37:00
	15	8:20																2	3	6	15	26	62:00
	20	8:00															2	3	7	10	23	47	102:00
	25	7:40														1	3	6	8	19	26	61	134:00
	30	7:40														2	5	7	17	22	39	75	177:00
	40	7:20													4	6	9	15	17	34	51	90	‘236:00
	60	6:00									4	10	10	10	10	10	14	28	32	50	90	187	465:00
	90	4:40					‘3	8	8	10	10	10	10	16	24	24	34	48	64	90	142	187	698:00
	120	4:00			4	8	8	8	8	10	14	24	24	24	34	42	58	66	102	122	142	187	895:00
	180	3:30	6	8	8	8	14	20	21	21	28	40	40	48	56	82	98	100	114	122	142	187	1173:00

Table 9-9. Surface Decompression Table Using Oxygen.

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) breathing air at water stops (feet/meters)				Surface Interval	Time at 40-foot chamber stop (min) on oxygen	Surface	Total decompression time (min:sec)
			60 18.2	50 15.2	40 12.1	30 9.1				
70 21.3	50	2:20					TOTAL TIME FROM LAST WATER STOP TO FIRST CHAMBER STOP NOT TO EXCEED 5 MINUTES		1-MINUTE 20 SECONDS ASCENT FROM 40 FEET IN CHAMBER TO SURFACE	2:20
	90	2:20						15		22:40
	120	2:20						23		30:40
	150	2:20						31		43:40
	180	2:20						39		51:40
80 24.3	40	2:40								2:40
	70	2:40						14		22:00
	85	2:40						20		28:00
	100	2:40						26		34:00
	115	2:40						31		44:00
	130	2:40						37		50:00
	150	2:40						44		57:00
90 27.4	30	3:00								3:00
	60	3:00						14		22:20
	70	3:00						20		28:20
	80	3:00						25		33:20
	90	3:00						30		38:20
	100	3:00						34		47:20
	110	3:00						39		52:20
	120	3:00						43		56:20
	130	3:00						48		61:20
100 30.4	25	3:20								3:20
	50	3:20						14		22:40
	60	3:20						20		28:40
	70	3:20						26		34:40
	80	3:20						32		45:40
	90	3:20						38		51:40
	100	3:20						44		57:40
	110	3:20						49		62:40
	120	2:20				3		53		69:20
110 33.5	20	3:40								3:40
	40	3:40						12		21:00
	50	3:40						19		28:00
	60	3:40						26		35:00
	70	3:40						33		47:00
	80	2:40				1		40		55:00
	90	2:40				2		46		62:00
	100	2:40				5		51		70:00
	110	2:40				12		54		80:00

Table 9-9. Surface Decompression Table Using Oxygen (Continued).

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) breathing air at water stops (feet/meters)				Surface Interval	Time at 40-foot chamber stop (min) on oxygen	Surface	Total decompression time (min:sec)
			60 18.2	50 15.2	40 12.1	30 9.1				
120 **36.5**	15	4:00					TOTAL TIME FROM LAST WATER STOP TO FIRST CHAMBER STOP NOT TO EXCEED 5 MINUTES		1-MINUTE 20 SECONDS ASCENT FROM 40 FEET IN CHAMBER TO SURFACE	4:00
	30	4:00						9		18:20
	40	4:00						16		25:20
	50	4:00						24		33:20
	60	3:00				2		32		48:20
	70	3:00				4		39		57:20
	80	3:00				5		46		65:20
	90	3:00			3	7		51		75:20
	100	3:00			6	15		54		89:20
130 **39.6**	10	4:20								4:20
	30	4:20						12		21:40
	40	4:20						21		30:40
	50	3:20				3		29		41:40
	60	3:20				5		37		56:40
	70	3:20				7		45		66:40
	80	3:00			6	7		51		78:40
	90	3:00			10	12		56		92:40
140 **42.6**	10	4:40								4:40
	25	4:40						11		21:00
	30	4:40						15		25:00
	35	4:40						20		30:00
	40	3:40				2		24		36:00
	45	3:40				4		29		43:00
	50	3:40				6		33		54:00
	55	3:40				7		38		60:00
	60	3:40				8		43		66:00
	65	3:20			3	7		48		73:00
	70	3:00		2	7	7		51		82:00
150 **45.7**	5	5:00								5:00
	25	5:00						13		23:20
	30	5:00						18		28:20
	35	4:00				4		23		37:20
	40	3:40			3	6		27		46:20
	45	3:40			5	7		33		60:20
	50	3:20		2	5	8		38		68:20
	55	3:00	2	5	9	4		44		79:20

Table 9-9. Surface Decompression Table Using Oxygen (Continued).

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) breathing air at water stops (feet/meters)				Surface Interval	Time at 40-foot chamber stop (min) on oxygen	Surface	Total decompression time (min:sec)
			60 18.2	50 15.2	40 12.1	30 9.1				
160 48.7	5	5:20					**TOTAL TIME FROM LAST WATER STOP TO FIRST CHAMBER STOP NOT TO EXCEED 5 MINUTES**		**1-MINUTE 20 SECONDS ASCENT FROM 40 FEET IN CHAMBER TO SURFACE**	5:20
	20	5:20						11		21:40
	25	5:20						16		26:40
	30	4:20				2		21		33:40
	35	4:00			4	6		26		46:40
	40	3:40		3	5	8		32		63:40
	45	3:20	3	4	8	6		38		74:40
170 51.8	5	5:40								5:40
	20	5:40						13		24:00
	25	5:40						19		30:00
	30	4:20			3	5		23		42:00
	35	4:00		4	4	7		29		55:00
	40	3:40	4	4	8	6		36		74:00

Table 9-10. *Surface Decompression Table Using Air.*

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) at water stops (feet/meters)			Surface Interval	Chamber stops (air) (min) (feet/meters)		Total decompression time (min:sec)
			30 9.1	20 6.0	10 3.0		20 6.0	10 3.0	
40 12.1	230	1:00			3			7	15:20
	250	1:00			3			11	19:20
	270	1:00			3			15	23:20
	300	1:00			3			19	27:20
50 15.2	120	1:20			3			5	13:40
	140	1:20			3			10	18:40
	160	1:20			3			21	29:40
	180	1:20			3			29	37:40
	200	1:20			3			35	43:40
	220	1:20			3			40	48:40
	240	1:20			3			47	55:40
60 18.2	80	1:40			3			7	16:00
	100	1:40			3			14	23:00
	120	1:40			3			26	35:00
	140	1:40			3			39	48:00
	160	1:40			3			48	57:00
	180	1:40			3			56	65:00
	200	1:20		3			3	69	81:30
70 21.3	60	2:00			3			8	17:20
	70	2:00			3			14	23:20
	80	2:00			3			18	27:20
	90	2:00			3			23	32:20
	100	2:00			3			33	42:20
	110	1:40		3			3	41	53:50
	120	1:40		3			4	47	60:50
	130	1:40		3			6	52	67:50
	140	1:40		3			8	56	73:50
	150	1:40		3			9	61	79:50
	160	1:40		3			13	72	94:50
	170	1:40		3			19	79	107:50
80 24.3	50	2:20			3			10	19:40
	60	2:20			3			17	26:40
	70	2:20			3			23	32:40
	80	2:00		3			3	31	44:10
	90	2:00		3			7	39	56:10
	100	2:00		3			11	46	67:10
	110	2:00		3			13	53	76:10
	120	2:00		3			17	56	83:10
	130	2:00		3			19	63	92:10
	140	2:00		26			26	69	128:10
	150	2:00		32			32	77	148:10

Table 9-10. Surface Decompression Table Using Air (Continued).

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) at water stops (feet/meters)			Surface Interval	Chamber stops (air) (min) (feet/meters)		Total decompression time (min:sec)
			30 9.1	20 6.0	10 3.0		20 6.0	10 3.0	
90 27.4	40	2:40			3			7	17:00
	50	2:40			3			18	28:00
	60	2:40			3			25	35:00
	70	2:20		3			7	30	47:30
	80	2:20		13			13	40	73:30
	90	2:20		18			18	48	91:30
	100	2:20		21			21	54	103:30
	110	2:20		24			24	61	116:30
	120	2:20		32			32	68	139:30
	130	2:00	5	36			36	74	158:30
100 30.4	40	3:00			3			15	25:20
	50	2:40		3			3	24	37:50
	60	2:40		3			9	28	47:50
	70	2:40		3			17	39	66:50
	80	2:40		23			23	48	101:50
	90	2:20	3	23			23	57	113:50
	100	2:20	7	23			23	66	126:50
	110	2:20	10	34			34	72	157:50
	120	2:20	12	41			41	78	179:50
110 33.5	30	3:20			3			7	17:40
	40	3:00		3			3	21	35:10
	50	3:00		3			8	26	45:10
	60	3:00		18			18	36	80:10
	70	2:40	1	23			23	48	103:10
	80	2:40	7	23			23	57	118:10
	90	2:40	12	30			30	64	144:10
	100	2:40	15	37			37	72	169:10
120 35.5	25	3:40			3			6	17:00
	30	3:40			3			14	25:00
	40	3:20		3			5	25	41:30
	50	3:20		15			15	31	69:30
	60	3:00	2	22			22	45	99:30
	70	3:00	9	23			23	55	118:30
	80	3:00	15	27			27	63	140:30
	90	3:00	19	37			37	74	175:30
	100	3:00	23	45			45	80	201:30

Table 9-10. Surface Decompression Table Using Air (Continued).

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) at water stops (feet/meters)					Surface Interval	Chamber stops (air) (min) (feet/meters)		Total decompression time (min:sec)
			50 15.2	40 12.1	30 9.1	20 6.0	10 3.0		20 6.0	10 3.0	
130 39.6	25	4:00					3			10	21:20
	30	3:40				3			3	18	32:50
	40	3:40				10			10	25	53:50
	50	3:20			3	21			21	37	90:50
	60	3:20			9	23			23	52	115:50
	70	3:20			16	24			24	61	133:50
	80	3:00		3	19	35			35	72	172:50
	90	3:00		8	19	45			45	80	205:50
140 42.6	20	4:20					3			6	17:40
	25	4:00				3			3	14	29:10
	30	4:00				5			5	21	40:10
	40	3:40			2	16			16	26	69:10
	50	3:40			6	24			24	44	107:10
	60	3:40			16	23			23	56	127:10
	70	3:20		4	19	32			32	68	164:10
	80	3:20		10	23	41			41	79	203:10
150 45.7	20	4:20				3			3	7	22:30
	25	4:20				4			4	17	34:30
	30	4:20				8			8	24	49:30
	40	4:00			5	19			19	33	85:30
	50	4:00			12	23			23	51	118:30
	60	3:40		3	19	26			26	62	145:30
	70	3:40		11	19	39			39	75	192:30
	80	3:20	1	17	19	50			50	84	230:30
160 48.7	20	4:40				3			3	11	26:50
	25	4:40				7			7	20	43:50
	30	4:20			2	11			11	25	58:50
	40	4:20			7	23			23	39	101:50
	50	4:00		2	16	23			23	55	128:50
	60	4:00		9	19	33			33	69	172:50
	70	3:40	1	17	22	44			44	80	217:50
170 51.8	15	5:00				3			3	5	21:10
	20	5:00				4			4	15	33:10
	25	4:40			2	7			7	23	49:10
	30	4:40			4	13			13	26	66:10
	40	4:20		1	10	23			23	45	112:10
	50	4:20		5	18	23			23	61	140:10
	60	4:00	2	15	22	37			37	74	197:10
	70	4:00	8	17	19	51			51	86	242:10

Table 9-10. Surface Decompression Table Using Air (Continued).

Depth feet/meters	Bottom time (min)	Time to first stop or surface (min:sec)	Time (min) at water stops (feet/meters)					Surface Interval	Chamber stops (air) (min) (feet/meters)		Total decompression time (min:sec)
			50	40	30	20	10		20	10	
			15.2	12.1	9.1	6.0	3.0		6.0	3.0	
180 **54.8**	15	5:20				3			3	6	22:30
	20	5:00			1	5			5	17	38:30
	25	5:00			3	10			10	24	57:30
	30	5:00			6	17			17	27	77:30
	40	4:40		3	14	23			23	50	123:30
	50	4:20	2	9	19	30			30	65	165:30
	60	4:20	5	16	19	44			44	81	219:30
190 **57.9**	15	5:40				4			4	7	25:50
	20	5:20			2	6			6	20	44:50
	25	5:20			5	11			11	25	62:50
	30	5:00		1	8	19			19	32	89:50
	40	5:00		8	14	23			23	55	133:50
	50	4:40	4	13	22	33			33	72	187:50
	60	4:40	10	17	19	50			50	84	240:50

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10-4.3 **Special Procedures.** In the event there is a switch to air during the NITROX dive, using the diver's maximum depth and bottom time follow the U.S. Navy Air Decompression Table for the actual depth of the dive.

10-4.4 **Omitted Decompression.** In the event that the loss of gas required a direct ascent to the surface, any decompression requirements must be addressed using the standard protocols for "omitted decompression." For omitted decompression dives that exceed the maximum depth listed on Table 10-1, the diving supervisor must rapidly calculate the diver's EAD and follow the omitted decompression procedures based on the diver's EAD, not his or her actual depth. If time will not permit this, the diving supervisor can elect to use the diver's actual depth and follow the omitted decompression procedures.

10-4.5 **Dives Exceeding the Normal Working Limit.** The EAD Table has been developed to restrict dives with a ppO_2 greater than 1.4 ata and limits dive duration based on CNS oxygen toxicity. Dives exceeding the normal working limits of Table 10-1 require the Commanding Officer's authorization and are restricted to surface-supplied diving equipment only. All Equivalent Air Depths provided below the normal working limit line have the maximum allowable exposure time listed alongside. This is the maximum time a diver can safely spend at that depth and avoid CNS oxygen toxicity. Repetitive dives are not authorized when exceeding the normal working limits of Table 10-1.

10-5 NITROX REPETITIVE DIVING

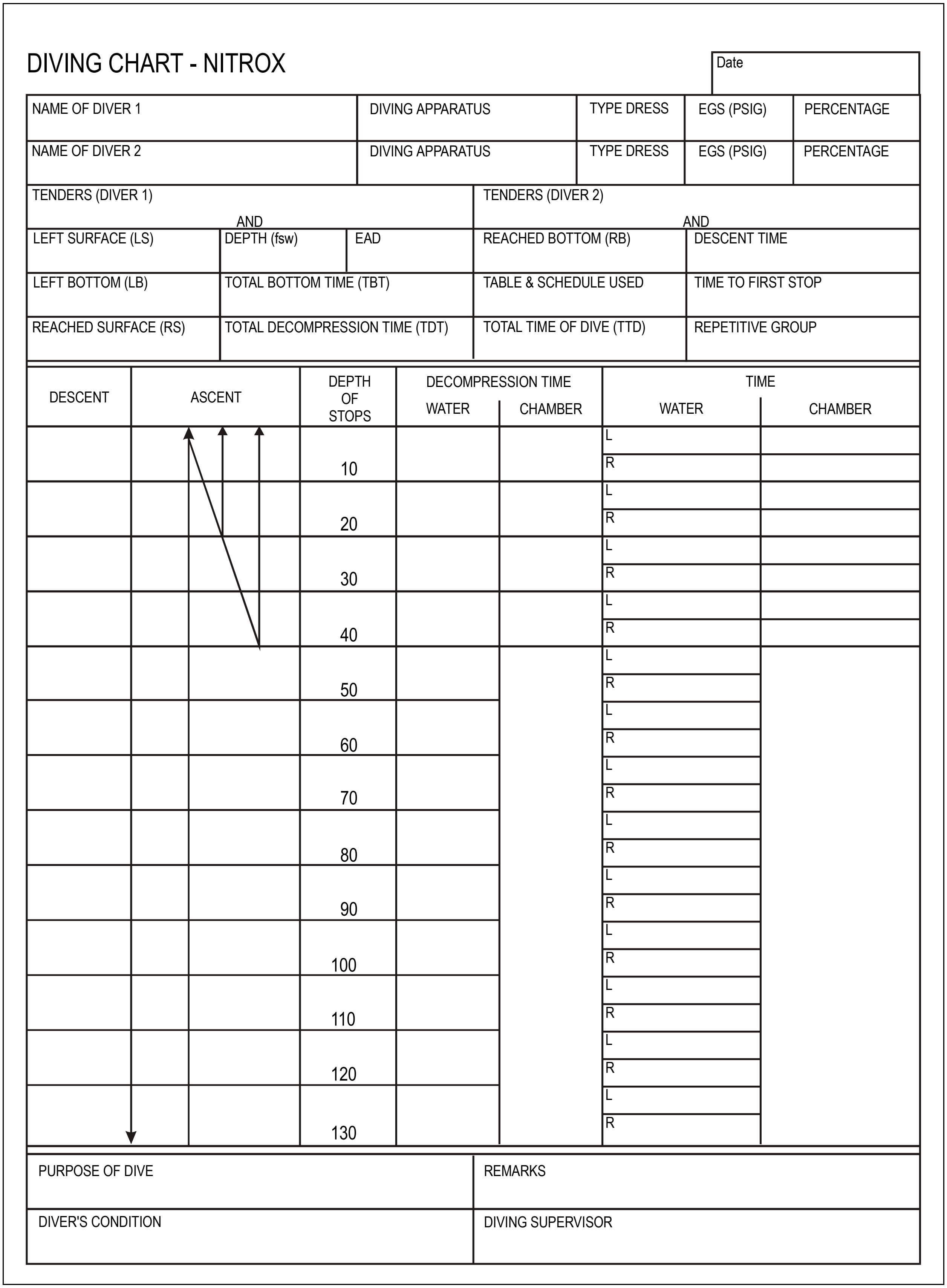
Repetitive diving is possible when using NITROX or combinations of air and NITROX. Once the EAD is determined for a specific dive, the Standard Navy Air Tables are used throughout the dive using the EAD from Table 10-1.

The Residual Nitrogen Timetable for Repetitive Air Dives will be used when applying the EAD for NITROX dives. Determine the Repetitive Group Designator for the dive just completed using either Table 9-7, Unlimited/No-Decompression Limits and Repetitive Group Designation Table for Unlimited/No-Decompression Air Dives or Table 9-8, U.S. Navy Standard Air Decompression Table.

Enter Table 9-7, Residual Nitrogen Timetable for Repetitive Air Dives, using the repetitive group designator. If the repetitive dive is an air dive, use Table 9-7 as is. If the repetitive dive is a NITROX dive, determine the EAD of the repetitive dive from Table 10-1 and use that depth as the repetitive dive depth.

10-6 NITROX DIVE CHARTING

The NITROX Diving Chart (Figure 10-1) should be used for NITROX diving and filled out as described in Chapter 9. The NITROX chart has additional blocks for the EAD and the percentage of gas in the NITROX mix.



DIVING CHART - NITROX

Date

NAME OF DIVER 1	DIVING APPARATUS	TYPE DRESS	EGS (PSIG)	PERCENTAGE
NAME OF DIVER 2	DIVING APPARATUS	TYPE DRESS	EGS (PSIG)	PERCENTAGE

TENDERS (DIVER 1) AND	TENDERS (DIVER 2) AND

LEFT SURFACE (LS)	DEPTH (fsw)	EAD	REACHED BOTTOM (RB)	DESCENT TIME
LEFT BOTTOM (LB)	TOTAL BOTTOM TIME (TBT)		TABLE & SCHEDULE USED	TIME TO FIRST STOP
REACHED SURFACE (RS)	TOTAL DECOMPRESSION TIME (TDT)		TOTAL TIME OF DIVE (TTD)	REPETITIVE GROUP

DESCENT	ASCENT	DEPTH OF STOPS	DECOMPRESSION TIME		TIME	
			WATER	CHAMBER	WATER	CHAMBER
		10			L R	
		20			L R	
		30			L R	
		40			L R	
		50			L R	
		60			L R	
		70			L R	
		80			L R	
		90			L R	
		100			L R	
		110			L R	
		120			L R	
		130			L R	

PURPOSE OF DIVE	REMARKS
DIVER'S CONDITION	DIVING SUPERVISOR

Figure 10-1. NITROX Diving Chart.

10-7 FLEET TRAINING FOR NITROX

A Master Diver shall conduct training for NITROX diving prior to conducting NITROX diving operations. Actual NITROX dives are not required for this training. The following are the minimum training topics to be covered:

- Pulmonary and CNS oxygen toxicity associated with NITROX diving.
- EAD tables and their association with the Navy air tables.
- Safe handling of NITROX mixtures.

NITROX Charging and Mixing Technicians must be trained on the following topics:

- Oxygen handling safety.
- Oxygen analysis equipment.
- NITROX mixing techniques.
- NITROX cleaning requirements (MIL-STD-1330 Series).

10-8 NITROX DIVING EQUIPMENT

NITROX diving can be performed using a variety of equipment that can be broken down into two general categories: surface-supplied or closed- and open-circuit scuba. Closed-circuit scuba apparatus is discussed in Chapter 17.

10-8.1 **Open-Circuit Scuba Systems.** Open-circuit scuba systems for NITROX diving are identical to air scuba systems with one exception: the scuba bottles are filled with NITROX (nitrogen-oxygen) rather than air. There are specific regulators authorized for NITROX diving, which are identified on the ANU list. These regulators have been tested to confirm their compatibility with the higher oxygen percentages encountered with NITROX diving.

10-8.1.1 **Regulators.** Scuba regulators designated for NITROX use should be cleaned to the standards of MIL-STD-1330. Once designated for NITROX use and cleaned, the regulators should be maintained to the level of cleanliness outlined in MIL-STD-1330.

10-8.1.2 **Bottles.** Scuba bottles designated for use with NITROX should be oxygen cleaned and maintained to that level. The bottles should have a NITROX label in large yellow letters on a green background. Once a bottle is cleaned and designated for NITROX diving, it should not be used for any other type of diving (Figure 10-2).

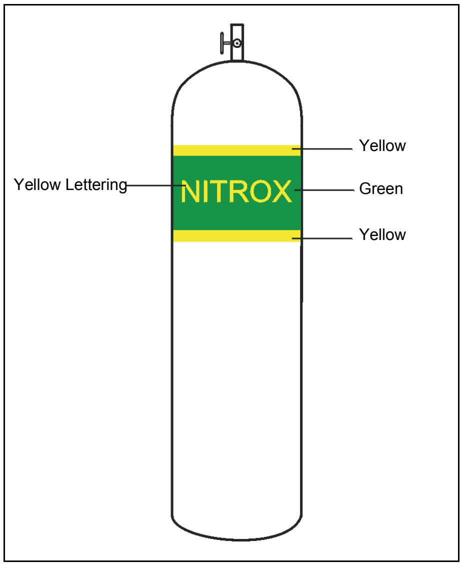


Figure 10-2. NITROX Scuba Bottle Markings.

10-8.2 **General.** All high-pressure flasks, scuba cylinders, and all high-pressure NITROX charging equipment that comes in contact with 100 percent oxygen during NITROX diving, mixing, or charging evolutions must be cleaned and maintained for NITROX service in accordance with the current MIL-STD-1330 series.

10-8.3 **Surface-Supplied NITROX Diving.** Surface-supplied NITROX diving systems must be modified to make them compatible with the higher percentage of oxygen found in NITROX mixtures. A request to convert the system to NITROX must be forwarded to NAVSEA 00C for review and approval. The request must be accompanied by the proposed changes to the Pre-survey Outline Booklet (PSOB) permitting system use with NITROX. Once the system is designated for NITROX, it shall be labeled NITROX with large yellow letters on a green background. MIL-STD-1330D outlines the cleanliness requirements to which a surface-supplied NITROX system must be maintained.

Once a system has been cleaned and designated for NITROX use, only air meeting the requirements of Table 10-2 shall be used to charge the system gas flasks. Air diving, using a NITROX designated system, is authorized if the air meets the purity requirements of Table 10-2.

The EGS used in surface-supplied NITROX diving shall be filled with the same mixture that is being supplied to the diver ± 0.5 percent.

10-9 EQUIPMENT CLEANLINESS

Cleanliness and the procedures used to obtain cleanliness are a concern with NITROX systems. MIL-STD-1330 is applicable to anything with an oxygen level higher than 25 percent by volume. Therefore, MIL-STD-1330 must be followed when dealing with NITROX systems. Personnel involved in the maintenance and repair of NITROX equipment shall complete an oxygen clean worker course, as described in MIL-STD-1330. Even with oxygen levels of 25 to 40 percent, there is still a greater risk of fire than with compressed air. Materials that would not normally burn in air may burn at these higher O_2 levels. Normally combustible materials require less energy to ignite and will burn faster. The energy required for ignition can come from different sources, for example adiabatic compression or particle impact/spark. Another concern is that if improper cleaning agents or processes are used, the agents themselves can become fire or toxic hazards. It is therefore important to adhere to MIL-STD-1330 to reduce the risk of damage or loss of equipment and injury or death of personnel.

10-10 BREATHING GAS PURITY

It is essential that all gases used in producing a NITROX mixture meet the breathing gas purity standards for oxygen (Table 4-3) and nitrogen (Table 4-5). If air is to be used to produce a mixture, it must be compressed using an oil free NITROX approved compressor or meet the purity requirements of oil free air (Table 10-2). Prior to diving, all NITROX gases shall be analyzed using an ANU approved O_2 analyzer accurate to within ± 0.5 percent.

10-11 NITROX MIXING

NITROX mixing can be accomplished by a variety of techniques to produce a final predetermined nitrogen-oxygen mixture. The techniques for mixing NITROX are listed as follows:

1. **Continuous Flow Mixing**. There are two techniques for continuous flow mixing:

    a. **Mix-maker**. A mix-maker uses a precalibrated mixing system that proportions the amount of each gas in the mixture as it is delivered to a common mixing chamber. A mix-maker performs a series of functions that ensures accurate mixtures. The gases are regulated to the same temperature and pressure before they are sent through precision metering valves. The valves are precalibrated to provide the desired mixing pressure. The final mixture can be provided directly to the divers or be compressed using an oil-free compressor into storage banks.

    b. **Oxygen Induction**. Oxygen induction uses a system where low pressure oxygen is delivered to the intake header of an oil-free compressor, where it is mixed with the air being drawn into the compressor. Oxygen flow is adjusted and the compressor output is monitored for oxygen content. When the desired NITROX mixture is attained the gas is diverted to the storage banks for diver use while being continually monitored for oxygen content (Figure 10-3).

2. **Mixing by Partial Pressure**. Partial pressure mixing techniques are similar to those used in helium-oxygen mixed gas diving and are discussed in Chapter 16.

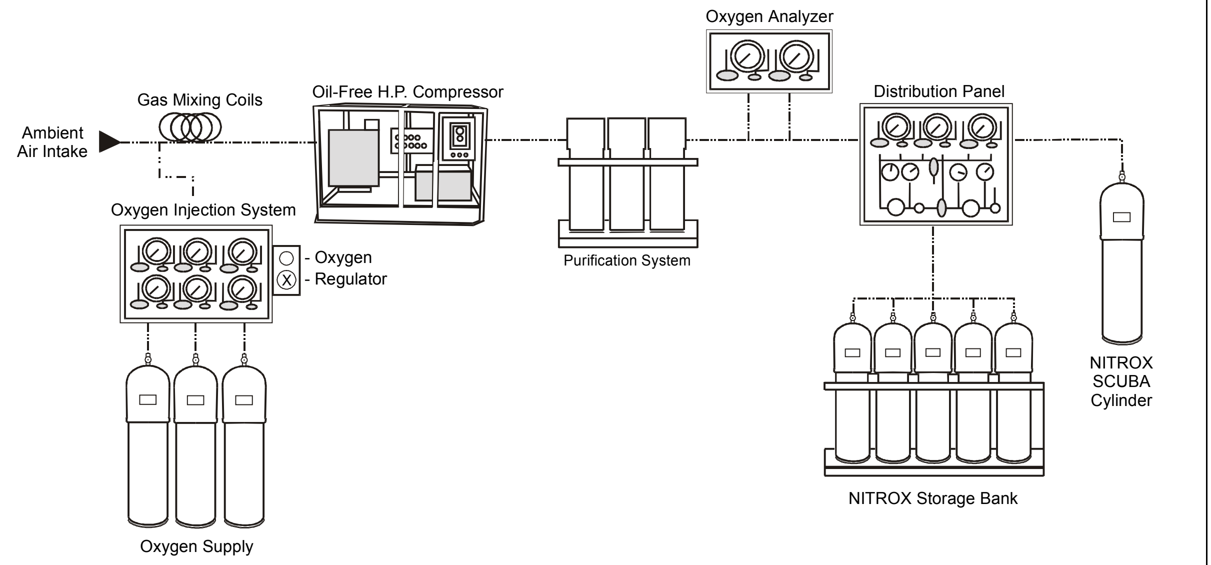


Figure 10-3. NITROX O_2 Injection System.

a. **Partial Pressure Mixing with Air.** Oil-free air can be used as a Nitrogen source for the partial pressure mixing of NITROX using the following procedures:

- Prior to charging air into a NITROX bottle, the NITROX mixing technician shall smell, taste, and feel the oil-free air coming from the compressor for signs of oil, mist, or particulates, or for any unusual smell. If any signs of compressor malfunction are found, the system must not be used until a satisfactory air sample has been completed.
- Prior to charging with oxygen, to produce a NITROX mix, the NITROX-charging technician shall charge the bottle to at least 100 psi with oil-free air. This will reduce the risk of adiabatic compression temperature increase. Once 100 psi of oil-free air has been added to the charging vessel, the required amount of oxygen should then be added. The remaining necessary amount of oil-free air can then be safely charged into the bottle. The charging rate for NITROX mixing shall not exceed 200 psi per minute.

WARNING **Mixing contaminated or non-oil free air with 100% oxygen can result in a catastrophic fire and explosion.**

- Compressed air for NITROX mixing shall meet the purity standards for "Oil Free Air," (Table 10-2). All compressors producing air for NITROX mixing shall have a filtration system designed to produce oil-free air that has been approved by NAVSEA 00C3. In addition, all compressors producing oil-free air for NITROX charging shall have an air sample taken within 90 days prior to use.

Table 10-2. *Oil Free Air.*

Constituent	**Specification**
Oxygen (percent by volume)	20-22%
Carbon dioxide (by volume)	500 ppm (max)
Carbon monoxide (by volume)	2 ppm (max)
Total hydrocarbons [as Methane (CH_4) by volume]	25 ppm (max)
Odor	Not objectionable
Oil, mist, particulates	0.1 mg/m^3 (max)
Separated Water	None
Total Water	0.02 mg/1 (max)
Halogenated Compounds (by volume):	
Solvents	0.2 ppm (max)

3. **Mixing Using a Membrane System**. Membrane systems selectively separate gas molecules of different sizes such as nitrogen or oxygen from the air. By removing the nitrogen from the air in a NITROX membrane system the oxygen percent is increased. The resulting mixture is NITROX. Air is fed into an in-line filter canister system that removes hydrocarbons and other contaminants. It is then passed into the membrane canister containing thousands of hollow membrane fibers. Oxygen permeates across the membrane at a controlled rate. The amount of nitrogen removed is determined by a needle valve. Once the desired nitrogen-oxygen ratio is achieved, the gas is diverted through a NITROX approved compressor and sent to the storage banks (see Figure 10-4 and Figure 10-5). Membrane systems can also concentrate CO_2 and argon.

4. **Mixing Using Molecular Sieves**. Molecular sieves are columns of solid, highly selective chemical absorbent which perform a similar function to membrane systems, and are used in a similar fashion. Molecular sieves have the added advantage of absorbing CO_2 and moisture from the feed gas.

5. **Purchasing Premixed NITROX**. Purchasing premixed NITROX is an acceptable way of obtaining a NITROX mixture. When purchasing premixed NITROX it is requisite that the gases used in the mixture meet the minimum purity standards for oxygen (Table 4-3) and nitrogen (Table 4-5).

10-12 NITROX MIXING, BLENDING, AND STORAGE SYSTEMS

NITROX mixing, blending, and storage systems shall be designed for oxygen service and constructed using oxygen-compatible material following accepted military and commercial practices in accordance with either ASTM G-88, G-63, G-94, or MIL-STD-438 and -777. Commands should contact NAVSEA 00C for specific guidance on developing NITROX mixing, blending, or storage systems. Commands are not authorized to build or use a NITROX system without prior NAVSEA 00C review and approval.

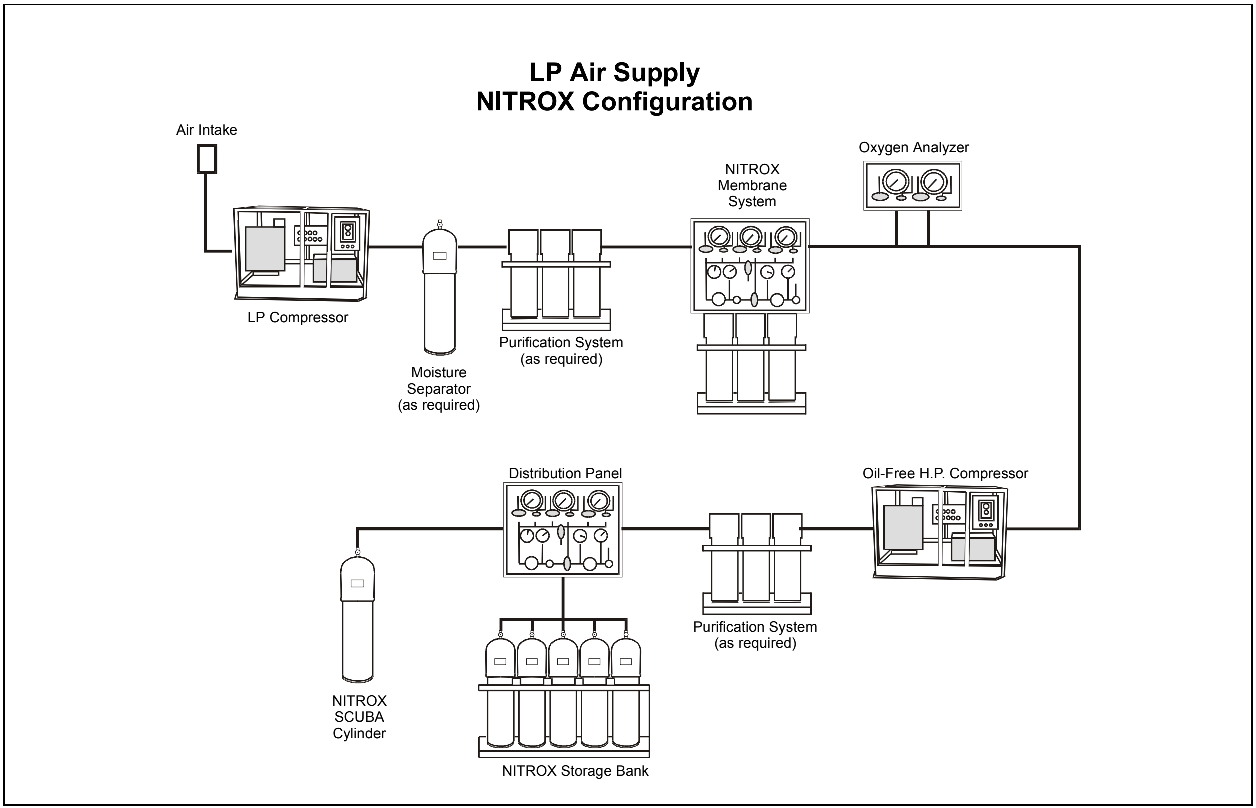


Figure 10-4. LP Air Supply NITROX Membrane Configuration.

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15 SATURATION DIVING

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CHAPTER 13

Mixed Gas Operational Planning

13-1 INTRODUCTION

13-1.1 Purpose. This chapter discusses the planning associated with mixed gas diving operations. Most of the provisions in Chapter 6, Operations Planning, also apply to mixed gas operations and should be reviewed for planning. In planning any mixed gas operation, the principles and techniques presented in this chapter shall be followed.

13-1.2 Scope. This chapter outlines a comprehensive planning process that may be used in whole or in part to effectively plan and execute diving operations in support of military operations.

13-1.3 Additional Sources of Information. This chapter is not the only source of information available to the diving team when planning mixed gas diving operations. Operation and maintenance manuals for the diving equipment, intelligence reports, and oceanographic studies all contain valuable planning information. The nature of the operation will dictate the procedures to be employed and the planning and preparations required for each. While it is unlikely that even the best planned operation can ever anticipate all possible contingencies, attention to detail in planning will minimize complications that could threaten the success of a mission.

13-1.4 Complexity of Mixed Gas Diving. Mixed gas diving operations are complex, requiring constant support and close coordination among all personnel. Due to extended decompression obligations, mixed gas diving can be hazardous if not properly planned and executed. Seemingly minor problems can quickly escalate into emergency situations, leaving limited time to research dive protocols or operational orders to resolve the situation. Each member of the diving team must be qualified on his watch station and be thoroughly competent in executing applicable operating and emergency procedures. Safety is important in any diving operation and must become an integral part of all operations planning.

13-1.5 Medical Considerations. The Diving Officer, Master Diver, and Diving Supervisor must plan the operation to safeguard the physical and mental well being of each diver. All members of the team must thoroughly understand the medical aspects of mixed gas, oxygen, and saturation diving. A valuable source of guidance in operations planning is the Diving Medical Officer (DMO), a physician trained specifically in diving medicine and physiology.

Mixed gas diving entails additional risks and procedural requirements for the diver and the support team. At the surface, breathing a medium other than air causes physiological changes in the body. When a diver breathes an unusual medium under increased pressure, additional alterations in the functioning of the mind and body may occur. Each diver must be aware of the changes that can occur and how they may affect his performance and safety. Mixed gas diving procedures that minimize the effects of these changes are described in this and the following chapters. Every mixed gas diver must be thoroughly familiar with these procedures.

Typical medical problems in mixed gas and oxygen diving include decompression sickness, oxygen toxicity, thermal stress, and carbon dioxide retention. Deep saturation diving presents additional concerns, including high pressure nervous syndrome (HPNS), dyspnea, compression arthralgia, skin infections, and performance decrements. These factors directly affect the safety of the diver and the outcome of the mission and must be addressed during the planning stages of an operation. Specific information concerning medical problems particular to various mixed gas diving modes are contained in Volume 5.

13-2 ESTABLISH OPERATIONAL TASKS

Preparing a basic outline and schedule of events for the entire operation ensures that all phases will be properly coordinated. This chapter gives specific guidelines that should be considered when analyzing the operational tasks. Mixed gas diving requires additional considerations in the areas of gas requirements, decompression, and medical support.

Mixed gas diving requires a predetermined supply of breathing gases and carbon dioxide absorbent material. Operations must be planned thoroughly to determine usage requirements in order to effectively obtain required supplies in port or at sea prior to the start of the mission. See paragraph 13-3.10 and Table 13-1 for specific gas/material requirements. Logistic requirements may include planning for on-site resupply of mixed gases and other supplies and for relief of diving teams from Fleet units. Consult unit standing operating procedures for resupply guidance and personnel procurement (refer to OPNAVINST 3120.32 [series]).

Table 13-1. *Average Breathing Gas Consumption Rates.*

Diving Equipment	Gas Consumption (Normal)	Gas Consumption (Heavy Work)
MK 21 MOD 0 UBA MK 21 MOD 1 UBA EXO BR MS UBA MK 22 MOD 0 UBA	1.4 acfm (demand) 6.0 acfm (free flow)	2.5 acfm (demand) 6.0 acfm (free flow)

13-3 SELECT DIVING METHOD AND EQUIPMENT

Selecting the appropriate diving method is essential to any diving operations planning. The method will dictate many aspects of an operation including personnel and equipment.

13-3.1 **Mixed Gas Diving Methods.** Mixed gas diving methods are defined by the type of mixed gas diving equipment that will be used. The three types of mixed gas diving equipment are:

- Surface supplied gear (MK 21 MOD 1, EXO BR MS)
- Semiclosed circuit and closed circuit UBAs
- Saturation deep dive systems

For deep dives (190-300 fsw) of short duration, or for shallower dives where nitrogen narcosis reduces mental acuity and physical dexterity, helium-oxygen diving methods should be employed.

Because of the unusual hazards incurred by long exposures to extreme environmental conditions, extended excursions away from topside support, and great decompression obligations, semiclosed circuit and closed circuit diving should only be undertaken by specially trained divers. Semiclosed circuit and closed circuit diving operations are covered in depth in Volume 4.

Saturation diving is the preferred method for dives deeper than 300 fsw or for shallow dives where extensive in-water times are required. Disadvantages of saturation diving include the requirement for extensive logistic support and the inability of the support ship to easily shift position once the mooring is set. For this reason, it is very important that the ship be moored as closely over the work site as possible. Using side-scan sonar, remotely operated vehicles (ROVs) or precision navigation systems will greatly aid in the successful completion of the operation. Saturation diving is discussed in Chapter 15.

13-3.2 **Method Considerations.** In mixed gas diving, the principle factors influencing the choice of a particular method are:

- Depth and planned duration of the dive
- Equipment availability
- Quantities of gas mixtures available
- Qualifications and number of personnel available
- Type of work and degree of mobility required
- Environmental considerations such as temperature, visibility, type of bottom, current, and pollution levels
- Communication requirements
- Need for special operations procedures

13-3.3 **Depth.** Equipment depth limitations are contained in Table 13-2. The limitations are based on a number of interrelated factors such as decompression obligations, duration of gas supply and carbon dioxide absorbent material, oxygen tolerance, and the possibility of nitrogen narcosis when using emergency gas (air). Divers must be prepared to work at low temperatures and for long periods of time.

Table 13-2. *Equipment Operational Characteristics.*

Diving Equipment	Normal Working Limit (fsw)	Maximum Working Limit (fsw)	Chamber Requirement	Minimum Personnel
MK 21 MOD 1 UBA EXO BR MS UBA	300 (HeO_2) (Note 1)	380 (HeO_2) (Note 1)	On station (Note 2)	12
MK 21 MOD 0 UBA MK 22 MOD 0 UBA	950	950	Part of system	21 (7 per watch)

Notes:

1. Depth limits are based on considerations of working time, decompression obligation, oxygen tolerance and nitrogen narcosis.
2. An on-station chamber is defined as a certified and ready chamber at the dive site.

Operations deeper than 300 fsw usually require Deep Diving Systems (DDSs). The decompression obligation upon the diver is of such length that in-water decompression is impractical. Using a personnel transfer capsule (PTC) to transport divers to a deck decompression chamber (DDC) increases the margin of diver safety and support-ship flexibility.

13-3.4 **Bottom Time Requirements.** The nature of the operation may influence the bottom time requirements of the diver. An underwater search may be best undertaken by using multiple divers with short bottom times or by conducting a single bounce dive simply to identify a submerged object. Other tasks, such as underwater construction work, may require numerous dives with long bottom times requiring surface supplied or saturation diving techniques. Although primarily intended to support deep diving operations, saturation diving systems may be ideal to support missions as shallow as 150 fsw where the nature of the work is best accomplished using several dives with extended bottom times. Under these conditions, time is saved by eliminating in-water decompression obligations for each diver and by reducing the number of dive team changes, thus compensating for the increased logistical complexity such operations entail.

13-3.5 **Environment.** Environmental conditions play an important role in planning mixed gas diving operations. Environmental factors, such as those addressed in Chapter 6, should be considered when planning such operations. Mixed gas diving operations often involve prolonged dives requiring lengthy decompression and travels that carry divers great distances from a safe haven. Special attention should therefore be given to preventing diver hypothermia. Mixed gas diving apparatus are designed to minimize thermal stress, but the deepest, longest helium-oxygen dives place the greatest stress on the diver. Exposure to extreme surface conditions prior to the dive may leave the diver in a thermally compromised state. A diver who has been exposed to adverse environmental conditions should not be considered for mixed gas diving until complete rewarming of the diver has taken place, as shown by sweating, normal pulse, and return of normal core temperature. Subjective thermal comfort does not accurately indicate adequate rewarming.

13-3.6 **Mobility.** Some diving operations may dictate the use of a diving method that is selected as a result of special mobility requirements in addition to depth, bottom time and logistical requirements. The MK 21 MOD 1 is the preferred method when operations require mobility in the water column (see Figure 13-1).

Figure 13-1. Searching Through Aircraft Debris on the Ocean Floor.

For missions where mobility is an essential operating element and depth and bottom time requirements are great, closed circuit diving may be the only available option. Such diving is frequently required by special warfare and/or explosive ordnance disposal (EOD) personnel.

13-3.7 **Equipment Selection.** Equipment and supplies available for mixed gas diving operations by U.S. Navy personnel have been tested under stringent conditions to ensure that they will perform according to design specifications under the most difficult conditions that may be encountered. Several types of equipment are available for mixed gas operations. Equipment selection is based upon the chosen diving method, depth of the dive and the operation to be performed. Table 13-3 outlines the differences between equipment configurations.

The UBA MK 21 MOD 0 is an open circuit, demand-regulated diving helmet designed for saturation, mixed gas diving at depths in excess of 300 fsw and as

Table 13-3. *Mixed Mixed gasGas Diving Equipment.*

Type	Principal Applications	Minimum Personnel	Advantages	Disadvantages	Restrictions and Depth Limits
MK 21 MOD 1 EXO BR MS (Notes 1 & 3)	Deep search, inspection and repair.	12 (Note 3)	Horizontal mobility. Voice communications.	Support craft required. High rate of gas consumption.	Normal 300 fsw. Maximum: 380 fsw with CNO authorization.
MK 21 MOD 0 (Note 2)	Saturation diving search, salvage, and repair. Extensive bottom time.	21 (7 per watch) (Note 4)	Maximum diver safety. Bottom time efficiency. Maximum comfort. Continuous personnel monitoring.	Slow deployment. Large support craft and crew. Limited mobility. High rate of gas consumption.	Varies with DDS certification
MK 22 MOD 0 (Note 2)	Standby diver for PTC.	21 (7 per watch) (Note 4)	Collapsible for storage in PTC.	Slow deployment. Large support craft and crew. Limited mobility. High rate of gas consumption.	Varies with DDS certification

Notes:
1. surface supplied deep-sea
2. Saturation UBA
3. Minimum personnel consists of topside support and one diver in the water
4. Varies according to manning requirements of deep dive system

deep as 950 fsw. With the exception of the demand regulator, it is functionally identical to the UBA MK 21 MOD 1, which is used for air and mixed gas diving. The regulator for the MK 21 MOD 0 helmet is the Ultraflow 500, which provides improved breathing resistance and gas flow over the MK 21 MOD 1.

The UBA MK 22 MOD 0 is an open circuit, demand-regulated, band-mask version of the UBA MK 21 MOD 0. It is used for the standby diver for saturation, mixed gas diving at depths in excess of 300 fsw and as deep as 950 fsw. It is provided with a hood and head harness instead of the helmet shell to present a smaller profile for storage.

13-3.8 **Operational Characteristics.** Equipment operational characteristics are reviewed in Table 13-2 and specific equipment information can be found in paragraph 13-8.

All diving equipment must be certified or authorized for Navy use. Authorized equipment is listed in the NAVSEA/00C Authorized for Navy Use (ANU) list. For proper operation and maintenance of U.S. Navy approved diving equipment, refer to the appropriate equipment operation and maintenance manual.

13-3.9 **Support Equipment and ROVs.** In addition to the UBA, support equipment must not be overlooked. Items commonly used include tools, underwater lighting, power sources, and communications systems. The Coordinated Shipboard Allowance List (COSAL) for the diving platform is a reliable source of support equipment. Commercial resources may also be available.

Occasionally, a mission is best undertaken with the aid of a remotely operated vehicle (ROV). ROVs offer greater depth capabilities with less risk to personnel but at the expense of the mobility, maneuverability, and versatility that only manned operations can incorporate.

13-3.9.1 **Types of ROV.** There are two types of ROVs, tethered and untethered. Tethered ROVs receive power, control signals, and data through an umbilical. Untethered ROVs can travel three to five times faster than tethered ROVs, but because their energy source must be contained in the vehicle their endurance is limited. ROVs used in support of diving operations must have ground fault interrupter (GFI) systems installed to protect the divers.

13-3.9.2 **ROV Capabilities.** Currently, much of the Fleet's requirements for observation diving are being met by using ROVs. They have been used for search and salvage since 1966. State-of-the-art ROVs combine short-range search, inspection, and recovery capabilities in a single system. A typical ROV system includes a control and display console, a power source, a launch and retrieval system, and the vehicle itself. Tethered systems are connected to surface support by an umbilical that supplies power, control signals and data. Untethered search systems that will greatly increase current search rates with extended endurance rates of 24 hours or more are currently under development. Figure 13-2 shows a typical NAVSEA ROV.

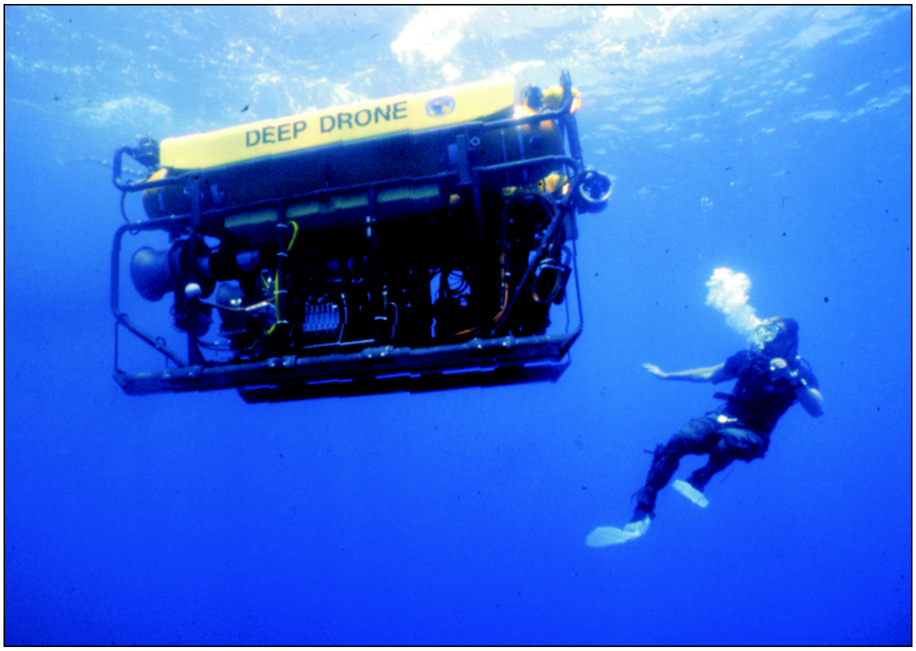

Figure 13-2. Remotely Operated Vehicle (ROV) Deep Drone.

13-3.10 **Diver's Breathing Gas Requirements.** In air diving, the breathing mixture is readily available, although pump and compressor capacities and the availability of back-up systems may impose operational limitations. The primary requirement for mixed gas diving is that there be adequate quantities of the appropriate gases on hand, as well as a substantial reserve, for all phases of the operation. The initial determinations become critical if the nearest point of resupply is far removed from the operation site.

13-3.10.1 **Gas Consumption Rates.** The gas consumption rates and carbon dioxide absorbent durations for various types of underwater breathing apparatus are shown in Table 13-1. Refer to Chapter 4 for required purity standards.

13-3.10.2 **Surface Supplied Diving Requirements.** For surface supplied diving, the diver gas supply system is designed so that helium-oxygen, oxygen, or air can be supplied to the divers as required. All surface supplied mixed gas diving systems require a primary and secondary source of breathing medium consisting of helium-oxygen and oxygen in cylinder banks and an emergency supply of air from compressors or high-pressure flasks. Each system must be able to support the gas flow and pressure requirements of the specified equipment. The gas capacity of the primary system must meet the consumption rate of the designated number of divers for the duration of the dive. The secondary system must be able to support recovery operations of all divers and equipment if the primary system fails. This may occur immediately prior to completing the planned bottom time at maximum depth when decompression obligations are the greatest. Emergency air supply is provided in the event all mixed gas supplies are lost.

13-3.10.3 **Deep Diving System Requirements.** A deep diving system must be able to store and supply enough gas to support saturation diving to the maximum certified depth. Deep diving systems can handle and store pure gases, and mix the required percentages of helium-oxygen as needed. When DDS type equipment is employed, additional quantities of gas must be included for DDC and PTC charging and for replacing losses due to leakage, transfer trunk and service lock usage and scrubber cycling. A DDS must also have an air system capable of supporting surface supplied air diving operations and initial pressurization of the DDS for saturation operations.

13-4 SELECTING AND ASSEMBLING THE DIVE TEAM

Selecting a properly trained team for a particular diving mission is critical. Refer to Chapter 6 for an expanded discussion on dive team selection, as well as the criteria for selecting qualified personnel for various tasks. It is critical to ensure that only formally qualified personnel are assigned. The Diving Officer, Master Diver, and Diving Supervisor must verify the qualification level of each team member. The size and complexity of deep dive systems reinforces the need for a detailed and comprehensive watch station qualification program.

13-4.1 **Diver Training.** Training must be given the highest command priority. The command that dives infrequently, or with insufficient training and few work-up dives between operations, will be ill prepared in the event of an emergency. The dive team must be exercised on a regular diving schedule using both routine and nonroutine drills to remain proficient not only in the water but on topside support tasks as well. Cross-training ensures that divers are qualified to substitute for one another when circumstances warrant.

13-4.2 **Personnel Requirements.** To ensure a sufficient number of properly trained and qualified individuals are assigned to the most critical positions on a surface supplied mixed gas dive station, the following minimum stations shall be manned by formally trained (NDSTC) mixed gas divers:

- Diving Officer
- Diving Medical Officer (required on site for all dives exceeding the normal working limit)
- Master Diver
- Diving Supervisor
- Diving Medical Technician

All other assignments to a surface supplied mixed gas dive station shall be filled in accordance with Table 13-4.

13-4.3 **Diver Fatigue.** Fatigue will predispose a diver to decompression sickness. A tired diver is not mentally alert. Mixed gas dives shall not be conducted using a fatigued diver. The command must ensure that all divers making a mixed gas dive are well rested prior to the dive. All divers making mixed gas dives must have at least 8 hours of sleep within the last 24 hours before diving.

13-5 BRIEFING THE DIVE TEAM

Large personnel requirements and the increased complexities of mixed gas diving operations make comprehensive briefings of all personnel extremely important. For mixed gas surface supplied operations, briefings of each day’s schedule are appropriate. In addition, during saturation diving operations, a dive protocol is required to be read and signed in accordance with the unit’s instructions. The briefing should cover all aspects of the operation including communications, equipment, gas supply, and emergencies such as fouling and entrapment. Each diving member should understand his own role as well as that of his diving companions and the support crew (Figure 13-3).

While the operation is in progress, divers returning to the surface or to the PTC should be promptly debriefed. This ensures that topside personnel are kept advised of the progress of the dive and have the information necessary to modify the dive plan or protocol as appropriate.

Table 13-4. *Surface Supplied Mixed Gas Dive Team*

	Deep-Sea (MK 21, EXO BR MS)	
Designation	**One Diver**	**Two Divers**
Diving Officer	1 (Note 1)	1 (Note 1)
Diving Medical Officer	1 (Notes 1 and 4)	1 (Notes 1 and 4)
Diving Supervisor/Master Diver	1 (Notes 1 and 5)	1 (Notes 1 and 5)
Diving Medical Technician	1 (Notes 1 and 6)	1 (Notes 1 and 6)
Diver	1 (Note 2)	2 (Note 2)
Standby Diver	1 (Note 2)	1 (Note 2)
Tender	3 (Note 2)	5 (Note 2)
Timekeeper/Recorder	1 (Note 2)	1 (Note 2)
Rack Operator	1 (Note 2)	1 (Note 2)
Winch Operator	1 (Note 3)	1 (Note 3)
Console Operator	1 (Note 2)	1 (Note 2)
Total Personnel Required	12	15

Notes:

1. To ensure sufficient properly trained and qualified individuals are assigned to the most critical positions on a surface supplied mixed gas dive station, the following minimum stations shall be manned by formally trained (NDSTC) mixed gas divers:

   Diving Officer
   Diving Medical Officer
   Master Diver
   Diving Supervisor
   Diving Medical Technician

2. The following stations shall be manned by formally trained (NDSTC) surface supplied divers:

   Diver
   Standby Diver
   Rack Operator
   Console Operator
   Timekeeper/Recorder

3. The following stations should be a qualified diver. When circumstances require the use of a non-diver, the Diving Officer, Master Diver, and Diving Supervisor must ensure that the required personnel has been thoroughly instructed in the required duties. These stations include:

   Tender
   Standby Tender
   Winch Operator

4. A Diving Medical Officer is required on site for all dives exceeding the normal working limit.
5. Master Diver may serve as the Diving Officer if so designated in writing by the Commanding Officer.
6. Diving Medical Technician required when no Diving Medical Officer is available.

Figure 13-3. Dive Team Brief for Divers.

13-6 FINAL PREPARATIONS AND SAFETY PRECAUTIONS

Prior to the start of a mixed gas diving operation, it is important to check that all necessary preparations have been made and that all safety precautions have been checked. This ensures that the diving team is properly supported in its mission and that all possible contingencies have been evaluated in case an unexpected circumstance should arise.

13-7 RECORD KEEPING

Chapter 5 describes the objectives and importance of maintaining accurate records. The Diving Officer, Master Diver, and Diving Supervisor should identify the records required for their respective systems and tailor them to suit their needs. The purpose of any record is to provide an accurate and detailed account of every facet of the diving operation and a tabulation of supplies expended to support the operation (e.g., gases, carbon dioxide absorbent, etc.). Any unusual circumstances regarding dive conduct (i.e., treatments, operational/emergency procedures, or deviation from procedures) established in the U.S. Navy Diving Manual shall be brought to the attention of the Commanding Officer and logged in the Command Smooth Diving Log.

13-8 MIXED GAS DIVING EQUIPMENT

There are several modes of diving that are characterized by the diving equipment used. The following descriptions outline capabilities and logistical requirements for various mixed gas diving systems.

13-8.1 **Minimum Required Equipment.** Minimum required equipment for the pool phase of dive training conducted at Navy diving schools may be modified as necessary. Any modifications to the minimum required equipment listed herein must be noted in approved lesson training guides.

Minimum Equipment:

1. MK 21 MOD 1 helmet or EXO BR MS full face mask with tethered umbilical
2. Thermal protection garment
3. Weight belt
4. Dive knife
5. Swim fins or shoes/booties
6. EGS bottle with submersible tank pressure gauge
7. Integrated diver's vest/harness

13-8.2 MK 21 MOD 1 and EXO BR MS Surface Supplied Helium-Oxygen Description.

Principle of Operation:

Surface supplied open circuit mixed gas (HeO_2) system

Operational Considerations:

1. Adequate mixed gas supply
2. Master Diver required on station for mixed gas operations
3. Diving Medical Officer required on-site for dives deeper than 300 fsw
4. Recompression chamber required on site
5. Planned exceptional exposure dives or dives exceeding normal working limits require CNO approval
6. Breathing gas heater
7. Hot water suit

Figure 13-4. MK 21 MOD 1 UBA.

CHAPTER 14

Surface Supplied Mixed Gas Diving Procedures

14-1 INTRODUCTION

14-1.1 **Purpose.** The purpose of this chapter is to familiarize divers with the U.S. Navy surface supplied mixed gas diving procedures.

14-1.2 **Scope.** Surface supplied, open circuit mixed gas diving is conducted with helium oxygen mixtures supplied from the surface by a flexible hose. Surface supplied mixed gas diving is particularly suited for operations beyond the depth limits of air diving, yet short of the depths and times requiring the use of a saturation diving system. Surface supplied mixed gas diving is also useful in the air diving range when freedom from nitrogen narcosis is required.

14-2 PLANNING THE OPERATION

Planning surface supplied mixed gas dives involves many of the same considerations used when planning an air dive. Planning aspects that are unique to surface supplied mixed gas diving include the logistics of providing several different gas mixtures to the diver and repetitive diving limitations discussed below.

14-2.1 **Depth and Exposure Limits.** The normal operational limit for surface supplied mixed gas diving is 300 fsw for 30 minutes.

Within each decompression table (Table 14-3), exceptional exposure dives are enclosed in bold black boxes to separate them from normal working dives. Exceptional exposure dives require lengthy decompression and are associated with an increased risk of decompression sickness and exposure to the elements. Exceptional exposures should be undertaken only at the Commanding Officer’s discretion in an emergency. Planned exceptional exposure dives require prior CNO approval.

Repetitive diving is not allowed in surface supplied helium oxygen diving, except as outlined in paragraph 14-3.6. Following a "no-decompression dive" the diver must wait 12 hours before making a second dive. Following a decompression dive, the diver must wait 18 hours. To minimize pulmonary oxygen toxicity effects, a diver should take a one day break after four consecutive days of diving.

14-2.2 **Ascent to Altitude.** Following a no-decompression dive, the diver must wait 12 hours before ascent to altitude. Following a decompression dive, the diver must wait 24 hours.

14-2.3 **Water Temperature.** Loss of body temperature (hypothermia) can be a major problem during long, deep dives. A hot water suit is preferred for surface supplied dives in cold water.

14-2.4 **Gas Mixtures.** Four gas mixtures are required to dive the surface supplied mixed gas tables over their full range:

1. Bottom Mixture - The bottom mixture may vary from 90% helium 10% oxygen to 60% helium 40% oxygen depending on the diver's depth. The allowable range of bottom mixtures for each depth is shown in Table 14-3.

- 50% Helium 50% Oxygen - This mixture is used from 90 fsw to 40 fsw during decompression. Oxygen concentration in the mixture may range from 49 to 51 percent.

- 100% Oxygen - Oxygen is used at the 30 and 20 fsw water stops during inwater decompression and at 50, 40 and 30 fsw in the chamber during surface decompression.

- Air - Air is used as an emergency backup gas throughout the dive and to provide air breaks during oxygen breathing.

Helium oxygen mixtures must be analyzed for oxygen content with an instrument having an accuracy of ±0.5 percent.

14-2.5 **Emergency Gas Supply.** All divers are equipped with an emergency gas supply (EGS). The EGS gas mixture shall be the same as the bottom mixture unless the bottom mixture contains less than 16 percent oxygen, in which case the EGS gas mixture may range from 15 to 17 percent oxygen. The EGS shall be an adequately charged ANU approved scuba cylinder. An adequately charged scuba cylinder is defined as: the pressure that provides sufficient gas to bring the diver to his first decompression stop or the surface for no-decompression dives. It is assumed that this will give topside personnel enough time to perform required emergency procedures to restore surface supplied air.

14-3 SURFACE SUPPLIED HELIUM OXYGEN DESCENT AND ASCENT PROCEDURES

The surface supplied Helium Oxygen Decompression Table (Table 14-3) is used to decompress divers from surface supplied helium oxygen dives. The table is in a depth time format similar to the U.S. Navy Air Decompression Table and is used in a similar fashion

14-3.1 **Selecting the Bottom Mix.** The Surface Supplied Helium Oxygen Decompression Table (Table 14-3) specifies maximum and minimum concentrations of oxygen allowable in the helium oxygen mixture at depth. The maximum oxygen concentration has been selected so that the diver never exceeds an oxygen partial pressure of 1.3 ata while on the bottom. The minimum oxygen percentage allowed in the mixture is 14 percent for depths to 200 fsw and 10 percent for depths in excess of 200 fsw. Diving with a mixture near maximum oxygen percentage is encouraged as it offers a decompression advantage to the diver. For operational planning, the range of possible depths should be established and a mixture selected that will meet the maximum/minimum specification across the depth range.

14-3.2 **Selecting the Decompression Schedule.** To select a proper decompression table and schedule, measure the deepest depth reached by the diver and enter the table at the exact or next greater depth. When using a pneumofathometer to measure depth, correct the observed depth reading as shown in Table 14-1. Ensure the pneumofathometer is located at mid-chest level.

Table 14-1. *Pneumofathometer Correction Factors*

Pneumofathometer Depth Reading	Correction Factor
0-100 fsw	+1 fsw
101-200	+2 fsw
201-300	+4 fsw
301-400	+7 fsw

Example.

The diver's pneumofathometer reads 250 fsw. In the depth range of 201-300 fsw, the pneumofathometer underestimates the diver's depth by 4 fsw. To determine a diver’s depth, add 4 fsw to the pneumofathometer reading giving the diver’s depth as 254 fsw.

Bottom time is measured as the time from leaving the surface to leaving the bottom, rounded up to the next whole minute, except as noted in paragraph 14-3.5. Enter the table at the exact or next greater bottom time.

14-3.3 **Travel Rates.** The descent rate is not critical, but it should not exceed 75 fsw/min. Ascent to the first stop, between stops, and during final ascent to the surface is at a constant rate of 30 fsw/min except as outlined in paragraph 14-3.11. For all but the first stop the ascent time between stops is included in the time of the subsequent stop. For all but the first stop, stop time begins when the diver leaves the previous stop.

14-3.4 **Decompression Breathing Gases.** Decompress on bottom mixture to 90 fsw, then shift the diver to a 50% helium 50% oxygen mixture. Upon arrival at the 30 fsw stop, shift the diver to 100% oxygen.

For all dives, surface decompression may be used after completing the 40 fsw water stop as described in paragraph 14-3.11. During surface decompression, the diver surfaces while breathing 50% helium 50% oxygen.

14-3.5 **Special Procedures for Descent with Less than 16 Percent Oxygen.** To prevent hypoxia, a special descent procedure is required when the bottom mixture contains less than 16% oxygen:

1. Place the diver on air on the surface.

2. Make the appropriate predive checks.

3. Have the diver descend to 20 fsw.

4. At 20 fsw, shift the diver to the bottom mix and ventilate the diver for 20 seconds.

5. Confirm the diver is on bottom mix, then perform a final leak check. The diver is allowed 5 minutes to descend to 20 fsw, shift to the bottom mixture and perform equipment checks.

6. Have the diver begin descent.

7. Start bottom time.

- If the diver spends 5 minutes or less performing above procedures, bottom time starts when the diver leaves 20 fsw.

- If the diver spends more than 5 minutes performing above procedures, bottom time starts at the 5 minute mark.

8. If it is necessary to bring the diver back to the surface from 20 fsw to correct a problem:

- Shift the diver from the bottom mixture back to air.

- Ventilate the diver.

- Confirm the diver is on air.

- Have the diver begin ascent.

- When the diver reenters the water, the 5 minute grace period begins again. No adjustment of bottom time is required for the previous exposure at 20 fsw.

14-3.6 **Aborting Dive During Descent.** Inability to equalize the ears or sinuses may force the dive to be aborted during descent.

1. If it is necessary to bring the diver back to the surface from depths of 100 fsw and shallower:

- Ensure the diver is in a no-decompression status.

- If the bottom mixture is 16% oxygen or greater, ascend directly to the surface at 30 fsw/min.

- If the bottom mixture is less than 16% oxygen, ascend to 20 fsw at 30 fsw/min.

- Shift the diver from the bottom mixture back to air.
- Ventilate the diver.
- Confirm the diver is on air.
- Have the diver begin ascent to the surface.
- If desired, another dive may be performed following a dive aborted 100 fsw and shallower. Add the bottom time of the aborted dive to the bottom time of the new dive when calculating a table and schedule for the new dive.

2. If it is necessary to abort a dive deeper than 100 fsw:

- Follow the normal decompression schedule to the surface.
- Repetitive diving is not allowed following a dive aborted deeper than 100 fsw.

14-3.7 **Procedures for Shifting to 50 Percent Helium/50 Percent Oxygen at 90 fsw.** All dives except no-decompression dives require a shift from bottom mixture to 50% helium 50% oxygen at 90 fsw during decompression. Follow these steps:

1. Shift the console to 50% helium 50% oxygen when the diver reaches 90 fsw.
2. If there is a decompression stop at 90 fsw, ventilate each diver for 20 seconds at 90 fsw.
3. Confirm the divers are on 50% helium 50% oxygen
4. If there is no decompression stop at 90 fsw, delay ventilation until arrival at the next shallower stop.

Gas shift time is included in the stop time.

14-3.8 **Procedures for Shifting to 100 Percent Oxygen at 30 fsw.** All in-water decompression dives require a shift to 100 percent oxygen at the 30 fsw stop. Upon arrival at the stop, ventilate each diver with oxygen following these steps:

1. Shift the console to 100% oxygen when the diver reaches 30 fsw.
2. Ventilate each diver for 20 seconds.
3. Verify the diver's voice change.

Gas shift time is included in the stop time.

14-3.9 **30 fsw and 20 fsw Water Stops.** At the 30 fsw and 20 fsw water stops, the diver breathes oxygen for 30 minute periods separated by 5 minute air breaks. The air breaks do not count toward required decompression time. When an air break is required, shift the console to air for 5 minutes then back to 100% oxygen. Ventilation of the divers is not required. If the final oxygen breathing period is 35 minutes or less, the final air break is not required.

Example

1. Divers follow in-water decompression on a 220 fsw for 20 minute decompression schedule as outlined in Table 14-3.
2. Upon leaving the 40 fsw water stop, the divers start their 23 minute 30 fsw water stop time.
3. Upon reaching the 30 fsw water stop, the divers are shifted to 100% oxygen and ventilated.
4. At 23 minutes, calculated from the time the divers left their 40 fsw water stop, the divers travel to 20 fsw to complete their 41 minute 20 fsw water stop.
5. Seven minutes from the time the divers left their 30 fsw water stop, the console is shifted to air. This is due to completing a total of 30 minutes from leaving the 40 fsw stop. No ventilation is required.
6. After five minutes on air, the console is shifted back to oxygen. No ventilation is required.
7. Since the remaining oxygen time is less than 35 minutes, the divers breathe oxygen for the last 34 minutes prior to ascent to the surface. Divers remain on oxygen for ascent.

14-3.10 **Ascent from the 20 fsw Water Stop.** For normal in-water decompression, the diver surfaces from 20 fsw on oxygen. Ascent rate is 30 fsw/min.

14-3.11 **Surface Decompression Procedures (SUR D).** Surface decompression procedures are preferred over in-water decompression procedures for routine operations. SUR D procedures improve the diver's comfort and safety. A diver is eligible for surface decompression when he has completed the 40 fsw water stop. To initiate surface decompression:

1. Bring the diver to the surface at 40 fsw/min and undress him.
2. Place the diver in the recompression chamber. Use of an inside tender when two divers undergo surface decompression is at the discretion of the dive supervisor. If an inside tender is not used, both divers will carefully monitor each other in addition to being closely observed by topside personnel.
3. Compress on air to 50 fsw at a maximum compression rate of 100 fsw/min and place the diver on 100 percent oxygen by mask. The mask will be strapped on both divers to ensure a good oxygen seal.

WARNING **The interval from leaving 40 fsw in the water to arriving at 50 fsw in the chamber cannot exceed 5 minutes.**

4. In the chamber, have the divers breathe oxygen for 30 minute periods separated by 5-minute air breaks. The number of oxygen periods required is indicated in Table 14-3. The first period consists of 15 minutes on oxygen at 50 fsw followed by 15 minutes on oxygen at 40 fsw. Periods 2, 3, and 4 are spent at 40 fsw. Periods 5, 6, 7 and 8 are spent at 30 fsw. Ascent from 50 to 40 and from 40 to 30 fsw is at 30 fsw/min. Ascent time is included in the oxygen/air time. Ascent from 40 to 30 fsw, if required, should take place during the air break.

5. When the last oxygen breathing period has been completed, return the diver to breathing chamber air.

6. Ascend to the surface at a rate of 30 fsw/min.

14-3.12 **Variation in Rate of Ascent.** The rate of ascent to the first stop and between subsequent stops is 30 fsw/minute. Minor variations in the rate of travel between 20 and 40 fsw/minute are acceptable.

14-3.12.1 **Early arrival at the first stop:** If the divers arrive early at the first stop:

1. Begin timing the first stop when the required travel time has been completed

2. If the first stop requires a gas shift, initiate the gas shift and ventilation upon arrival at the stop, but begin the stop time only when the required travel time has been completed.

14-3.12.2 **Delays in Arriving at the First Stop.**

1. Delay less than 1 minute. Delays in arrival at the first stop of less than 1 minute may be ignored.

2. For delays in excess of 1 minute:

   - Round up the delay to the next whole minute.
   - Add the rounded up delay time to the bottom time.
   - Recalculate the required decompression.

   — If no change in schedule is required, continue on the planned decompression.

   — If a change in schedule is required and the new schedule calls for a decompression stop or stops deeper than the diver's current depth, perform any missed deeper stops at the diver's current depth. Do not go deeper.

Example

If the delay time to arrival at the first stop is 3 minutes and 25 seconds, round up to the next whole minute and add 4 minutes to the bottom time. Recheck the decompression table to see if the decompression stop depths or times have changed.

14-3.12.3 Delays in Leaving a Stop or Arrival at the Next Stop.

- Delays Deeper than 90 fsw.

  1. Delays less than 1 minute may be ignored.

  2. Greater than 1 minute. Add the delay to the bottom time and recalculate the required decompression. If a new schedule is required, pick up the new schedule at the present stop or subsequent stop if the delay occurs between stops. Ignore any missed stops or time deeper than the depth at which the delay occurred. If a delay occurs between stops, restart subsequent stop time at completion of the delay.

- Delays 90 fsw and shallower:

  1. Delays less than 1 minute may be ignored.

  2. Delays greater than 1 minute require no special action except as described below under special considerations when decompressing with high oxygen partial pressure. Resume the normal decompression schedule at the completion of the delay. If a delay occurs between stops, restart subsequent stop time at completion of the delay.

- Special considerations when decompressing with high oxygen partial pressure:

  1. Delays greater than 5 minutes between 90 and 70 fsw. Shift the diver to air to avoid the risk of CNS oxygen toxicity. At the completion of the delay, return the diver to 50% helium 50% oxygen. Add the time on air to the bottom time and recalculate the required decompression. If a new schedule is required, pick up the new schedule at the present stop or subsequent stop if delay occurs between stops. Ignore any missed stops or time deeper than the depth at which the delay occurred.

  2. Delays leaving the 30 fsw stop. Delays greater than 1 minute leaving your 30 fsw stop shall be subtracted from your 20 fsw stop time.

14-3.12.4 **Delays in Travel from 40 fsw to the Surface for Surface Decompression.** Disregard any delays in travel from 40 fsw to the surface during surface decompression unless the diver exceeds the 5-minute surface interval. If the diver exceeds the 5-minute surface interval, treat the diver for omitted decompression (see paragraph 14-4.12).

14-4 SURFACE SUPPLIED HELIUM OXYGEN EMERGENCY PROCEDURES

In surface supplied mixed gas diving, specific procedures are used in emergency situations. The following paragraphs detail these procedures. Other medical/physiological factors that surface supplied mixed gas divers need to consider are covered in detail in Volume 5. The U.S. Navy Treatment Tables are also presented in Volume 5.

14-4.1 Bottom Time in Excess of the Table.

In the rare instance of diver entrapment or umbilical fouling, bottom times may exceed 120 minutes, the longest value shown in the table. When it is foreseen that bottom time will exceed 120 minutes, immediately contact the Navy Experimental Diving Unit for advice on which decompression procedure to follow. If advice cannot be obtained in time:

1. Decompress the diver using the 120 minute schedule for the deepest depth attained.
2. Shift to 100 percent oxygen at 40 fsw.
3. Surface the diver after completing 30 minutes on oxygen at 40 fsw. Oxygen time at 40 fsw starts when divers are confirmed on oxygen.
4. Compress the diver to 60 fsw in the chamber as fast as possible not to exceed 100 fsw/min.
5. Treat the diver on an extended Treatment Table 6 (Table 21-8). Extend Treatment Table 6 for two oxygen breathing periods at 60 fsw (20 minutes on oxygen, then 5 minutes on air, then 20 minutes on oxygen) and two oxygen breathing periods at 30 fsw (60 minutes on oxygen, then 15 minutes on air, then 60 minutes on oxygen).

14-4.2 Loss of Helium Oxygen Supply on the Bottom. Follow this procedure if the umbilical helium oxygen supply is lost on the bottom:

1. Shift the diver to the emergency gas system (EGS).
2. Abort the dive.
3. Remain on the EGS until arrival at 90 fsw.
4. At 90 fsw, shift the diver to 50% helium 50% oxygen and complete the decompression as planned.
5. If the EGS becomes exhausted before 90 fsw is reached, shift the diver to air, complete decompression to 90 fsw, shift the diver to 50% helium 50% oxygen, and continue the decompression as planned.

14-4.3 **Loss of 50 Percent Oxygen Supply During In-Water Decompression.** If the diver cannot be shifted to 50% helium 50% oxygen at 90 fsw or the 50% helium 50% oxygen supply is lost during decompression:

1. Shift the diver to air and continue the decompression as planned while trying to correct the problem.

2. Shift the diver to 50% helium 50% oxygen once the problem is corrected. Time spent on air counts toward decompression.

3. If the problem cannot be corrected:

   - Continue the planned decompression on air.
   - Shift the diver from air to oxygen upon arrival at the 50 fsw stop.
   - Breathe oxygen at 50 and 40 fsw for the decompression times indicated in (Table 14-3), but not to exceed 16 minutes at 50 fsw. Oxygen time at 50 fsw starts when divers are confirmed on oxygen. If the 50 fsw stop exceeds 16 minutes, travel divers to 40 fsw and add remaining 50 fsw stop time to your 40 fsw stop time on oxygen.
   - Surface decompress per paragraph 14-3.11 following completion of the 40 fsw stop.

14-4.4 **Loss of Oxygen Supply During In-Water Decompression.** If the diver cannot be shifted to oxygen at 30 fsw or the oxygen supply is lost during the 30 or 20 fsw water stops:

1. Switch back to 50% helium 50% oxygen. If a switch to 50% helium 50% oxygen is not possible, switch the diver to air.

2. If the problem can be quickly remedied, reventilate the diver with oxygen and resume the schedule at the point of interruption. Consider any time on helium oxygen or air as dead time.

3. If the problem cannot be remedied, initiate surface decompression. Ignore any time already spent on oxygen at 30 or 20 fsw. The five minute surface interval requirement for surface decompression begins upon leaving the 30 or 20 fsw stop.

4. If the problem cannot be remedied and surface decompression is not feasible, complete the decompression on 50% helium 50% oxygen or air. For 50% helium 50% oxygen, double the remaining oxygen time at each water stop. For air, triple the remaining oxygen time.

Example.

A diver loses oxygen 15 minutes into the 30 fsw water stop and is switched back to the 50% helium 50% oxygen decompression mixture. The problem cannot be corrected. The divers original schedule called for 32 minutes of oxygen at 30 fsw and 58 minutes of oxygen at 20 fsw.

Solution.

Seventeen minutes of oxygen time (32 - 15) remain at 30 fsw. Fifty-eight minutes remain at 20 fsw. The diver should spend an additional 34 minutes (17 x 2) at 30 fsw on the 50/50 mixture, followed by 116 minutes (58 x 2) at 20 fsw. Surface the diver on completing the 20 fsw stop.

14-4.5 **Loss of Oxygen Supply in the Chamber During Surface Decompression.** If the oxygen supply in the chamber is lost during surface decompression, have the diver breathe chamber air.

- Temporary Loss. Return the diver to oxygen breathing. Consider any time on air as dead time.
- Permanent Loss. Multiply the remaining oxygen time by three to obtain the equivalent chamber decompression time on air. If 50% helium 50% oxygen is available, multiply the remaining oxygen time by two to obtain the equivalent chamber decompression time on 50/50. If the loss occurred at 50 or 40 fsw, allocate 10% of the equivalent air or helium oxygen time to the 40 fsw stop, 20% to the 30 fsw stop, and 70% to the 20 fsw stop. If the diver is at 50 fsw, ascend to 40 fsw to begin the stop time. If the loss occurred at 30 fsw, allocate 30% of the equivalent air or helium oxygen time to the 30 fsw stop and 70% to the 20 fsw stop. Round the stop times up to the next whole minute. Surface upon completion of the 20 fsw stop.

Example.

The oxygen supply to the chamber is lost 10 minutes into the first 30 minute period on oxygen. Helium oxygen is not available. The original surface decompression schedule called for three 30 min oxygen breathing periods (total of 90 minutes of oxygen). The diver is at 50 fsw.

Solution.

The remaining oxygen time is 80 minutes (90-10). The equivalent chamber decompression time on air is 240 minutes (3 x 80). The 240 minutes of air stop time should be allocated as follows: Twenty-four minutes at 40 fsw (240 x 0.1), 48 minutes at 30 fsw (240 x 0.2), and 168 minutes at 20 fsw (240 x 0.7). As addressed above, the diver should ascend from 50 to 40 fsw and begin the 24 minute stop time at 40 fsw.

14-4.6 **Decompression Gas Supply Contamination.** If the decompression gas supply becomes contaminated with the bottom mixture, 50/50 mix, air, or oxygen:

1. Find the source of the contamination and correct the problem. Probable sources include:

- An improper valve line-up on the console. This can be verified by checking oxygen percentage on console oxygen analyzer.
- Accidental opening of the emergency gas supply (EGS) valve.

2. When the problem is corrected:

   - Ventilate each diver for 20 seconds and confirm divers are on decompression gas.
   - Continue decompression as planned. Do not lengthen stop times to compensate for the time spent correcting the problem.

14-4.7 CNS Oxygen Toxicity Symptoms (Nonconvulsive) at the 90-60 fsw Water Stops.

CNS oxygen toxicity symptoms are unlikely but possible while the diver is breathing 50% helium 50% oxygen in the water at depths 60 fsw and deeper. If symptoms of oxygen toxicity do appear, take the following actions:

1. Bring the divers up 10 feet and shift to air to reduce the partial pressure of oxygen. Shift the console as the divers are traveling.

2. Ventilate both divers upon arrival at the shallower stop. Ventilate the stricken diver first.

3. Remain at the shallower stop until the missed time at the previous stop is made up.

4. Resume the planned decompression breathing air.

5. Upon arrival at the next shallower stop, return the divers to the 50% helium 50% oxygen mixture. Ignore any missed time on the 50/50 mixture. A recurrence of symptoms is highly unlikely because of the reduced oxygen partial pressure at the shallower depth.

Example.

Red Diver has an oxygen toxicity symptom 5 minutes into his scheduled 9 minute 80 fsw stop. The stage with both divers travels to 70 fsw and the console is shifted to air. Upon arrival at 70 fsw, Red diver is ventilated for 20 seconds followed by Green diver. The divers remain at 70 fsw for the remaining 4 minutes left from their 80 fsw stop and then start their 10 minute scheduled 70 fsw stop time at the completion of the 4 minutes. Upon reaching 60 fsw, the console is shifted back to their 50/50 mixture and both divers are ventilated.

14-4.8 Oxygen Convulsion at the 90-60 fsw Water Stop. If symptoms of oxygen toxicity progress to an oxygen convulsion at 90-60 fsw despite the measures taken above, a serious emergency has developed. Only general management guidelines can be presented here. Topside supervisory personnel must take whatever action they deem necessary to bring the casualty under control.

Follow these procedures when the diver is convulsing at the 90-60 fsw water stops:

1. Shift both divers to air if this action has not already been taken.

2. Have the unaffected diver ventilate himself and then ventilate the stricken diver.

3. If only one diver is in the water, launch the standby diver immediately and have him ventilate the stricken diver.

4. Hold the divers at depth until the tonic-clonic phase of the convulsion has subsided. The tonic-clonic phase of a convulsion generally lasts 1 to 2 minutes.

5. At the end of the tonic-clonic phase, have the dive partner or standby diver ascertain whether the diver is breathing. The presence or absence of breath sounds will also be audible over the intercom.

6. If the diver appears not to be breathing, have the dive partner or standby diver attempt to reposition the head to open the airway. Airway obstruction will be the most common reason why an unconscious diver fails to breathe.

7. If the affected diver is breathing, have the dive partner or standby diver tend the stricken diver and decompress both divers on air following the original schedule. Shift the divers to 50% helium 50% oxygen upon arrival at 50 fsw. Surface decompress upon completion of the 40 fsw water stop.

8. If it is not possible to verify that the affected diver is breathing, leave the unaffected diver at the stop to complete decompression, and surface the affected diver and the standby diver at 30 fsw/min. Shift the unaffected diver back to his 50/50 mixture for completion of decompression. The standby diver should maintain an open airway on the stricken diver during ascent. On the surface the affected diver should receive any necessary airway support and be immediately recompressed and treated for arterial gas embolism and missed decompression in accordance with Table 21-5 and Figure 21-5.

14-4.9 CNS Oxygen Toxicity Systems (Nonconvulsive) at 30 and 20 fsw Water Stops.

If the diver develops symptoms of CNS oxygen toxicity at the 30 or 20 fsw water stops, take the following action:

1. Shift the console to air and initiate surface decompression.

2. If surface decompression is not feasible, ventilate both divers with air and complete decompression in the water on air. Compute the remaining stop

times on air by tripling the remaining oxygen time at each stop. See paragraph 14-4.4 for an example.

14-4.10 Oxygen Convulsion at the 30 and 20 fsw Water Stop. If symptoms progress to an oxygen convulsion despite the above measures, a serious emergency has developed and the following actions must be taken.

1. Shift both divers to air and follow the guidance given in paragraph 14-4.8 for stabilizing the diver and determining whether he is breathing.
2. If the diver is breathing, hold him at depth until he is stable, then surface decompress.
3. If surface decompression is not feasible, ventilate both divers with air and complete decompression in the water on air. Compute the remaining stop times on air by tripling the remaining oxygen time at each stop. See paragraph 14-4.4 for an example.
4. If the diver is not breathing, surface the diver at 30 fsw/min while maintaining an open airway and treat the diver for arterial gas embolism (Figure 21-5).

14-4.11 Oxygen Toxicity Symptoms in the Chamber. At the first sign of CNS oxygen toxicity, the patient should be removed from oxygen and allowed to breathe chamber air. Fifteen minutes after all symptoms have completely subsided, resume oxygen breathing at the point of interruption. If symptoms of CNS oxygen toxicity develop again or if the first symptom is a convulsion, take the following action:

1. Remove the mask.
2. After all symptoms have completely subsided, decompress 10 feet at a rate of 1 fsw/min. For a convulsion, begin travel when the patient is fully relaxed and breathing normally.
3. Resume oxygen breathing at the shallower depth at the point of interruption.
4. If another oxygen symptom occurs, complete decompression on chamber air. Follow the guidance given in paragraph 14-4.5 for permanent loss of chamber oxygen supply to compute the air decompression schedule.

14-4.12 Asymptomatic Omitted Decompression. Certain emergencies may interrupt or prevent required decompression. Unexpected surfacing, exhausted gas supply and bodily injury are examples of such emergencies. Table 14-2 shows the initial management steps to be taken when the diver has an uncontrolled ascent.

14-4.12.1 **Blowup from a Depth Greater Than 50 fsw.** Blowup from a depth greater than 50 fsw when more than 60 minutes of decompression are missed is an extreme emergency. The diver shall be returned as rapidly as possible to the full depth of the dive or the deepest depth of which the chamber is capable, whichever is shallower.

Table 14-2. *Management of Asymptomatic Omitted Decompression*

Deepest Decompression Stop Omitted	Decompression Status	Surface Interval (Note 1)	ACTION
None	No decompression stops required	N/A	Observe on surface for one hour
	Stops required.	5 Minutes	.Follow SUR D procedure
	Within SUR D limits.	>5 minutes	
50 fsw or Shallower	Stops required. Not within SUR D limits.	Any	Compress to 60 fsw as fast as possible, not to exceed 100 fsw/min. Use Treatment Table 6.
	Stops required. Less than 60 minutes missed.	Any	
Deeper than 50 fsw	Stops required. Greater than 60 minutes missed	Any	Compress to depth of dive not to exceed 225 fsw. Use Treatment Table 8. For saturation systems: Compress to depth of dive. Saturate two hours. Use saturation decompression without an initial upward excursion

14-4.12.1.1 ***For Nonsaturation Systems.*** For nonsaturation systems, the diver shall be rapidly compressed on air to the depth of the dive or to 225 feet, whichever is shallower. For compressions deeper than 165 feet, remain at depth for 30 minutes. For compressions to 165 feet and shallower, remain at depth for a minimum of two hours. Decompress on USN Treatment Table 8 for Deep Blowup (Figure 21-12). While deeper than 165 feet, a helium oxygen mixture with 16 percent to 21 percent oxygen, if available, may be breathed by mask to reduce narcosis.

14-4.12.1.2 ***For Saturation Systems.*** For saturation systems, initial rapid compression on air to 60 fsw, followed by compression on pure helium to the full depth of the dive or deeper if symptom onset warrants. The diver shall breathe 84% helium/16% oxygen by mask during the compression (if possible) to avoid the possibility of hypoxia as a result of gas pocketing in the chamber. Once at the saturation depth, the length of time spent can be dictated by the circumstances of the diver, but should not be less than 2 hours. During this 2 hours, treatment gas should be administered to the diver as outlined in Chapter 15, paragraph 15-23.8.2. The chamber oxygen partial pressure should be allowed to fall passively to 0.44-0.48 ata. Begin saturation decompression without an upward excursion.

14-4.13 **Symptomatic Omitted Decompression.** If the diver develops symptoms of decompression sickness or gas embolism before recompression for omitted decompression can be accomplished, immediate treatment using the appropriate oxygen or air recompression table is essential. Guidance for table selection and use is given in Chapter 21. If the depth of the deepest stop omitted was greater than 50 fsw and more than 60 minutes of decompression have been missed, use of Treatment Table 8 for Deep Blowup or saturation treatment is indicated. On Treatment Tables 4 and 8, a 40-50% oxygen balance helium or nitrogen mixture may be breathed as treatment gas at 165 fsw and shallower. At 60 fsw and shallower, pure oxygen may be given to the diver as treatment gas. For all treatment gases (HeO_2, N_2O_2, and O_2) a schedule of 25 minutes on gas and 5 minutes on chamber air should be followed for four cycles. Additional oxygen may be given at 60 fsw and shallower after a 2 hour interval of chamber air. See USN Treatment Tables 4 and 7 (Chapter 21) for guidance on additional oxygen breathing.

In all cases of deep blowup, the services of a Diving Medical Officer shall be sought at the earliest possible moment.

14-4.14 **Light Headed or Dizzy Diver on the Bottom.** Dizziness is a common term used to describe a number of feelings, including light headedness, unsteadiness, vertigo (a sense of spinning), or the feeling that one might pass out. There are a number of potential causes of dizziness in surface supplied diving, including hypoxia, a gas supply contaminated with toxic gases such as methylchloroform, and trauma to the inner ear caused by difficult clearing of the ear. At the low levels of oxygen percentage specified for surface supplied diving, oxygen toxicity is an unlikely cause unless the wrong gas has been supplied to the diver.

14-4.14.1 **Initial Management.** The first step to take is to have the diver stop work and ventilate the rig while topside checks the oxygen content of the supply gas. These actions should eliminate hypoxia and hypercapnia as a cause. If ventilation does not improve symptoms, the cause may be a contaminated gas supply. Shift banks to the standby helium oxygen supply and continue ventilation. If the condition clears, isolate the contaminated bank for future analysis and abort the dive on the standby gas supply. If the entire gas supply is suspect, place the diver on the EGS and abort the dive. Follow the guidance of paragraph 14-4.2 for ascents.

14-4.14.2 **Vertigo.** Vertigo due to inner ear problems will not respond to ventilation and in fact may worsen. One form of vertigo, however, alternobaric vertigo, may be so short lived that it will disappear during ventilation. Alternobaric vertigo will usually occur just as the diver arrives on the bottom and often can be related to a difficult clearing of the ear. It would be unusual for alternobaric vertigo to occur after the diver has been on the bottom for more than a few minutes. Longer lasting vertigo due to inner ear barotrauma will not respond to ventilation and will be accompanied by an intense sensation of spinning and marked nausea. Also, it is usually accompanied by a history of difficult clearing during the descent. These characteristic symptoms may allow the diagnosis to be made. A wide variety of ordinary medical conditions may also lead to dizziness. These conditions may occur while the diver is on the bottom. If symptoms of dizziness are not cleared by ventilation and/or shifting to alternate gas supplies, have the dive partner or standby diver assist the diver(s) and abort the dive.

14-4.15 **Unconscious Diver on the Bottom.** An unconscious diver on the bottom constitutes a serious emergency. Only general guidance can be given here. Management decisions must be made on site, taking into account all known factors. The advice of a Diving Medical Officer shall be obtained at the earliest possible moment.

If the diver becomes unconscious on the bottom:

1. Make sure that the breathing medium is adequate and that the diver is breathing. Verify manifold pressure and oxygen percentage.

2. Check the status of any other divers.

3. Have the dive partner or standby diver ventilate the afflicted diver to remove any accumulated carbon dioxide in the helmet and ensure the correct oxygen concentration.

4. If there is any reason to suspect gas contamination, shift to the standby helium oxygen supply and ventilate both divers, ventilating the non-affected diver first.

5. When ventilation is complete, have the dive partner or standby diver ascertain whether the diver is breathing. The presence or absence of breath sounds will be audible over the intercom.

6. If the diver appears not to be breathing, the dive partner/standby diver should attempt to reposition the diver's head to open the airway. Airway obstruction will be the most common reason why an unconscious diver fails to breathe.

7. Check afflicted diver for signs of consciousness:

   - If the diver has regained consciousness, allow a short period for stabilization and then abort the dive.
   - If the diver remains unresponsive but is breathing, have the dive partner or standby diver move the afflicted diver to the stage. This action need not be rushed.
   - If the diver appears not to be breathing, maintain an open airway while moving the diver rapidly to the stage.

8. Once the diver is on the stage, observe again briefly for the return of consciousness.

   - If consciousness returns, allow a period for stabilization, then begin decompression.
   - If consciousness does not return, bring the diver to the first decompression stop at a rate of 30 fsw/min (or to the surface if the diver is in a no-decompression status).

9. At the first decompression stop:

   - If consciousness returns, decompress the diver on the standard decompression schedule using surface decompression.
   - If the diver remains unconscious but is breathing, decompress on the standard decompression schedule using surface decompression.
   - If the diver remains unconscious and breathing cannot be detected in spite of repeated attempts to position the head and open the airway, an extreme emergency exists. One must weigh the risk of catastrophic,

even fatal, decompression sickness if the diver is brought to the surface, versus the risk of asphyxiation if the diver remains in the water. As a general rule, if there is any doubt about the diver's breathing status, assume he is breathing and continue normal decompression in the water. If it is absolutely certain that the diver is not breathing, leave the unaffected diver at his first decompression stop to complete decompression and surface the affected diver at 30 fsw/minute, deploying the standby diver as required. Recompress the diver immediately and treat for omitted decompression according to Table 14-2.

14-4.16 **Decompression Sickness in the Water.** Decompression sickness may develop in the water during surface supplied diving. This possibility is one of the principal reasons for limiting dives to 300 fsw and allowing exceptional exposures only under emergency circumstances. The symptoms of decompression sickness may be joint pain or more serious manifestations such as numbness, loss of muscular function, or vertigo.

Management of decompression sickness in the water will be difficult under the best of circumstances. Only general guidance can be presented here. Management decisions must be made on site taking into account all known factors. The advice of a Diving Medical Officer shall be obtained at the earliest possible moment.

14-4.16.1 **Decompression Sickness Deeper than 30 fsw.** If symptoms of decompression sickness occur deeper than 30 fsw, recompress the diver 10 fsw. The diver may remain on 50% helium 50% oxygen during recompression from 90 to 100 fsw. Remain at the deeper stop for 1.5 times the stop time called for in the decompression table. If no stop time is indicated in the table, use the next shallower stop time to make the calculation. If symptoms resolve or stabilize at an acceptable level, decompress the diver to the 40 fsw water stop by multiplying each intervening stop time by 1.5 or more as needed to control the symptoms. Shift to 50% helium 50% oxygen at 90 fsw if the diver is not already on this mixture. Shift to 100 percent oxygen at 40 fsw and complete a 30 minute stop, then surface decompress and treat on Treatment Table 6. If during this scenario, symptoms worsen to the point that it is no longer practical for the diver to remain in the water, surface the diver and follow the guidelines for symptomatic omitted decompression outlined in Chapter 21 of Volume 5.

14-4.16.2 **Decompression Sickness at 30 fsw and Shallower.** If symptoms of decompression sickness occur at 30 fsw or shallower, remain on oxygen and recompress the diver 10 fsw. Remain at the deeper stop for 30 minutes. If symptoms resolve, surface decompress the diver at the end of the 30 minute period and treat on Treatment Table 6. If symptoms do not resolve, but stabilize at an acceptable level, decompress the diver to the surface on oxygen by multiplying each intervening stop time by 1.5 or more as needed to control symptoms. Treat on Treatment Table 6 upon reaching the surface. If during this scenario symptoms worsen to the point that it is no longer practical for the diver to remain in the water, surface the diver and follow guidelines for symptomatic omitted decompression outlined in Chapter 21 of Volume 5.

14-4.17 Decompression Sickness During the Surface Interval. If symptoms of Type I decompression sickness occur during travel from 40 fsw to the surface during surface decompression or during the surface undress phase, compress the diver to 50 fsw following normal surface decompression procedures. Delay neurological exam until divers reach their 50 fsw stop and are on oxygen. If Type 1 symptoms resolve during the 15 minute 50 fsw stop and no neurological signs are found, continue normal decompression for the schedule of the dive. If symptoms do not resolve during the 15 minute 50 fsw stop or any neurological symptoms are present, compress divers to 60 fsw on oxygen and follow guidelines for treatment of decompression sickness outlined in Chapter 21 of Volume 5.

If symptoms of Type II decompression sickness occur during travel from 40 fsw to the surface, during the surface undress phase or the neurological exam at 50 fsw is abnormal, compress the diver to 60 fsw and follow guidelines for treatment of decompression sickness outlined in Chapter 21 of Volume 5.

14-5 CHARTING SURFACE SUPPLIED HELIUM OXYGEN DIVES

Chapter 5 provides information for maintaining a Command Diving Log and personal diving log and for reporting individual dives to the Naval Safety Center. In addition to these records, every Navy HeO_2 dive shall be recorded on a HeO_2 diving chart similar to Figure 14-1. The HeO_2 diving chart is a convenient means of collecting the dive data, which in turn will be transcribed in the dive log. It is also useful in completing a mishap report for a diving related accident.

14-5.1 Charting an HeO_2Dive. Figure 14-1 is a blank HeO_2 Diving Chart. Figure 14-2 is an example of a Surface Decompression dive. Figure 14-3 is an example of an In-water Decompression dive. Figure 14-4 is an example of a Surface Decompression dive with a hold on descent and delay on ascent.

When logging times on an HeO_2 diving chart, times will be recorded in a minute and second format. Clock time, however, will be logged in hours and minutes. The following rounding rules are used when calculating clock time:

1. All ascent times are rounded up to the next whole minute.

2. All stop times are rounded to the nearest whole minute. Round down for 1 to 30 seconds and round up from 31 to 59 seconds.

Date:		
Diver 1:	Diver 2:	Diver 3:
Rig: PSIG: O2%:	Rig: PSIG: O2%:	Rig: PSIG: O2%:
Diving Supervisor:	Timekeeper/Recorder:	Bottom Mix:

EVENT	STOP TIME	CLOCK
LS or 20 fsw		
RB		
LB		
R 1st Stop		
190 fsw		
180 fsw		
180 fsw		
170 fsw		
160 fsw		
150 fsw		
140 fsw		
130 fsw		
120 fsw		
110 fsw		
100 fsw		
90 fsw		
80 fsw		
70 fsw		
60 fsw		
50 fsw		
40 fsw		
30 fsw		
20 fsw		
RS		
Reached 50fsw(RCC)		
50 fsw (RCC)		
40 fsw (RCC)		
30 fsw (RCC)		
20 fsw (RCC)		
RS (RCC)		

TDT	TTD

EVENT	TIME/DEPTH
Descent Time (Water)	
Stage Depth (fsw)	
Maximum Depth	
Table/Schedule	
Time to 1st Stop (Planned)	
Bottom Time	
Time to 1st Stop (Actual)	
Delay to 1st Stop	
Ascent Time - Water (Actual)	
Undress Time - Sur D (Actual)	
Descent Chamber - Sur D (Actual)	
Total Sur D 40 to 50 - (Actual)	
Ascent Time - Chamber (Actual)	

HOLDS ON DESCENT

DEPTH	PROBLEM

DELAYS ON ASCENT

DEPTH	PROBLEM

DIVING REMARKS

Figure 14-1. HEO_2 Diving Chart.

Date: **11Aug 00**		
Diver 1: **MR1 K. Riendeau**	Diver 2: **HT1 Mabry**	Diver 3: **PH2 LIppman**
Rig: **MK-21** PSIG: **3000** O_2%: **16.2**	Rig: **MK-21** PSIG: **2950** O_2%: **16.2**	Rig: **MK-21** PSIG: **3000** O_2%: **16.2**
Diving Supervisor: **BM1 J.Annon**	Timekeeper/Recorder: **EN2 Golden**	Bottom Mix: **15.2**

EVENT	STOP TIME	CLOCK
LS or 20 fsw		**0800**
RB		**0804**
LB		**0839**
R 1st Stop		**0843**
190 fsw		
180 fsw		
180 fsw		
170 fsw		
160 fsw		
150 fsw		
140 fsw		
130 fsw		
120 fsw		
110 fsw	**:07**	**0850**
100 fsw		
90 fsw	**:03**	**0853**
80 fsw	**:07**	**0900**
70 fsw	**:09**	**0909**
60 fsw	**:13**	**0922**
50 fsw	**:13**	**0935**
40 fsw	**:13**	**0948**
30 fsw		
20 fsw		
RS		**0950**
Reached50fsw(RCC)		**0953**
50 fsw (RCC)	**:15::09**	**1008**
40 fsw (RCC)	**:15+:5+:30+:5+:30+ :5+:30**	**1208**
30 fsw (RCC)		
20 fsw (RCC)		
RS (RCC)		**1210**
TDT	TTD	
3:31	**4:10**	

EVENT	TIME/DEPTH
Descent Time (Water)	**:04**
Stage Depth (fsw)	**212**
Maximum Depth	**222+4=226**
Table/Schedule	**230/40:40 Sur D**
Time to 1st Stop (Planned)	**:03::24**
Bottom Time	**:39**
Time to 1st Stop (Actual)	**:03::49**
Delay to 1st Stop	**::25**
Ascent Time -Water (Actual)	**:01::03**
Undress Time -Sur D (Actual)	**:02::15**
Descent Chamber -Sur D (Actual)	**::58**
Total Sur D 40 to 50 (Actual)	**:04::16**
Ascent Time -Chamber (Actual)	**:01::20**

HOLDS ON DESCENT

DEPTH	PROBLEM

DELAYS ON ASCENT

DEPTH	PROBLEM

DIVING REMARKS

Figure 14-2. HEO_2 Diving Chart for Surface Decompression Dive.

Date: **11Aug 00**		
Diver **1 GM2 Urban**:	Diver 2: **HT1 Turner**	Diver 3: **HM2 Griffin**
Rig: **MK-21** PSIG: **2950** O2%: **16.2**	Rig: **MK-21** PSIG: **2950**	Rig: **MK-21** PSIG: **3000** O2%:**16.2**
Diving Supervisor: **HT1 Coffelt**	Timekeeper/Recorder**SM2 Guillen**	Bottom Mix: **15.2**

EVENT	STOP TIME	CLOCK	EVENT	TIME/DEPTH
LS or 20 fsw		**0800**	Descent Time (Water)	**:04**
RB		**0804**	Stage Depth (fsw)	**212**
LB		**0839**	Maximum Depth	**222+4=226**
R 1st Stop		**0843**	Table/Schedule	**230/:40 Inwater**
190 fsw			Time to 1st Stop (Planned)	**:03:24**
180 fsw			Bottom Time	**:39**
180 fsw			Time to 1st Stop (Actual)	**:03::49**
170 fsw			Delay to 1st Stop	**::25**
160 fsw			Ascent Time - Water (Actual)	**::40**
150 fsw			Undress Time - Sur D (Actual)	
140 fsw			Descent Chamber -Sur D (Actual)	
130 fsw			Total Sur D 40 to 50 - (Actual)	
120 fsw			Ascent Time - Chamber (Actual)	
110 fsw	**:07**	**0850**	**HOLDS ON DESCENT**	
100 fsw		**0900**	**DEPTH**	**PROBLEM**
90 fsw	**:03**	**0909**		
80 fsw	**:07**	**0922**		
70 fsw	**:09**	**0935**		
60 fsw	**:13**	**0948**	**DELAYS ON ASCENT**	
50 fsw	**:13**	**1027**	**DEPTH**	**PROBLEM**
40 fsw	**:13**	**1141**		
30 fsw	**:30+:5+:4**	**1142**		
20 fsw	**:25+:5+:30+:5+:8**			
RS			**DIVING REMARKS**	
Reached 50fsw(RCC)				
50 fsw (RCC)				
40 fsw (RCC)				
30 fsw (RCC)				
20 fsw (RCC)				
RS (RCC)				
TDT	TTD			
3:03	**3:42**			

Figure 14-3. HEO$_2$ Diving Chart for Inwater Decompression Dive.

Date**: 11 Aug 00**		
Diver 1: **GM3 Friction**	Diver 2: **BM2 Blanchard**	Diver 3: **TM2 Ogburn**
Rig: **MK-21** PSIG: **3000** O2%:**16.2**	Rig:**MK-21** PSIG:**2950** O2%: **16.2**	Rig: **MK-21** PSIG:**2975** O2%:**16.2**
Diving Supervisor: **EN1 Hordinski**	Timekeeper/Recorder: **BM2 Clark**	Bottom Mix:**15.2**

EVENT	STOP TIME	CLOCK
LS or 20 fsw		**0800**
RB		**0807**
LB		**0838**
R 1st Stop		**0843**
190 fsw		
180 fsw		
180 fsw		
170 fsw		
160 fsw		
150 fsw		
140 fsw		
130 fsw		
120 fsw		
110 fsw	**:07**	**0850**
100 fsw		
90 fsw	**:03**	**0853**
80 fsw	**:07**	**0900**
70 fsw	**:09**	**0909**
60 fsw	**:13**	**0922**
50 fsw	**:13**	**0935**
40 fsw	**:30**	**0948**
30 fsw		
20 fsw		
RS		**0950**
Reached 50 fsw(RCC)		**0953**
50 fsw (RCC)	**:15::09**	**1008**
40 fsw (RCC)	**:15+:5+:30+:5+ :30+:5+:30**	**1208**
30 fsw (RCC)		
20 fsw (RCC)		
RS (RCC)		**1210**
TDT	TTD	
3:32	**4:10**	

EVENT	TIME/DEPTH
Descent Time (Water)	**:07**
Stage Depth (fsw)	**212**
Maximum Depth	**222+4=226**
Table/Schedule	**230/:40 Sur D**
Time to 1st Stop (Planned)	**:03::24**
Bottom Time	**:38+:02=:40**
Time to 1st Stop (Actual)	**:04::47**
Delay to 1st Stop	**:1::23**
Ascent Time - Water (Actual)	**:01::03**
Undress Time -Sur D (Actual)	**:02::15**
Descent Chamber-Sur D(Actual)	**::58**
Total Sur D 40 to 50 - (Actual)	**:04::16**
Ascent Time -Chamber (Actual)	**:01::20**

HOLDS ON DESCENT	
DEPTH	**PROBLEM**
32’	**Red Diver - Right Ear**

DELAYS ON ASCENT	
DEPTH	**PROBLEM**
150’	**Winch Problem (Fixed)**

DIVING REMARKS

1. Delay on Ascent. Added :02 to bottom time. Didn’t change schedule.

2. Red Diver had trouble clearing due to position of nose clearing device. DMT checked ears post dive. No barotrauma noted.

Figure 14-4. HEO_2 Diving Chart for Surface Decompression Dive Withholds.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table*

Decompression Stops (fsw)

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
60	10	2:00																		0	0
	20	2:00																		0	0
	30	2:00																		0	0
	40	2:00																		0	0
Max O_2=*40.0%*	60	0:40																10	11	16	1
Min O_2=*14.0%*	80	0:40																10	13	22	2
	100	0:40																10	16	27	2
	120	0:40																10	17	28	2
70	10	2:20																		0	0
	20	2:20																		0	0
	30	2:20																		0	0
	40	1:00																10	10	16	1
Max O_2=*40.0%*	60	1:00																10	14	24	2
Min O_2=*14.0%*	80	1:00																10	18	30	2
	100	1:00																10	19	34	2
	120	1:00																10	21	37	2
80	10	2:40																		0	0
	20	2:40																		0	0
	25	2:40																		0	0
	30	1:20																10	11	16	1
Max O_2=*38.0%*	40	1:20																10	13	21	2
Min O_2=*14.0%*	60	1:20																10	18	32	2
	80	1:20																10	21	38	2
	100	1:20																10	24	42	3
	120	1:20																10	25	45	3
90	10	3:00																		0	0
	20	3:00																		0	0
	30	1:40																10	13	21	2
	40	1:40																10	16	26	2
Max O_2=*34.9%*	60	1:40																10	21	38	2
Min O_2=*14.0%*	80	1:40																10	25	45	3
	100	1:40																10	28	50	3
	120	1:40																10	29	52	3

Decompression Stops (fsw)

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont't)*

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
100	10	3:20																		0	0
	15	3:20																		0	0
	20	2:00																10	11	17	1
	30	2:00																10	15	24	2
Max O_2=*32.3%* Min O_2=*14.0%*	40	2:00																10	18	32	2
	60	2:00																10	25	44	3
	80	2:00																10	28	52	3
	100	2:00																10	31	56	3
	120	2:00																10	32	58	3
110	10	2:20																10	8	11	1
	20	2:20																10	12	20	1
	30	2:20																10	17	28	2
	40	2:20																10	20	36	2
Max O_2=*30.0%* Min O_2=*14.0%*	60	2:20																10	27	49	3
	80	2:20																10	31	58	3
	100	2:20																10	33	62	4
	120	2:20																10	35	64	4
120	10	2:40																10	9	13	1
	20	2:40																10	14	23	2
	30	2:40																10	19	33	2
	40	2:40																10	23	42	3
Max O_2=*28.0%* Min O_2=*14.0%*	60	2:40																10	30	55	3
	80	2:40																10	34	63	4
	100	2:40																10	36	66	4
	120	2:40															10	10	35	65	4
130	10	2:40															10	10	6	8	1
	20	2:40															10	10	12	19	1
	30	2:40															10	10	18	30	2
	40	2:20															10	10	22	40	3
Max O_2=*26.3%* Min O_2=*14.0%*	60	2:20															10	10	29	52	3
	80	2:20															10	10	33	60	3
	100	2:20															10	10	35	64	4
	120	2:20														7	11	11	35	66	4

Exceptional Exposure times are surrounded by the black box

***Table 14-3**. Surface Supplied Helium Oxygen Decompression Table (cont't)*

Decompression Stops (fsw)

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
140	10	3:00															10	10	6	8	1
	20	3:00															10	10	12	19	1
	30	3:00															10	10	18	30	2
	40	3:00														7	10	10	22	40	2
Max O_2=24.8%	60	3:00														7	10	10	29	52	3
Min O_2=14.0%	80	3:00														7	10	10	33	60	3
	100	3:00														7	10	10	35	64	4
	120	3:00														7	11	11	35	66	4
150	10	3:20															10	10	7	8	1
	20	3:00														7	10	10	14	22	2
	30	3:00														7	10	10	19	34	2
	40	3:00														7	10	10	24	44	3
Max O_2=23.4%	60	3:00														7	10	10	31	56	3
Min O_2=14.0%	80	3:00														7	10	10	35	64	4
	100	3:00														7	13	13	36	66	4
	120	3:00														9	16	16	36	66	5
160	10	3:20														7	10	10	8	10	1
	20	3:20														7	10	10	15	24	2
	30	3:20														7	10	10	21	37	2
	40	3:20														7	10	10	26	47	3
Max O_2=22.2%	60	3:20													7	6	10	10	30	56	3
Min O_2=14.0%	80	3:00													7	9	10	10	35	66	4
	100	3:00													7	13	14	14	35	66	5
	120	3:00													7	17	17	17	36	66	5
170	10	3:20													7	0	10	10	8	12	1
	20	3:20													7	0	10	10	16	28	2
	30	3:20													7	1	10	10	23	42	3
	40	3:20													7	4	10	10	28	52	3
Max O_2=21.1%	60	3:20													7	10	10	10	33	62	4
Min O_2=14.0%	80	3:20													9	14	14	14	35	66	4
	100	3:00													5	18	18	18	36	66	5
	120	3:00													9	21	21	21	36	66	5

Exceptional Exposure times are surrounded by the black box.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont’t)*

Decompression Stops (fsw)

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
180	10	3:40													7	0	10	10	9	14	1
	20	3:40													7	0	10	10	17	30	2
	30	3:40													7	4	10	10	25	45	3
	40	3:20												7	0	8	10	10	30	54	3
Max O_2=20.1%	60	3:20												7	5	11	11	11	35	64	4
Min O_2=14.0%	80	3:20												7	9	15	15	15	36	66	4
	100	3:20												7	13	19	19	19	36	66	5
	120	3:20												7	17	23	23	23	36	66	6
190	10	4:00												7	7	0	10	10	10	15	1
	20	3:40												7	0	2	10	10	19	34	2
	30	3:40												7	0	7	10	10	26	46	3
	40	3:40												7	4	9	10	10	31	56	3
Max O_2=19.2%	60	3:40												7	9	13	13	13	34	62	4
Min O_2=14.0%	80	3:20											7	3	13	18	18	18	36	66	5
	100	3:20											7	6	16	21	21	21	36	66	6
	120	3:20											7	8	20	23	23	23	36	66	7
200	10	4:00												7	0	0	10	10	11	17	1
	20	4:00												7	0	4	10	10	20	36	2
	30	3:40											7	0	3	7	10	10	27	50	3
	40	3:40											7	0	7	10	10	10	31	58	3
Max O_2=18.4%	60	3:40											7	4	10	14	14	14	35	66	4
Min O_2=14.0%	80	3:40											7	8	14	18	18	18	36	66	5
	100	3:40											7	12	17	23	23	23	36	66	6
	120	3:40											8	15	21	23	23	23	36	66	7
210	10	4:20												7	0	0	10	10	12	19	1
	20	4:00											7	0	1	6	10	10	22	38	2
	30	4:00											7	0	6	7	10	10	29	53	3
	40	4:00											7	3	9	10	10	10	33	60	3
Max O_2=17.7%	60	3:40										7	0	9	11	17	17	17	35	66	5
Min O_2=10.0%	80	3:40										7	3	11	15	20	20	20	36	66	6
	100	3:40										7	6	14	19	23	23	23	36	66	7
	120	3:40										7	8	18	23	23	23	23	36	66	7

Exceptional Exposure times are surrounded by the black box.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont't)*

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
220	10	4:40												7	0	2	10	10	13	20	1
	20	4:20											7	0	3	7	10	10	23	41	3
	30	4:20											7	2	6	9	10	10	30	54	3
	40	4:00										7	0	6	9	11	11	11	34	62	4
Max O_2=17.0%	60	4:00										7	4	9	12	18	18	18	36	66	5
Min O_2=10.0%	80	4:00										7	8	12	17	21	21	21	36	66	6
	100	4:00										7	12	15	20	23	23	23	36	66	7
	120	4:00										8	14	19	23	23	23	23	36	66	8
230	10	4:40											7	0	0	3	10	10	14	22	2
	20	4:20										7	0	3	4	7	10	10	24	44	3
	30	4:20										7	0	5	7	10	10	10	31	57	3
	40	4:00									7	0	3	7	9	13	13	13	34	64	4
Max O_2=16.3%	60	4:00									7	0	8	10	14	18	18	18	36	66	6
Min O_2=10.0%	80	4:00									7	3	10	14	18	23	23	23	36	66	7
	100	4:00									7	6	12	17	23	23	23	23	36	66	8
	120	4:00									7	7	16	19	23	23	23	23	36	66	8
240	10	4:40										7	0	0	3	4	10	10	14	24	2
	20	4:40										7	0	3	5	7	10	10	25	46	3
	30	4:20									7	0	3	6	7	10	10	10	32	58	3
	40	4:20									7	0	5	8	9	14	14	14	35	64	4
Max O_2=15.7%	60	4:20									7	4	8	11	14	19	19	19	36	66	6
Min O_2=10.0%	80	4:20									7	7	11	16	18	23	23	23	36	66	7
	100	4:20									7	10	14	19	23	23	23	23	36	66	8
	120	4:00								7	3	12	17	19	23	23	23	23	36	66	8
250	10	5:00										7	0	0	3	4	10	10	15	25	2
	20	4:40									7	0	0	3	7	7	10	10	26	47	3
	30	4:40									7	0	4	6	8	10	10	10	32	60	4
	40	4:40									7	2	5	9	9	14	14	14	35	64	4
Max O_2=15.2%	60	4:20								7	0	7	9	12	16	21	21	21	36	66	6
Min O_2=10.0%	80	4:20								7	3	9	13	15	21	23	23	23	36	66	7
	100	4:20								7	6	11	14	19	23	23	23	23	36	66	8
	120	4:20								7	8	13	19	20	23	23	23	23	36	66	8

Exceptional Exposure times are surrounded by the black box.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont't)*

Decompression Stops (fsw)

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
260	10	5:00									7	0	0	0	4	4	10	10	16	27	2
	20	5:00									7	0	3	4	6	7	10	10	27	50	3
	30	4:40								7	0	2	5	6	9	10	10	10	33	62	4
	40	4:40								7	0	3	8	9	10	15	15	15	35	64	5
Max O_2=16.3% Min O_2=10.0%	60	4:40								7	3	7	10	14	16	21	21	21	36	66	6
	80	4:40								7	6	10	13	17	23	23	23	23	36	66	7
	100	4:20							7	2	9	13	16	20	23	23	23	23	36	66	8
	120	4:20							7	4	11	14	19	20	23	23	23	23	36	66	8
270	10	5:20									7	0	0	3	3	4	10	10	17	28	2
	20	5:00								7	0	0	3	6	6	8	10	10	29	52	3
	30	5:00								7	0	3	6	6	9	13	13	13	34	62	4
	40	5:00							7	0	2	5	8	8	12	16	16	16	35	66	5
Max O_2=14.2% Min O_2=10.0%	60	4:40							7	0	6	8	10	14	19	23	23	23	36	66	6
	80	4:40							7	3	8	11	14	17	23	23	23	23	36	66	7
	100	4:40							7	5	11	13	16	20	23	23	23	23	36	66	8
	120	4:40							7	8	12	16	19	20	23	23	23	23	36	66	8
280	10	5:40									7	0	0	3	3	4	10	10	18	31	2
	20	5:20								7	0	0	4	6	7	7	10	10	30	54	3
	30	5:00							7	0	1	5	5	9	9	12	12	12	35	64	4
	40	5:00							7	0	4	6	8	9	12	17	17	17	35	66	5
	60	5:00							7	4	6	8	12	15	18	23	23	23	36	66	7
Max O_2=13.7% Min O_2=10.0%	80	4:40						7	0	7	9	11	15	17	23	23	23	23	36	66	8
	100	4:40						7	2	9	11	15	17	20	23	23	23	23	36	66	8
	120	4:40						7	4	11	13	16	19	20	23	23	23	23	36	66	8
290	10	5:40								7	0	0	0	4	3	4	10	10	19	33	2
	20	5:20							7	0	0	2	6	6	6	9	10	10	30	56	3
	30	5:20							7	0	2	5	5	9	9	14	14	14	34	63	5
	40	5:20							7	0	5	7	8	11	13	17	17	17	35	66	5
Max O_2=13.3% Min O_2=10.0%	60	5:00						7	0	6	7	9	12	15	20	23	23	23	36	66	7
	80	5:00						7	2	8	10	12	16	19	23	23	23	23	36	66	8
	100	5:00						7	5	10	12	15	19	20	23	23	23	23	36	66	8
	120	5:00						7	8	11	16	17	19	20	23	23	23	23	36	66	8

Exceptional Exposure times are surrounded by the black box.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont't)*

Decompression Stops (fsw)

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
300	10	6:00								7	0	0	0	4	3	4	10	10	19	33	2
	20	5:40							7	0	0	2	6	6	6	9	10	10	30	56	3
	30	5:40							7	0	2	5	5	9	9	14	14	14	34	63	5
	40	5:40							7	0	5	7	8	11	13	17	17	17	35	66	6
Max O_2=12.9% Min O_2=10.0%	60	5:20						7	0	6	7	9	12	15	20	23	23	23	36	66	7
	80	5:20						7	2	8	10	12	16	19	23	23	23	23	36	66	8
	100	5:20						7	5	10	12	15	19	20	23	23	23	23	36	66	8
	120	5:20						7	8	11	16	17	19	20	23	23	23	23	36	66	8
310	10	6:00							7	0	0	0	3	3	3	7	10	10	21	36	2
	20	5:40						7	0	0	2	4	5	6	7	10	10	10	31	57	4
	30	5:40						7	0	2	4	5	7	8	11	15	15	15	35	66	5
	40	5:20					7	0	1	4	6	7	8	12	15	19	19	19	36	66	7
Max O_2=12.5% Min O_2=10.0%	60	5:20					7	0	5	6	9	11	13	17	20	23	23	23	36	66	8
	80	5:20					7	3	7	9	11	13	17	20	23	23	23	23	36	66	8
	100	5:20					7	5	9	11	13	17	19	20	23	23	23	23	36	66	8
	120	5:20					7	7	12	13	16	17	19	20	23	23	23	23	36	66	8
320	10	6:20							7	0	0	0	4	3	3	7	10	10	21	38	2
	20	6:00						7	0	0	3	5	5	6	8	10	10	10	32	59	4
	30	5:40					7	0	0	4	4	6	7	9	11	17	17	17	35	66	5
	40	4:40					7	0	4	4	6	7	9	12	16	20	20	20	36	66	6
Max O_2=12.2% Min O_2=10.0%	60	5:20				7	0	2	6	8	9	11	14	17	23	23	23	23	36	66	8
	80	5:20				7	0	6	8	8	13	14	19	20	23	23	23	23	36	66	8
	100	5:20				7	2	7	10	13	16	17	19	20	23	23	23	23	36	66	8
	120	5:20				7	4	9	12	13	16	17	19	20	23	23	23	23	36	66	8
330	10	6:20						7	0	0	0	2	3	3	4	7	10	10	22	40	2
	20	6:00					7	0	0	2	3	4	6	5	10	10	10	10	33	60	4
	30	6:00					7	0	1	4	5	6	8	8	13	17	17	17	35	66	6
Max O_2=11.8% Min O_2=10.0%	40	5:40				7	0	1	4	5	7	7	10	12	17	20	22	22	36	66	7
	60	5:40				7	0	5	6	8	9	11	15	20	23	23	23	23	36	66	8
	80	5:40				7	2	7	8	10	13	15	19	20	23	23	23	23	36	66	8
	100	5:40				7	5	9	9	13	16	17	19	20	23	23	23	23	36	66	8
	120	5:20			7	1	7	10	13	15	16	17	19	20	23	23	23	23	36	66	8

Exceptional Exposure times are surrounded by the black box.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont’t)*

			Decompression Stops (fsw)																		
Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
340	10	6:40						7	0	0	0	3	3	3	4	7	10	10	23	41	3
	20	6:20					7	0	0	2	4	5	7	8	9	10	10	10	33	60	5
	30	6:00				7	0	0	3	5	5	6	8	9	13	18	18	18	35	66	6
	40	6:00				7	0	2	4	6	7	8	10	13	16	22	22	22	36	66	7
Max O_2=11.5%	60	5:40			7	0	3	5	6	9	10	13	16	18	21	23	23	23	36	66	8
Min O_2=10.0%	80	5:40			7	0	7	7	8	11	13	15	19	20	23	23	23	23	36	66	8
	100	5:40			7	2	8	8	12	13	16	17	19	20	23	23	23	23	36	66	8
	120	5:40			7	4	9	11	13	15	16	17	19	20	23	23	23	23	36	66	8
350	10	6:40					7	0	0	0	2	2	3	3	5	7	10	10	21	43	3
	20	6:20				7	0	0	0	4	4	5	5	7	9	13	13	13	31	63	5
	30	6:20				7	0	1	4	4	5	7	8	11	13	18	18	18	33	66	6
	40	6:00			7	0	1	3	5	6	7	8	11	14	17	23	23	23	33	66	7
Max O_2=11.2%	60	6:00			7	0	5	5	8	8	11	12	16	19	23	23	23	23	33	66	8
Min O_2=10.0%	80	6:00			7	2	7	7	10	11	13	17	19	20	23	23	23	23	33	66	8
	100	5:40		7	0	6	8	9	11	15	16	17	19	20	23	23	23	23	33	66	8
	120	5:40		7	1	7	9	12	14	15	16	17	19	20	23	23	23	23	33	66	8
360	10	7:00					7	0	0	0	2	2	3	3	7	7	10	10	25	44	3
	20	6:40				7	0	0	2	3	4	5	5	8	10	13	13	13	34	63	5
	30	6:20			7	0	0	3	3	5	6	7	8	11	13	19	19	19	36	66	6
	40	6:20			7	0	2	4	5	7	7	9	10	14	20	23	23	23	36	66	7
Max O_2=10.9%	60	6:20			7	2	5	6	7	9	11	14	16	19	23	23	23	23	36	66	8
Min O_2=10.0%	80	6:00		7	0	6	6	8	11	12	14	16	19	20	23	23	23	23	36	66	8
	100	6:00		7	2	7	8	11	13	13	16	17	19	20	23	23	23	23	36	66	8
	120	6:00		7	4	8	10	12	14	15	16	17	19	20	23	23	23	23	36	66	8
370	10	7:00				7	0	0	0	0	3	3	3	3	7	7	10	10	25	46	3
	20	6:40			7	0	0	0	3	4	4	5	5	8	10	13	13	13	34	63	5
	30	6:20		7	0	0	2	3	4	4	7	7	8	11	16	19	19	19	36	66	7
	40	6:20		7	0	0	4	4	5	6	8	10	11	14	20	23	23	23	36	66	8
Max O_2=10.6%	60	6:20		7	0	4	5	7	8	9	11	13	17	20	23	23	23	23	36	66	8
Min O_2=10.0%	80	6:00	7	0	3	6	7	9	10	12	15	17	19	20	23	23	23	23	36	66	8
	100	6:00	7	0	6	7	9	10	14	15	16	17	19	20	23	23	23	23	36	66	8
	120	6:00	7	1	7	9	11	13	14	15	16	17	19	20	23	23	23	23	36	66	8

Exceptional Exposure times are surrounded by the black box.

Table 14-3. *Surface Supplied Helium Oxygen Decompression Table (cont't)*

Depth (fsw)	Bottom Time (min.)	Time to First Stop (min:sec)	Decompression Stops (fsw) 190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	Chamber O_2 Periods
			BOTTOM MIX										50% O_2						100% O_2		
380	10	7:20				7	0	0	0	0	3	3	3	3	7	7	10	10	25	46	3
	20	7:00			7	0	0	0	3	4	4	5	5	8	10	13	13	13	34	63	6
	30	6:40		7	0	0	2	3	4	4	7	7	8	11	16	19	19	19	36	66	7
	40	6:40		7	0	0	4	4	5	6	8	10	11	14	20	23	23	23	36	66	8
Max O_2=10.4%	60	6:20		7	0	4	5	7	8	9	11	13	17	20	23	23	23	23	36	66	8
Min O_2=10.0%	80	6:20	7	0	3	6	7	9	10	12	15	17	19	20	23	23	23	23	36	66	8
	100	6:20	7	0	6	7	9	10	14	15	16	17	19	20	23	23	23	23	36	66	8
	120	6:20	7	1	7	9	11	13	14	15	16	17	19	20	23	23	23	23	36	66	8

Exceptional Exposure times are surrounded by the black box.

15-15.1 **UBA Gas.** An adequate quantity of gas within an oxygen partial pressure range of 0.44–1.25 ata shall be available for use.

15-15.2 **Emergency Gas.** Emergency gas is used as a backup breathing supply in the event of DDC or PTC atmosphere contamination. An emergency gas with an oxygen partial pressure of 0.16 to 1.25 ata shall be immediately available to the built-in breathing system (BIBS). The volume of emergency breathing gas shall be sufficient to supply the divers for the time needed to correct the DDC atmosphere.

Upward excursions of the PTC or DDC or decompression shall not be started during emergency gas breathing unless the oxygen partial pressure of the diver's inspired gas is 0.42 ata or above.

Example. An emergency gas schedule for a dive to 850 fsw is:

Bank Mix	Allowable Depth Range (fsw)	Shift Depth (fsw)
#1 84/16 HeO_2	0–224	200
#2 96/4 HeO_2	99–998	

15-15.3 **Treatment Gases. .** Treatment gases having an oxygen partial pressure range of 1.5 to 2.8 shall be available in the event of decompression sickness. The premixed gases shown in Table 15-4 may be used over the depth range of 0 – 1,600 fsw. A source of treatment gas shall be available as soon as treatment depth is reached. The source shall be able to supply a sufficient volume of breathing gas to treat each chamber occupant.

Table 15-4. *Treatment Gases.*

Depth (fsw)	Mix
0–60	100% O_2
60–100	40/60% HeO_2
100–200	64/36% HeO_2
200–350	79/21% HeO_2
350–600	87/13% HeO_2
600–1000	92/08% HeO_2
1000–1600	95/05% HeO_2

15-16 ENVIRONMENTAL CONTROL

Helium-oxygen gas mixtures conduct heat away from the diver very rapidly. As a result, temperatures higher than those required in an air environment are necessary to keep a diver comfortable. As depth increases, the temperature necessary to achieve comfort may increase to the 85–93°F range.

As a general guideline to achieve optimum comfort for all divers, the temperature should be kept low enough for the warmest diver to be comfortable. Cooler divers can add clothing as needed. All divers should be questioned frequently about their comfort.

The relative humidity should be maintained between 30 and 80 percent with 50 to 70 percent being the most desirable range for diver comfort, carbon dioxide scrubber performance, and fire protection.

15-17 FIRE ZONE CONSIDERATIONS

Every effort shall be made to eliminate any fire hazard within a chamber. When oxygen percentages are elevated as during the later stages of decompression, a fire will burn rapidly once started, perhaps uncontrollably. As a result, special precautions are necessary to protect the diver's safety when in the fire zone. The fire zone is where the oxygen concentration in the chamber is 6 percent or greater. Using standard saturation diving procedures (oxygen partial pressure between 0.44 and 0.48 ata), fire is possible at depths less than 231 fsw. Thus, during a saturation dive the divers will be in the fire zone during initial compression to depth and during the final stages of decompression.

Example. The chamber atmosphere is 0.48 ata ppO_2. The minimum oxygen percentage for combustion is 6 percent. Compute the fire zone depth.

The fire zone depth is computed as follows:

$$\begin{aligned}\text{Fire zone depth (fsw)} &= \frac{ppO_2 \times 33}{O_2\%/100} - 33 \\ &= \frac{0.48 \times 33}{0.06} - 33 \\ &= 231\ \text{fsw}\end{aligned}$$

Although the design of the DDS minimizes fire potential, personnel must remain vigilant at all times to prevent fires. Appropriate precautions for fire prevention include:

- Fire-suppression systems, if available, must be operational at all times when in the fire zone.
- Chamber clothing, bed linen, and towels shall be made of 100% cotton. Diver swim trunks made of a 65% polyester–35% cotton material is acceptable.
- Mattresses and pillows shall be made of fire-retardant material when in the fire zone.
- Limit combustible personal effects to essential items.
- Limit reading material, notebooks, etc., in the fire zone.

is activated, all divers shall immediately go on BIBS. Watchstanders should monitor depth carefully because an extensive fire will cause an increase in depth. If the fire suppression system fails to extinguish the fire, rapid compression of the chamber with helium may extinguish the fire, in that helium lowers the oxygen concentration and promotes heat transfer. After the fire is extinguished, chamber atmosphere contaminant emergency procedures shall be followed.

15-22.4 **PTC Emergencies.** PTC emergencies, like DDC emergencies, require specific, timely, and uniform responses in order to prevent injury or casualty to divers, watchstanders, and equipment.

15-23 SATURATION DECOMPRESSION

Saturation decompression may be initiated by an upward excursion as long as the excursion remains within the limits permitted by the Unlimited Duration Excursion Tables. The alternative is to begin travel at the appropriate decompression rate without the upward excursion. Decompression travel rates are found on Table 15-9.

Table 15-9. *Saturation Decompression Rates.*

Depth	Rate
1,600 – 200 fsw	6 feet per hour
200 – 100 fsw	5 feet per hour
100 – 50 fsw	4 feet per hour
50 – 0 fsw	3 feet per hour

15-23.1 **Upward Excursion Depth.** The minimum depth to which the upward excursion may be made is found by entering Table 15-8 with the deepest depth attained by any diver in the preceding 48 hours. The total upward excursion actually chosen is determined by the Diving Officer and Master Diver, and approved by the Commanding Officer, taking into consideration environmental factors, the diver’s workload, and the diver’s physical condition.

15-23.2 **Travel Rate.** The travel rate for the upward excursion is 2 fsw/min. Beginning decompression with an upward excursion will save considerable time and may be used whenever practical.

15-23.3 **Post-Excursion Hold.** Due to the increased risk of decompression sickness following an upward excursion for dives with a storage depth of 200 fsw or less, a 2-hour post-excursion hold should be utilized. The 2-hour hold begins upon arrival at upward excursion depth.

15-23.4 **Rest Stops.** During decompression, traveling stops for a total of 8 hours out of every 24 hours. The 8 hours should be divided into at least two periods known as

"Rest Stops." At what hours these rest stops occur are determined by the daily routine and operations schedule. The 2-hour post-excursion hold may be considered as one of the rest stops.

15-23.5 **Saturation Decompression Rates.** Table 15-9 shows saturation decompression rates. Saturation decompression is executed by decompressing the DDC in 1-foot increments not to exceed 1 fsw per minute. For example, using a travel rate of 6 feet per hour will decompress the chamber 1 foot every 10 minutes. The last decompression stop before surfacing may be taken at 4 fsw to ensure early surfacing does not occur and that gas flow to atmosphere monitoring instruments remains adequate. This last stop would be 80 minutes, followed by direct ascent to the surface at 1 fsw/min.

Traveling is conducted for 16 hours in each 24-hour period. A 16-hour daily travel/rest outline example consistent with a normal day/night cycle is:

Daily Routine Schedule

2400–0600	Rest Stop
0600–1400	Travel
1400–1600	Rest Stop
1600–2400	Travel

This schedule minimizes travel when the divers are normally sleeping. Such a daily routine is not, however, mandatory. Other 16-hour periods of travel per 24-hour routines are acceptable, although they shall include at least two stop periods dispersed throughout the 24-hour period and travel may continue while the divers sleep. An example of an alternate schedule is:

Alternate Sample Schedule

2300–0500	Travel
0500–0700	Rest Stop
0700–0900	Travel
0900–1500	Rest Stop
1500–2300	Travel

The timing of the stop is dependent upon operational requirements.

15-23.6 **Atmosphere Control at Shallow Depths.** As previously stated, the partial pressure of oxygen in the chamber shall be maintained between 0.44 and 0.48 ata, with two exceptions. The first is just before making the initial Upward Excursion and the second during the terminal portion of saturation decompression. Approximately 1 hour before beginning an Upward Excursion, the chamber ppO_2 may be increased up to a maximum of 0.6 ata to ensure that the ppO_2 after excursion does not fall excessively. The ppO_2 should be raised just enough so the post-excursion ppO_2 does not exceed 0.48 ata. However, when excursions begin from depths of

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CHAPTER 17

Closed-Circuit Mixed-Gas UBA Diving

17-1 INTRODUCTION

Closed-circuit mixed-gas underwater breathing apparatus (UBA) is primarily employed by Naval Explosive Ordnance Disposal (EOD) and Special Warfare (SPECWAR) forces. This equipment combines the mobility of a free-swimming diver with the depth advantages of mixed gas. UBAs in this category permit completely autonomous diver operations without an umbilical. The term *closed-circuit* refers to the recirculation of 100 percent of the mixed-gas breathing medium. This results in bubble-free operation, except during ascent or inadvertent gas release. This capability makes closed-circuit UBAs well-suited for special warfare operations and for operations requiring a low acoustic signature. The U.S. Navy's use of the mixed-gas closed-circuit UBA was developed to satisfy the operational requirements of SPECWAR combat swimmers and EOD divers. Improvements in gas usage, dive duration, and depth capabilities provided by the UBA greatly increase the effectiveness of these divers. Dives to 150 feet of seawater (fsw) can be made when N_2O_2 (air) is used as a diluent. When using HeO_2 as a diluent, dives to 200 fsw can be made using 84/16 and to 300 fsw using 88/12. Current certification limits the MK 16 UBA diving to 200 fsw.

17-1.1 **Purpose.** This chapter provides general guidelines for MK 16 UBA diving, operations and procedures (Figures 17-1 and 17-2). For detailed operation and maintenance instructions, see technical manual SS600-AH-MMA-010 (MK 16).

17-1.2 **Scope.** This chapter covers MK 16 UBA principles of operations, operational planning, dive procedures, and medical aspects of mixed-gas closed-circuit diving. Refer to Chapter 16 for procedures for mixing divers' breathing gas.

Figure 17-1. MK 16 MOD 0 Closed-Circuit Mixed-Gas UBA.

17-2 PRINCIPLES OF OPERATION

The U.S. Navy closed-circuit mixed-gas UBA is a constant partial-pressure-of-oxygen rebreather. To conserve the gas supply and extend underwater duration, the efficiency of gas use is improved by:

- Removing carbon dioxide produced by metabolic action of the body.
- Adding pure oxygen to the breathing gas to replace the oxygen consumed.
- Recirculating the breathing gas for reuse.

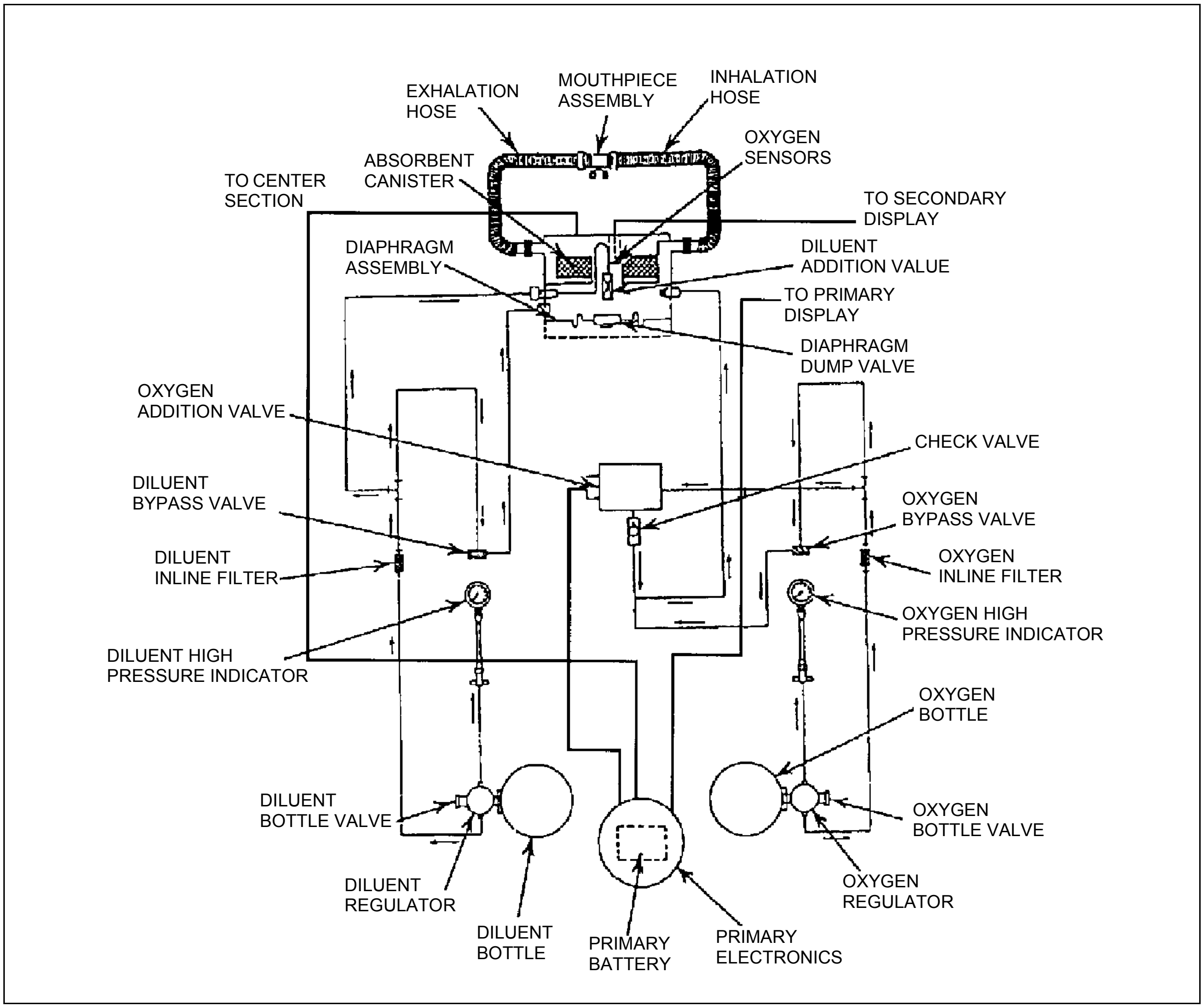

Figure 17-2. MK 16 MOD 0 UBA Functional Block Diagram.

17-2.1 **Recirculation and Carbon Dioxide Removal.** The diver's breathing medium is recirculated in a closed-circuit UBA to remove carbon dioxide and permit reuse of the inert diluent and unused oxygen in the mixture. The basic recirculation system consists of a closed loop that incorporates inhalation and exhalation hoses and associated check valves, a mouthpiece or full face mask (FFM), a carbon dioxide removal unit, and a diaphragm assembly.

17-2.1.1 **Recirculating Gas.** Recirculating gas is normally moved through the circuit by the natural inhalation-exhalation action of the diver's lungs. Because the lungs can produce only small pressure differences, the entire circuit must be designed for minimum flow restriction.

17-2.1.2 **Full Face Mask.** The FFM uses an integral oral-nasal mask or T-bit to reduce dead space and the possibility of rebreathing carbon dioxide-rich gas. Similarly, check valves used to ensure one-way flow of gas through the circuit must be close to the diver's mouth and nose to minimize dead space. All breathing hoses in the system

Figure 17-4. Underwater Breathing Apparatus MK 16 MOD 0.

Units requiring a deep operational capability should allow frequent opportunity for training, ensuring diver familiarity with equipment and procedures**. Workup dives are strongly recommended prior to diving at depths greater than 130 fsw.** MK 16 diver qualifications may be obtained only by completion of the MK 16 Basic Course (A-431-0075) or the Naval Special Warfare Center MK 16 qualifications course. MK 16 qualifications remain in effect as long as diver qualifications are maintained in accordance with Military Personnel Manual article 1410380. However, a diver who has not made a MK 16 dive in the previous six months must refamiliarize himself with MK 16 EPs and OPs and must complete a MK 16 training dive prior to making a MK 16 operational dive. Prior to conducting MK 16 decompression diving, a diver who has not conducted a MK 16 decompression dive within the previous six months must complete open water decompression training dives. Refer to Table 17-1 for the personnel requirements for MK 16 diving operations.

17-4.1 **Operating Limitations.** Using combat swimmer multilevel dive (CSMD) procedures provides SPECWAR divers with the option of conducting multiple-depth diving with the MK 16 UBA to a depth of 70 fsw (NEDU Report 13-83). However, the CSMD procedures may be used for dives between 70 and 110 fsw by adding 10 fsw, to the depth when entering the table. Refer to Table 17-2 for equipment depth limitations. Diving Supervisors must also consider the limiting factors presented in the following paragraphs when planning closed-circuit UBA operations.

Table 17-1. Personnel Requirements Chart for Mixed-Gas Diving.

Mixed-Gas UBA Dive Team	Optimum		Minimum	
Designation	**One Diver**	**Two Divers**	**One Diver**	**Two Divers**
Diving Officer	(Notes 3, 4)	(Notes 3, 4)	(Notes 3, 4)	(Notes 3, 4)
Diving Medical Officer	(Note 5)	(Note 5)	(Note 5)	(Note 5)
Diving Supervisor	1	1	1 (Note 2)	1 (Note 2)
Diver	1	2	1	2
Standby Diver	1 (Note 7)	1 (Note 7)	1 (Note 7)	1 (Note 7)
Diver Tender	1 (Note 1)	2 (Note 1)	1 (Note 1)	1 (Note 1)
Standby Diver Tender	1	1	(Note 8)	(Note 8)
Timekeeper/Recorder	1	1		
EBS Operator	(Note 6)	(Note 6)	(Note 6)	(Note 6)
Total Personnel Required	6	8	4	5

Notes:

1. One tender per diver when divers are surface tended. If using a buddy line, one tender is required for each buddy pair.
2. May act as timekeeper/recorder.
3. EOD Diving Officer is required on site for all EOD operations that involve a render safe procedure; for SPECWAR, a Diving Officer is not required on station. ***On station* is defined as at the dive location.**
4. Diving Officer may perform any other function simultaneously (i.e., Diving Officer/Diver).
5. A Diving Medical Officer is required on station for all dives exceeding the maximum working limit.
6. EBS Operator is for MK 16 in-water decompression dives.
7. At the Diving Supervisor’s discretion, the standby diver shall be fully dressed with the exception of scuba or MK 16, mask, and fins. These items shall be ready to don.
8. If the Standby Diver is deployed, the Diving Supervisor shall tend the Standby Diver.

Table 17-2. Equipment Operational Characteristics.

Diving Equipment	Maximum Working Limit (fsw) (Notes 1 and 2)	Chamber Requirement
MK 16 UBA	150 (air diluent) 200 (HeO_2 diluent)	Note 3 Note 3

Notes:

1. Depth limits are based on considerations of working time, decompression obligation, oxygen tolerance and nitrogen narcosis. The expected duration of the gas supply, the expected duration of the carbon dioxide absorbent, the adequacy of thermal protection, or other factors may also limit both the depth and the duration of the dive.
2. A Diving Medical Officer is required on station for all dives exceeding the maximum working limit.
3. Dives deeper than the maximum working limits require a recompression chamber on station. ***On station* is defined as at the dive location.**

17-4.1.1 **Oxygen Flask Endurance.** Ine calculating the endurance of the MK 16, only the oxygen flask is considered. The endurance of the oxygen flask is dependent upon the following:

- Flask floodable volume
- Initial predive pressure
- Required reserve pressure
- Oxygen consumption by the diver
- Effect of cold water immersion on flask pressure

17-4.1.1.1 ***Flask Floodable Volume.*** The oxygen flask floodable volume (fv) is 0.1 cubic foot (2.9 liters).

17-4.1.1.2 ***Initial Predive Pressure.*** The initial pressure is the pressure of the oxygen flask at ambient temperature when it has cooled following charging. A reserve pressure of 500 psig is required to drive the reducer. Calculation of initial pressure must also account for gas loss resulting from UBA predive calibration. Oxygen consumption by the diver is computed as 0.049 scfm (1.4 lpm). This is a conservative value for a diver swimming at 0.85 knot (Chapter 3, Figure 3-6). Refer to Table 17-3 for information on the average breathing gas consumption rates and CO_2 absorbent usage.

Table 17-3. *Average Breathing Gas Consumption Rates and CO_2 Absorbent Usage.*

				CO_2 Absorbent		
Diving Equipment	Overbottom Pressure (Minimum)	Gas Consumption (Normal)	Gas Consumption (Heavy Work)	Capacity (lbs.)	Duration 40°F (Note 1)	Duration 70°F (Note 1)
MK 16 UBA (Mixed-gas)	Variable with bottle pressure	12-15 psi/min	15-17 psi/min	7.75-8.0	5h	6h 40m

Note:

1. CO_2 absorbent duration is based upon a comfortable work rate (0.8-knot swimming speed).

17-4.1.1.3 ***Effect of Cold Water Immersion on Flask Pressure.*** Immersion in cold water will reduce the flask pressure and actual cubic feet (acf) of gas available for the diver, in accordance with Charles'/Gay-Lussac's gas law. Based upon direct measurement, available data, or experience, the coldest temperature expected during the dive is used.

17-4.1.1.4 ***Calculating Gas Endurance.*** Combining these factors produces the formula for MK 16 gas endurance:

MK 16 gas endurance =

$$F_V \times \frac{\left[\left(P_1 \times \frac{T_2}{T_1}\right) - P_R\right]}{VO_2 \times 14.7 \text{ psi}} \times \frac{492}{T_2}$$

Where:

F_V = Floodable volume of flask in cubic feet
P_I = Initial Pressure in psia
P_R = Reserve Pressure in psia
VO_2 = Oxygen consumption in medical scfm (32°F)
T_1 = Ambient air temperature in °R
T_2 = Coldest water temperature expected in °R

Rankine conversion factor:

°R = °F + 460

All pressure and temperature units must be absolute.

17-4.1.1.5 ***Example.*** The endurance of a MK 16 MOD 0 UBA charged to 2,500 psig for a dive in 50° F water when the ambient air temperature is 65° F would be computed as follows:

$$\begin{aligned}\text{MK 16 gas endurance} &= 0.1 \times \frac{[(2,514.7 \times 510/525) - 514.7]}{0.049 \times 14.7} \times \frac{492}{510} \\ &= 258 \text{ minutes}\end{aligned}$$

This duration assumes no gas loss from the UBA during the dive and only considers metabolic consumption of oxygen by the diver. Divers must be trained to minimize gas loss by avoiding leaks and unnecessary depth changes. Clearing a flooded face mask is a common cause of gas loss from the UBA. When a full face mask (FFM) is used, gas can pass from the UBA breathing loop into the FFM and escape into the surrounding seawater due to a poor face seal. Leaks that continue unchecked can deplete UBA gas supply rapidly. Additionally, during diver ascent, the dump valve opens to discharge breathing gas into the surrounding water, thereby preventing overinflation of the breathing diaphragm. Depth changes should be avoided as much as possible to minimize this gas loss.

17-4.1.2 **Diluent Flask Endurance.** Under normal conditions the anticipated duration of the MK 16 diluent flask will exceed that of the oxygen flask. The MK 16 diluent bottle holds approximately 21 standard cubic feet (595 liters) of gas at a stored pressure of 3,000 psig. Diluent gas is used to maintain the required gas volume in the breathing loop and is not depleted by metabolic consumption. As the diver descends, diluent is added to maintain the total pressure within the recirculation system at ambient water pressure. Loss of UBA gas due to offgassing at depth requires the addition of diluent gas to the breathing loop either automatically through the diluent add valve or manually through the diluent bypass valve to make up lost volume. Excessive gas loss caused by face mask leaks, frequent depth changes, or improper UBA assembly will deplete the diluent gas supply rapidly.

17-4.1.3 **Canister Duration.** Canister duration is estimated by using a working diver scenario. This allows an adequate safety margin for the diver in any situation. Table 17-4 shows the canister duration limits and approved absorbents for the MK 16 UBA.

Table 17-4. *MK 16 Canister Duration Limits.*

Canister Duration with HeO_2		
Temperature (°F)	**Depth (fsw)**	**Time (minutes)**
40 and above	0-300	300
29-39	0-100	300
35-39	101-300	240
29-34	101-300	120
Canister Duration with N_20_2		
Temperature (°F)	**Depth (fsw)**	**Time (minutes)**
29 and above	0-50	300
40 and above	51-150	200
29-39	51-150	100
NAVSEA-Approved Sodalime CO_2 Absorbents		
Name	**Vendor**	**NSN**
High Performance Sodasorb, Regular	W.R. Grace	6810-01-113-0110
Sofnolime 4-8 Mesh NI, L Grade	O.C. Lugo	6810-01-113-0110
Sofnolime 8-12 Mesh NI, D Grade	O.C. Lugo	6810-01-412-0637

17-4.1.4 **Thermal Protection.** Divers must be equipped with adequate thermal protection to perform effectively and safely. A cold diver will either begin to shiver or increase his exercise rate, both of which will increase oxygen consumption and decrease oxygen supply duration and canister duration. Refer to Chapter 11 for guidance on thermal protection.

17-4.2 **Equipment Requirements.** Equipment requirements for closed-circuit mixed-gas UBA training dives are provided in Table 17-5. Two equipment items merit special comment:

- **Safety Boat**. A minimum of one motorized safety boat must be present for all open-water dives. A safety boat is also recommended for tended pier dives or diving from shore. Safe diving practice in many situations, however, will require the presence of more than one safety boat. The Diving Supervisor must

Table 17-5. *MK 16 UBA Diving Equipment Requirements.*

General	Diving Supervisor	Divers	Standby Diver
1. Motorized safety boat (Note 1)	1. Dive watch	1. Dive watch (Note 2)	1. Dive watch
2. Radio (communications with parent unit, chamber, communication between safety boats when feasible)	2. Dive Bill list	2. Face mask	2. Face mask
3. High-intensity, wide-beam light (night operations)	3. U.S. Navy Standard Air Decompression Tables	3. Fins	3. Fins
4. Dive flags and/or special operations lights as required	4. Closed-Circuit Mixed-Gas UBA Decompression Tables using 0.7 ATA Constant Partial Pressure Oxygen in Nitrogen and in Helium.	4. Dive knife	4. Dive knife
5. Sufficient (2 quarts) fresh water in case of chemical injury	5. Recall device	5. Approved life preserver	5. Approved life preserver
		6. Appropriate thermal protection	6. Appropriate thermal protection
		7. Depth gauge (Note 2)	7. UBA with same depth capability
		8. Buddy line (as appropriate for EOD/SPECWAR operations) (Note 1)	8. Depth gauge
		9. Tending line (as appropriate for EOD operations) (Note 3)	9. Weight belt (if needed)
			10. Tending line

Notes:

1. See paragraph 17-4.2
2. See paragraph 17-4.2.6
3. See paragraph 17-4.4.4

determine the number of boats required based on the diving area, medical evacuation plan, night operations, and the number of personnel participating in the dive operation.

- **Buddy Lines**. Buddy lines are considered important safety equipment for closed-circuit UBA dives. In special diving situations, such as certain combat swimmer operations or tended diving, the use of buddy lines may not be feasible. The Diving Supervisor shall conduct dives without buddy lines only in situations where their use is not feasible or where their use will pose a greater hazard to the divers than by diving without them.

17-4.2.1 **Distance Line.** Any buddy line over 10 feet (3 meters) in length is referred to as a distance line. The length of the distance line shall not exceed 81 feet (25 meters). Distance lines shall be securely attached to both divers.

17-4.2.2 **Standby Diver.** When appropriate during training and non-influence diving operations, open circuit scuba may be used to a maximum depth of 130 fsw.

17-4.2.3 **Lines.** Diver marker lines shall be manufactured from any light line that is buoyant and easily marked as directed in paragraph 17-4.2.4 (one-quarter inch polypropylene is quite suitable).

17-4.2.4 **Marking of Lines.** Lines used for controlling the depth of the diver(s) for decompression diving shall be marked. This includes tending lines, marker lines, and lazy-shot lines. Lines shall be marked with red and yellow or black bands starting at the diver(s) or clump end. Red bands will indicate 50 feet and yellow or black bands will mark every 10 feet.

17-4.2.5 **Diver Marker Buoy.** Diver marker buoys will be constructed to provide adequate visual reference to monitor the divers location. Additionally, the amount of line will be of sufficient length for the planned dive profile.

17-4.2.6 **Depth Gauge/Wrist Watch.** A single depth gauge and wrist watch may be used when diving with a partner and using a distance line.

17-4.3 Recompression Chamber Considerations.

A recompression chamber and a Diving Medical Officer are not required on station (*on station* is defined as at the dive location) as prerequisites for closed-circuit UBA diving operations, unless the dive(s) will exceed the maximum working limit. However, the following items should be determined prior to beginning diving operations:

- Location of the nearest functional recompression chamber. Positive confirmation of the chamber's availability in case of emergency should be obtained.
- Location of the nearest available Diving Medical Officer if not at the nearest recompression chamber.
- Location of the nearest medical facility for treatment of injuries and medical problems not requiring recompression therapy.
- The optimal method of transportation to the treatment chamber or medical facility. If coordination with other units for aircraft/boat/vehicle support is necessary, the Diving Supervisor shall know the telephone numbers and points of contact necessary to make these facilities available as quickly as possible in case of emergency. A medical evacuation plan should be included in the Diving Supervisor brief. Preparing an emergency assistance checklist similar to that in Chapter 6 is recommended.

17-4.4 Diving Procedures for MK 16.

17-4.4.1 **Employing a Single, Untended EOD Diver.** Generally, it is safer for divers to work in pairs rather than singly. However, to do so when diving on underwater influence ordnance doubles the diver bottom time expended, increases the risk to life from live ordnance detonation, and increases the risk of detonation caused by the additional influence signature of the second diver. The EOD Diving Officer may authorize the employment of a single, untended diver when it is deemed that the ordnance hazard is greater than the hazard presented by diving alone. All single, untended divers must use a full face mask (FFM). The EOD Diving Officer or Diving Supervisor shall consider the following factors when deciding whether to operate singly or in pairs:

- Experience of the diver
- Confidence of the team
- Type and condition of ordnance suspected
- Environmental conditions
- Degree of operational urgency required

17-4.4.2 **Simulated Training Scenarios.** Simulated ordnance training scenarios do not constitute a real threat, therefore single untended divers shall not be used in training operations. The diver shall be surface tended or marked by attaching a buoy to him.

17-4.4.3 **EOD Standard Safety Procedures.** The following standard safety procedures shall be observed during EOD diving operations:

- An EOD Diving Officer shall be on scene during all phases of an explosive ordnance disposal diving operation involving a Render Safe Procedure (RSP).

- When diving on unknown or influence ordnance, the standby diver's equipment shall be the same type as the diver neutralizing the ordnance.

17-4.4.4 **Diving Methods.** Diving methods include:

- **Single Marked Diving**. Consists of a single diver with FFM marked with a lightweight buoyant line attached to a surface float. Upon completion of a dive requiring decompression, the diver will signal the diving supervisor that he is ready to surface. The diving boat will then approach the surface float and recover the diver.

- **Paired Marked Diving**. Procedures for paired marked diving are identical to the procedures for a single marked diver, but with the addition of the second diver connected by a buddy/distance line.

tactical equipment, etc.) are available, and that the UBA functions properly before allowing the divers to enter the water. Appropriate check lists to confirm proper functioning of the UBA are provided in the MK 16 O&M manual.

17-6 WATER ENTRY AND DESCENT

The maximum descent rate is 60 feet per minute. During descent, the UBA will automatically compensate for increased water pressure and provide an adequate volume of gas for breathing. During descent the oxygen partial pressure may increase as oxygen is added to the breathing mixture as a portion of the diluent. Depending on rate and depth of descent, the primary display on the MK 16 UBA may illuminate flashing green. It may take from 2 to 15 minutes to consume the additional oxygen added by the diluent during descent. While breathing down the ppO_2, the diver should continuously monitor the primary and secondary display until the ppO_2 returns to setpoint level.

17-7 UNDERWATER PROCEDURES

17-7.1 **General Guidelines.** The divers shall adhere to the following guidelines as the dive is conducted.

WARNING **Failure to adhere to these guidelines could result in serious injury or death.**

- Monitor primary and secondary display frequently (every 2-3 minutes)
- Wear adequate thermal protection
- Know and use the proper amount of weights for the thermal protection worn and the equipment carried
- Check each other’s equipment carefully for leaks at the start of the dive
- Do not exceed the UBA canister duration and depth limitations for the dive (paragraph 17-4.1.3)
- Minimize gas loss from the UBA (avoid mask leaks and frequent depth changes, if possible)
- Maintain frequent visual or touch checks with buddy
- Be alert for symptoms suggestive of a medical disorder (paragraph 17-11)
- Use tides and currents to maximum advantage

17-7.2 **At Depth.** If the UBA is performing normally at depth, no adjustments will be required. The ppO_2 control system will add oxygen from time to time. Monitor UBA primary and secondary displays and high pressure gauges in strict accordance with the MK 16 O&M manual. Items to monitor include:

MK 16 MOD 0 DIVE RECORD SHEET

Diving Supervisor		Date
Water Temp	Air Temp	Depth (fsw)
Table	Schedule	Planned Bottom Time
Required EBS Pressure		Actual EBS Pressure

	Name	Repet Group	Rig No.	O_2 Pressure	Diluent Pressure	Batt %	LS	LB	RS	TBT
Diver 1										
Diver 2										
Standby Diver										

Descent Rate	Scheduled Time at Stop		Stop Depth	Actual Time at Stop		Travel Time	Remarks
	Divers	Standby		Divers	Standby		
			10				
			20				
			30				
			40				
			50				
			60				
			70				
			80				

Figure 17-6. MK 16 MOD 0 Dive Record Sheet.

- **Primary Display**. Check the primary display frequently as outlined in the MK 16 O&M manual (paragraph 3-4.6.1) to ensure that the oxygen level remains at the setpoint during normal activity at a constant depth (the oxygen-addition valve operation on the MK 16 cannot be heard).

- **Secondary Display**. Check the secondary display frequently (every 2-3 minutes) as outlined in the MK 16 O&M manual (paragraph 3-4.6.2) to ensure that all sensors are consistent with the primary display and that plus and minus battery voltages are properly indicating.

- **High-Pressure Indicators**. Check the oxygen- and diluent-pressure indicators frequently as outlined in the MK 16 O&M manual (paragraph 3-4.6.3) to ensure that the gas supply is adequate to complete the dive.

17-8 ASCENT PROCEDURES

The maximum ascent rate for the MK 16 is 30 feet per minute. During ascent, when water pressure decreases, the diaphragm dump valve compensates for increased gas volume by discharging the excess gas into the water. As a result, oxygen in the breathing gas mixture may be vented faster than O_2 is replaced by the addition valve. In this case, the primary display may alternate red/green before the low-ppO_2 signal (blinking red) appears. This is a normal transition period and shall not cause concern. Monitor the secondary display frequently on ascent and add oxygen by depressing the bypass valve during this instance.

17-9 POSTDIVE PROCEDURES

Postdive procedures shall be completed in accordance with the appropriate postdive checklists in the MK 16 UBA O&M manual.

17-10 DECOMPRESSION PROCEDURES

When diving with an open-circuit UBA, ppO_2 increases with depth. With a closed-circuit UBA, ppO_2 remains constant at a preset level regardless of depth. Therefore, standard U.S. Navy decompression tables cannot be used.

17-10.1 **Use of Constant ppO_2 Decompression Tables.** Closed-circuit UBA users must use constant ppO_2 decompression tables Oxygen in Nitrogen (air diluent), and Oxygen in Helium (Helium-Oxygen diluent). Closed-circuit, mixed-gas UBA decompression tables (Table 17-14 and Table 17-15) are included at the end of this chapter.

17-10.2 **Monitoring ppO_2.** During decompression, it is very important to frequently monitor the secondary display and ensure a 0.7 ppO_2 is maintained as closely as possible. Always use the appropriate decompression table when surfacing, even if UBA malfunction has significantly altered the ppO_2.

NOTE **Surface decompression is not authorized for MK 16 operations. Appropriate surface decompression tables have not been developed for constant 0.7 ata ppO_2 closed-circuit diving.**

17-10.3 Rules for Using 0.7 ata Constant ppO_2 in Nitrogen and in Helium Decompression Tables.

NOTE **The rules using the 0.7 ata ppO_2 tables are the same for nitrogen and helium; however, the tables are not interchangeable.**

- These tables are designed to be used with MK 16 UBA (or any other constant ppO_2 closed-circuit UBA) with an oxygen setpoint of 0.7 ata or higher.
- When using helium as the inert gas, the amount of nitrogen must be minimized in the breathing loop. Flush the UBA well with helium-oxygen using proper purge procedure in the MK 16 UBA O&M manual.
- Tables are grouped by depth and within each depth group is a limit line. These tables are designed to be dived to the limit line. Schedules below the limit line provide for unforeseen circumstances when a diver might experience an inadvertent downward excursion or for an unforeseen reason overstay the planned bottom time.
- Tables/schedules are selected according to the maximum depth obtained during the dive and the bottom time (time from leaving the surface to leaving the bottom).
- General rules for using these tables are the same as for standard air tables:

  1. Enter the table at the listed depth that is exactly equal to or is next greater than the maximum depth attained during the dive.
  2. Select the bottom time from those listed for the selected depth that is exactly equal to or is next greater than the bottom time of the dive.
  3. Never attempt to interpolate between decompression schedules.
  4. Use the decompression stops listed for the selected bottom time.
  5. Ensure that the diver's chest is maintained as close as possible to each decompression depth for the number of minutes listed.
  6. Maximum ascent rate is 30 feet per minute.
  7. Begin timing each stop on arrival at the decompression stop depth and resume ascent when the specified time has elapsed. Do not include ascent time as part of stop time.

8. The last stop may be taken at 20 fsw if desired. After completing the prescribed 20-fsw stop, remain at any depth between 10 fsw and 20 fsw inclusive for the 10-fsw stop time as noted in the appropriate decompression table.

9. Always use the appropriate decompression table when surfacing even if UBA malfunction has significantly altered ppO_2.

- In emergency situations (e.g., UBA flood-out or failure), immediately ascend to the first decompression stop according to the original decompression schedule if deeper than the first stop, and shift to the Emergency Breathing System (EBS). The subsequent decompression is modified according to the diluent gas originally breathed.

  — **Helium-Oxygen Diluent**. Follow the original HeO_2 decompression schedule without modification while breathing air.

  — **Nitrogen-Oxygen (Air) Diluent**. Double all remaining decompression stops while breathing air. If the switch to emergency air is made while at a decompression stop, then double the remaining time at that stop and all shallower stops. If the dive falls within the no-decompression limit and a switch to EBS has occurred, a mandatory 10-minute stop at 20 fsw is required.

  If either of these procedures is used, the diver should be closely observed for signs of decompression sickness for 2 hours following the dive, but need not be treated unless symptoms arise.

- When selecting the proper decompression table, all dives within the past 12 hours must be considered. Repetitive dives are allowed. Repetitive diving decompression procedures vary depending on the breathing medium(s) selected for past dives and for the current dive. If a dive resulted in breathing from the EBS then no repetitive dives shall be made within the next 12 hours. Refer to the following tables:

  — Table 17-8a for Repetitive Dive Procedures for Various Gas Mediums.

  — Figure 17-7 for the Dive Worksheet for Repetitive 0.7 ata Constant Partial Pressure Oxygen in Nitrogen Dives.

  — Table 17-9 for the No-Decompression Limits and Repetitive Group Designation Table for No-Decompression 0.7 ata Constant Partial Pressure Oxygen in Nitrogen Dives.

  — Table 17-10 for the Residual Nitrogen Timetable for Repetitive 0.7 ata Constant Partial Pressure Oxygen in Nitrogen Dives.

17-10.4 **PPO_2 Variances.** The ppO_2 in the MK 16 UBAs is expected to vary slightly from 0.6 - 0.9 ata for irregular brief intervals. This does not constitute a malfunction.

Table 17-8a. *Repetitive Dive Procedures for Various Gas Mediums.*

WARNING
No repetitive dives are authorized after an emergency procedure requiring a shift to the EBS.

Selection of Repetitive Procedures for Various Gas Mediums

Previous Breathing Medium (Refer to Notes 1, 2, and 3)	Current Breathing Medium	Procedure from Table 17-8b
N_2O_2	N_2O_2	A
Air	N_2O_2	B
N_2O_2	Air	C
HeO_2	HeO_2	D
HeO_2	Air	E
Air	HeO_2	F
HeO_2	N_2O_2	G
N_2O_2	HeO_2	H

Notes:

1. If a breathing medium containing helium was breathed at any time during the 12-hour period immediately preceding a dive, use HeO_2 as the previous breathing medium.

2. If 100 percent oxygen rebreathers are used on a dive in conjunction with other breathing gases, treat that portion of the dive as if 0.7 ATA O_2 in N_2 was breathed.

3. If both air and 0.7 ATA O_2 in N_2 are breathed during a dive, treat the entire dive as an air dive. If the 0.7 ata O_2 in N_2 is breathed at depths 80 fsw or deeper, add the following correction factors to the maximum depth when selecting the appropriate air table.

Maximum Depth on N_2O_2	Correction Factor
Not exceeding 80 FSW	0
81-99	Plus 5
100-119	Plus 10
120-139	Plus 15
140-150	Plus 20

Table 17-8b. *Repetitive Dive Procedures for Various Gas Mediums.*

Notes:

A. (1) Use the Worksheet (Figure 17-7) for calculations.

(2) Determine the repetitive group letter for depth and time of dive conducted from Table 17-9 for no-decompression dives or from the Closed-Circuit Mixed-Gas UBA Decompression Tables (Table 17-14 and Table 17-15) for decompression dives. If the exact time or depth is not found, go to the next longer time or the next deeper depth.

(3) Locate the repetitive group letter in Table 17-10. Move across the table to the correct surface interval time. Move down to the bottom of the column for the new group designation.

(4) Move down the column of the new group designation to the depth of the planned dive. This is the residual nitrogen time (RNT). Add this to the planned bottom time of the next dive to find the decompression schedule and the new group designation.

(5) RNT Exception Rule: If the repetitive dive is to the same depth or deeper than the depth of the previous dive, and the RNT is longer than the original bottom time, use the original bottom time.

B. Use the repetitive group designation from the standard air decompression table or the no-decompression limits and repetitive group designation table for no-decompression air dives to enter Table 17-10. Compute the RNT as in procedure A. Do not use the residual nitrogen timetable for repetitive air dives to find the RNT.

C. (1) Determine the repetitive group designation for depth and time of dive conducted from Table 17-9 or Table 17-14. If the exact time or depth is not found, go to the next longer time or the next deeper depth.

(2) Locate the repetitive group letter in Table 17-10. Move across the table to the correct surface-interval time. Move down to the bottom of the column for the new group designation.

(3) Use the repetitive group designation from Table 17-10 as the new group designation in the residual nitrogen timetable for repetitive air dives (Chapter 10) to find the RNT.

D. Add the bottom time of the current dive to the sum of the bottom times for all dives within the past 12 hours to get the adjusted bottom time. Use the maximum depth attained within the past 12 hours and the adjusted bottom time to select the appropriate profile from Table 17-15.

E. Add the bottom times of all dives within the past 12 hours to get an adjusted bottom time. Using the standard air decompression table, find the maximum depth attained during the past 12 hours and the adjusted bottom time. The repetitive group from this air table may then be used as the surfacing repetitive group from the last dive. The residual nitrogen timetable for repetitive air dives is used to find the repetitive group at the end of the current surface interval and the appropriate residual nitrogen time for the current air dive.

F. Compute the RNT from the residual nitrogen timetable for repetitive air dives using the depth of the planned dive. Add the RNT to the planned bottom time to get the adjusted bottom time. Use Table 17-15 for the adjusted bottom time at the planned depth.

G. Add the bottom times of all dives within the past 12 hours to get an adjusted bottom time. Using Table 17-14, find the maximum depth attained during the past 12 hours and the adjusted bottom time. The repetitive group from the table may then be used as the surfacing repetitive group from the last dive. Table 17-10 is used to find the repetitive group at the end of the current surface interval and the appropriate RNT for the current dive.

H. Compute the RNT from Table 17-10 using the depth of the previous dive. Add the RNT to the planned bottom time to get the adjusted bottom time. Use Table 17-15 for the adjusted bottom time at the planned depth.

REPETITIVE DIVE WORKSHEET
FOR
0.7 ATA N_2O_2 DIVES

Part 1. Previous Dive:

_______________ minutes

_______________ feet

_______________ repetitive group designator from Table 17-9

Part 2. Surface Interval: _______________ hours _______________ minutes on the surface

_______________ final repetitive group from Table 17-10

Part 3. Equivalent Single Dive Time:

Enter Table 17-10 at the depth row for the new dive and the column of the final repetitive group to find the corresponding Residual Nitrogen Time (RNT).

_______________ minutes RNT

\+ _______________ minutes planned bottom time

= _______________ minutes equivalent single dive time

Part 4. Decompression Schedule for the Repetitive Dive:

_______________ minutes equivalent single dive time from Part 3

_______________ feet, depth of the repetitive dive.

Figure 17-7. Dive Worksheet for Repetitive 0.7 ata Constant Partial Pressure Oxygen in Nitrogen Dives.

Table 17-9. *No-Decompression Limits and Repetitive Group Designation Table for 0.7 ata Constant Partial Pressure Oxygen in Nitrogen Dives.*

Depth	No-Decompression Limits (min)	Repetitive Group Designation															
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
10	Unlimited	720															
20	720	154	423	720													
30	720	31	50	73	98	128	165	211	273	373	634	720					
40	367	17	27	38	50	63	76	91	107	125	144	167	192	222	258	304	367
50	143	12	19	26	34	42	50	59	68	78	88	99	111	123	137	143	
60	74	9	14	20	25	31	37	43	50	57	64	71	74				
70	51	7	11	16	20	25	30	34	39	45	50	51					
80	39	6	10	13	17	21	25	29	33	37	39						
90	32	5	8	11	14	18	21	24	28	31	32						
100	27	5	7	10	13	15	18	21	24	27							
110	24	4	6	9	11	14	16	19	21	24							
120	19	4	6	8	10	12	15	17	19								
130	16	3	5	7	9	11	13	15	16								
140	13	3	5	7	8	10	12	13									
150	11	3	4	6	8	9	11										
Limit Line																	
160	9	3	4	6	7	9											
170	8	3	4	5	7	8											

Table 17-10. *Residual Nitrogen Timetable for Repetitive 0.7 ata Constant Partial Pressure Oxygen in Nitrogen Dives.*

A																0:00 4:46*
B															0:00 2:35	2:36 6:03*
C														0:00 1:57	1:58 3:29	3:30 6:57*
D													0:00 1:50	1:51 2:49	2:50 4:21	4:22 7:49*
E												0:00 1:15	1:16 2:42	2:43 3:42	3:43 5:13	5:14 8:42*
F											0:00 0:44	0:45 2:08	2:09 3:34	3:35 4:34	4:35 6:06	6:07 9:34*
G										0:00 0:54	0:55 1:36	1:37 3:00	3:01 4:26	4:27 5:26	5:27 6:58	6:59 10:26*
H									0:00 1:04	1:05 1:46	1:47 2:28	2:29 3:52	3:53 5:19	5:20 6:18	6:19 7:50	7:51 10:18*
I								0:00 1:15	1:16 1:57	1:58 2:38	2:39 3:20	3:21 4:44	4:45 6:11	6:12 7:11	7:12 8:42	8:43 12:10*
J							0:00 0:43	0:44 2:07	2:08 2:49	2:50 3:31	3:32 4:13	4:14 5:36	5:37 7:03	7:04 8:03	8:04 9:35	9:36 12:43*
K						0:00 0:53	0:54 1:35	1:36 2:59	3:00 3:41	3:42 4:23	4:24 5:05	5:06 6:29	6:30 7:25	7:26 8:55	8:56 10:27	10:28 10:55*
L					0:00 1:04	1:05 1:46	1:47 2:27	2:28 3:51	3:52 4:33	4:34 5:15	5:16 5:57	5:58 7:21	7:22 8:48	8:49 9:47	9:48 11:19	11:20 14:47*
M				0:00 0:32	0:33 1:56	1:57 2:36	2:37 3:20	3:21 4:44	4:45 5:25	5:26 6:07	6:08 6:49	6:50 8:13	8:14 9:40	9:41 10:39	10:40 12:11	12:12 15:39*
N			0:00 0:42	0:43 1:24	1:25 2:48	2:49 3:30	3:31 4:12	4:13 5:36	5:37 6:18	6:19 7:00	7:01 7:41	7:42 9:05	9:06 10:32	10:33 11:32	11:33 13:03	13:04 16:31*
O		0:00 0:53	0:54 1:35	1:36 2:16	2:17 3:40	3:41 4:22	4:23 5:04	5:05 6:28	6:29 7:10	7:11 7:52	7:53 8:34	8:35 9:44	9:45 11:24	11:25 12:24	12:25 13:56	13:57 17:24*
Z	0:00 1:03	1:04 1:45	1:46 2:27	2:28 3:09	3:10 4:32	4:33 5:14	5:15 5:56	5:57 7:20	7:21 8:02	8:03 8:44	8:45 9:20	9:21 10:51	10:52 12:16	12:17 13:16	13:17 14:48	14:49 18:16*
	Z	**O**	**N**	**M**	**L**	**K**	**J**	**I**	**H**	**G**	**F**	**E**	**D**	**C**	**B**	**A**

New Group Designation

10																12:00
20														12:00	7:03	2:34
30						12:00	10:34	6:13	4:33	3:31	2:45	2:08	1:38	1:13	0:50	0:31
40	6:07	5:04	4:18	3:42	3:12	2:47	2:24	2:05	1:47	1:31	1:16	1:03	0:50	0:38	0:27	0:17
50	3:10	2:23	2:17	2:03	1:51	1:39	1:28	1:18	1:08	0:59	0:50	0:42	0:34	0:26	0:19	0:12
60	2:30	1:40	1:30	1:20	1:14	1:11	1:04	0:57	0:50	0:43	0:37	0:31	0:25	0:20	0:14	0:09
70	2:10	1:20	1:10	1:05	1:00	0:51	0:50	0:45	0:39	0:34	0:30	0:25	0:20	0:16	0:11	0:07
80	1:10	1:05	1:00	0:55	0:50	0:45	0:39	0:37	0:33	0:29	0:25	0:21	0:17	0:13	0:10	0:06
90	1:00	0:55	0:50	0:45	0:42	0:40	0:32	0:31	0:28	0:24	0:21	0:18	0:14	0:11	0:08	0:05
100	0:50	0:45	0:42	0:40	0:38	0:35	0:30	0:27	0:24	0:21	0:18	0:15	0:13	0:10	0:07	0:05
110	0:45	0:40	0:37	0:35	0:33	0:30	0:25	0:24	0:21	0:19	0:16	0:14	0:11	0:09	0:06	0:04
120	0:40	0:38	0:35	0:33	0:30	0:28	0:25	0:20	0:19	0:17	0:15	0:12	0:10	0:08	0:06	0:04
130	0:35	0:34	0:32	0:30	0:28	0:25	0:23	0:20	0:16	0:15	0:13	0:11	0:09	0:07	0:05	0:03
140	0:35	0:30	0:28	0:27	0:25	0:23	0:20	0:19	0:16	0:13	0:12	0:10	0:08	0:07	0:05	0:03
150	0:30	0:29	0:27	0:25	0:23	0:20	0:19	0:18	0:16	0:13	0:11	0:09	0:08	0:06	0:04	0:03
160	0:30	0:28	0:25	0:24	0:23	0:20	0:19	0:18	0:15	0:13	0:10	0:09	0:07	0:06	0:04	0:03
170	0:25	0:24	0:23	0:22	0:20	0:19	0:18	0:17	0:15	0:13	0:10	0:08	0:07	0:05	0:04	0:03

Residual Nitrogen Times (Minutes)

*** No RNT After This Time**

When addition of oxygen to the UBA is manually controlled, ppO_2 should be maintained in accordance with techniques and emergency procedures listed in the MK 16 O&M manual.

The Diving Supervisor and medical personnel should recognize that a diver who has been breathing a mixture with ppO_2 lower than 0.6 ata for any length of time may have a greater risk of developing decompression sickness. Such a diver requires observation after surfacing, but need not be treated unless symptoms of decompression sickness occur.

17-10.5 **Emergency Breathing System (EBS).** The Emergency Breathing System provides an alternate breathing source for decompressing diver(s) in the event of a MK 16 failure. The two types of EBS available for use are EBS Type I and EBS Type II MK 1 Mod 0. The systems have been designed and tested as an accurate method for topside to control and monitor breathing gas being supplied to a diver(s) during decompression. The EBS shall be deployed whenever MK 16 decompression diving is anticipated. In the event of MK 16 failure or malfunction, the diver(s) will transfer to the EBS as soon as possible and continue to use the EBS to complete the decompression profile. It is to be used only for its designed purpose as discussed in paragraph 17-10.3 as an emergency breathing source and not as a surface-supplied diving system.

17-10.5.1 **EBS Type I.** The EBS type I was designed and is intended to be used only in support of diving up to 200 fsw. NAVSEA Operation and Maintenance manual S9592-AN-MMO-010 provides detailed equipment descriptions, reference data, and information on operation and maintenance. This type of EBS is a non-certified system (Figure 17-8)

17-10.5.2 **EBS Type II MK 1 Mod 0.** The EBS II is a certified surface-supplied, in-water emergency life-support system, with capabilities to support two divers during decompression for dive profiles to 300 fsw (Figure 17-9). The EBS II enables voice communication capabilities between topside personnel and divers while the divers are using the MK 24 FFM (Figure 17-10). PEO MINEWAR technical manual SS600-AL-MMA-010 provides detailed equipment descriptions, reference data, and information on operation and maintenance.

17-10.5.3 **Required Gas Supply for the EBS.** When a decompression dive is planned, the Diving Supervisor must calculate the volume of gas required should a diver be required to breathe from the EBS throughout decompression.

17-10.5.3.1 ***Calculating EBS Gas Requirements.*** The following steps may be used to calculate EBS gas requirements (Figure 17-11):

1. Determine decompression profiles from appropriate closed-circuit mixed-gas UBA decompression tables using 0.7 ata constant partial pressure of oxygen.

2. Multiply the time of each decompression stop by the gas consumption rates (scfm) in Table 17-11 to obtain total volume required per stop. Table 17-11 assumes a light work rate (gas consumption = 0.63 acfm).

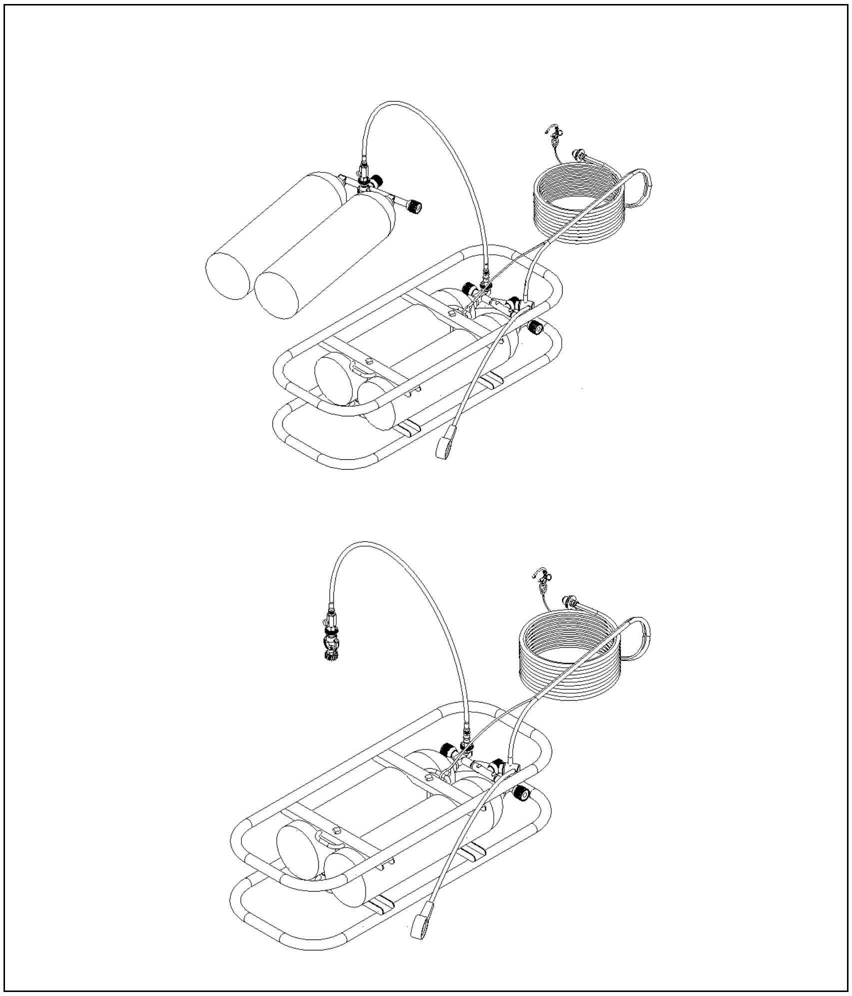

Figure 17-8. EBS Type 1.

3. Total the volumes required per stop to obtain total volume for decompression. The total should be rounded up to the nearest whole scf.

4. Multiply the total volume for decompression by a safety factor of 10 percent and add the product to the volume for decompression for total air volume required.

The volume of gas available in the EBS I may be obtained from Table 17-12 when twin 80-cubic foot scuba bottles are employed or from the following formula when other EBS configurations are used.

$$\text{EBS Volume Available (SCF)} = \frac{F_V \times N \times (P_1 - P_R)}{14.7}$$

Where:

C: Convulsions. The first sign of CNS oxygen toxicity may be a convulsion that occurs with little or no warning.

The most serious symptom of CNS oxygen toxicity is convulsion. Refer to Chapter 3 for a complete description of a convulsive episode. The following factors should be noted regarding an oxygen convulsion:

- The diver is unable to carry on any effective breathing during the convulsion.
- After the diver is brought to the surface, there will be a period of unconsciousness or neurologic impairment following the convulsion; these symptoms are indistinguishable from those of arterial gas embolism.
- No attempt should be made to insert any object between the clenched teeth of a convulsing diver. Although a convulsive diver may suffer a lacerated tongue, this trauma is preferable to the trauma that may be caused during the insertion of a foreign object. In addition, the person providing first aid may incur significant hand injury if bitten by the convulsing diver.
- There may be no warning of an impending convulsion to provide the diver the opportunity to return to the surface. Therefore, buddy lines are essential to safe closed-circuit oxygen diving.

18-2.1.4 **Causes of CNS Oxygen Toxicity.** Factors that increase the likelihood of CNS oxygen toxicity are:

- Increased partial pressure of oxygen. At depths less than 25 fsw, a change in depth of five fsw increases the risk of oxygen toxicity only slightly, but a similar depth increase in the 30-fsw to 50-fsw range may significantly increase the likelihood of a toxicity episode.
- Increased time of exposure
- Prolonged immersion
- Stress from strenuous physical exercise
- Carbon dioxide buildup. The increased tendency toward CNS oxygen toxicity may occur before the diver is aware of any symptoms of carbon dioxide buildup.
- Cold stress resulting from shivering or an increased exercise rate as the diver attempts to keep warm.
- Systemic diseases that increase oxygen consumption. Conditions associated with increased metabolic rates (such as certain thyroid or adrenal disorders) tend to cause an increase in oxygen sensitivity. Divers with these diseases should be excluded from oxygen diving.

18-2.1.5 **Treatment of Nonconvulsive Symptoms.** The stricken diver should alert his dive buddy and make a controlled ascent to the surface. The victim's life preserver should be inflated (if necessary) with the dive buddy watching him closely for progression of symptoms.

18-2.1.6 **Treatment of Underwater Convulsion.** The following steps should be taken when treating a convulsing diver:

1. Assume a position behind the convulsing diver. The weight belt should be left in place to prevent the diver from assuming a face down position on the surface. Release the victim's weight belt only if progress to the surface is significantly impeded.
2. Leave the victim's mouthpiece in his mouth. If it is not in his mouth, do not attempt to replace it; however, if time permits, ensure that the mouthpiece is switched to the SURFACE position.
3. Grasp the victim around his chest above the UBA or between the UBA and his body. If difficulty is encountered in gaining control of the victim in this manner, the rescuer should use the best method possible to obtain control. The UBA waist or neck strap may be grasped if necessary.
4. Make a controlled ascent to the surface, maintaining a slight pressure on the diver's chest to assist exhalation.
5. If additional buoyancy is required, activate the victim's life jacket. The rescuer should not release his own weight belt or inflate his own life jacket.
6. Upon reaching the surface, inflate the victim's life jacket if not previously done.
7. Remove the victim's mouthpiece and switch the valve to SURFACE to prevent the possibility of the rig flooding and weighing down the victim.
8. Signal for emergency pickup.
9. Once the convulsion has subsided, open the victim's airway by tilting his head back slightly.
10. Ensure the victim is breathing. Mouth-to-mouth breathing may be initiated if necessary.
11. If an upward excursion occurred during the actual convulsion, transport to the nearest chamber and have the victim evaluated by an individual trained to recognize and treat diving-related illness.

18-2.2 **Oxygen Deficiency (Hypoxia).** Oxygen deficiency, or *hypoxia*, is the condition in which the partial pressure of oxygen is too low to meet the metabolic needs of the body. Chapter 3 contains an in-depth description of this disorder. In the context of

- *Evaluation of the Modified Draeger LAR V Closed-Circuit Oxygen Rebreather*; NEDU Report 5-79
- *Unmanned Evaluation of Six Closed-Circuit Oxygen Rebreathers*; NEDU Report 3-82

18-4 CLOSED-CIRCUIT OXYGEN EXPOSURE LIMITS

The U.S. Navy closed-circuit oxygen exposure limits have been extended and revised to allow greater flexibility in closed-circuit oxygen diving operations. The revised limits are divided into two categories: Transit with Excursion Limits and Single Depth Limits.

18-4.1 **Transit with Excursion Limits Table.** The Transit with Excursion Limits (Table 18-4) call for a maximum dive depth of 20 fsw or shallower for the majority of the dive, but allow the diver to make a brief excursion to depths as great as 50 fsw. The Transit with Excursion Limits is normally the preferred mode of operation because maintaining a depth of 20 fsw or shallower minimizes the possibility of CNS oxygen toxicity during the majority of the dive, yet allows a brief downward excursion if needed (see Figure 18-3). Only a single excursion is allowed.

Table 18-4. *Excursion Limits.*

Depth	Maximum Time
21-40 fsw	15 minutes
41-50 fsw	5 minutes

18-4.2 **Single-Depth Oxygen Exposure Limits Table.** The Single-Depth Limits (Table 18-5) allow maximum exposure at the greatest depth, but have a shorter overall exposure time. Single-depth limits may, however, be useful when maximum bottom time is needed deeper than 25 fsw.

18-4.3 **Oxygen Exposure Limit Testing.** The Transit with Excursion Limits and Single-Depth Limits have been tested extensively over the entire depth range and are acceptable for routine diving operations. They are not considered exceptional exposure. It must be noted that the limits shown in this section apply only to closed-circuit 100-percent oxygen diving and are not applicable to deep mixed-gas diving. Separate oxygen exposure limits have been established for deep, helium-oxygen mixed-gas diving.

18-4.4 **Individual Oxygen Susceptibility Precautions.** Although the limits described in this section have been thoroughly tested and are safe for the vast majority of individuals, occasional episodes of CNS oxygen toxicity may occur. This is the basis for requiring buddy lines on closed-circuit oxygen diving operations.

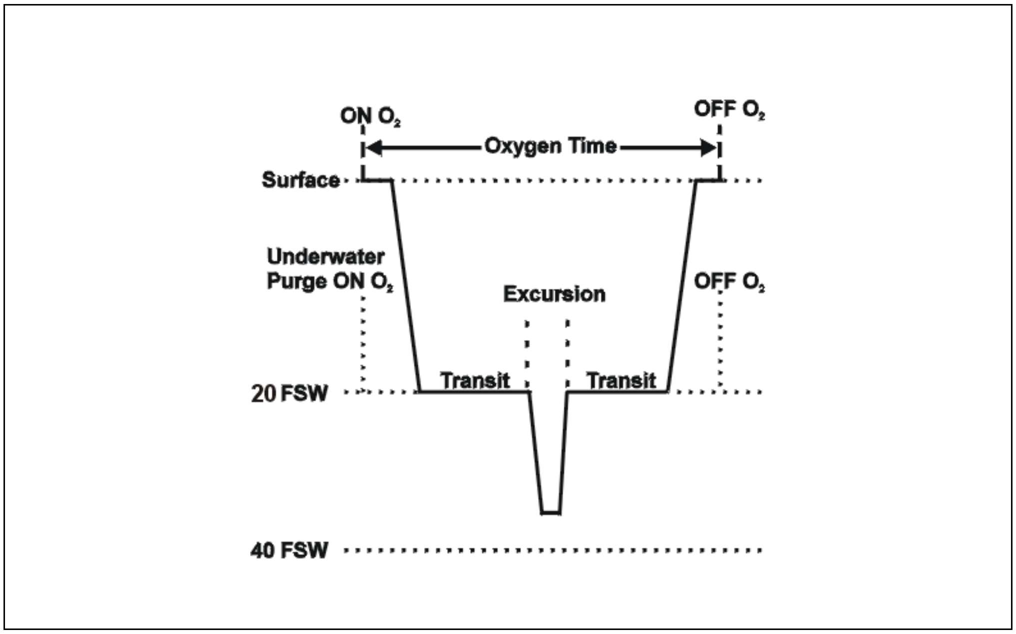

Figure 18-3. Example of Transit with Excursion.

Table 18-5. *Single-Depth Oxygen Exposure Limits.*

Depth	Maximum Oxygen Time
25 fsw	240 minutes
30 fsw	80 minutes
35 fsw	25 minutes
40 fsw	15 minutes
50 fsw	10 minutes

18-4.5 **Transit with Excursion Limits.** A 20 foot maximum depth for transit with one excursion, if necessary, will be the preferred option in most combat swimmer operations. When operational considerations necessitate a descent to deeper than 20 fsw for longer than allowed by the excursion limits, the appropriate single-depth limit should be used (paragraph 18-4.6).

18-4.5.1 **Transit with Excursion Limits Definitions.** The following definitions are illustrated in Figure 18-3:

- *Transit* is the portion of the dive spent at 20 fsw or shallower.
- *Excursion* is the portion of the dive deeper than 20 fsw.
- *Excursion time* is the time between the diver’s initial descent below 20 fsw and his return to 20 fsw or shallower at the end of the excursion.

- *Oxygen time* is calculated as the time interval between when the diver begins breathing from the closed-circuit oxygen UBA (on-oxygen time) and the time when he discontinues breathing from the closed-circuit oxygen UBA (off-oxygen time).

18-4.5.2 **Transit with Excursion Rules.** A diver who has maintained a transit depth of 20 fsw or shallower may make one brief downward excursion as long as he observes these rules:

- Maximum total time of dive (oxygen time) may not exceed 240 minutes.

- A single excursion may be taken at any time during the dive.

- The diver must have returned to 20 fsw or shallower by the end of the prescribed excursion limit.

- The time limit for the excursion is determined by the maximum depth attained during the excursion (Table 18-4). Note that the Excursion Limits are different from the Single-Depth Limits.

Example: Dive Profile Using Transit with Excursion Limits. A dive mission calls for a swim pair to transit at 15 fsw for 45 minutes, descend to 36 fsw, and complete their objective. As long as the divers do not exceed a maximum depth of 40 fsw, they may use the 40-fsw excursion limit of 15 minutes. The time at which they initially descend below 20 fsw to the time at which they finish the excursion must be 15 minutes or less.

18-4.5.3 **Inadvertent Excursions.** If an inadvertent excursion should occur, one of the following situations will apply:

- If the depth and/or time of the excursion exceeds the limits in Table 18-4 or if an excursion has been taken previously, the dive must be aborted and the diver must return to the surface.

- If the excursion was within the allowed excursion limits, the dive may be continued to the maximum allowed oxygen dive time, but no additional excursions deeper than 25 fsw may be taken.

- The dive may be treated as a single-depth dive applying the maximum depth and the total oxygen time to the Single-Depth Limits shown in Table 18-5.

Example 1. A dive pair is having difficulty with a malfunctioning compass. They have been on oxygen (oxygen time) for 35 minutes when they notice that their depth gauge reads 55 fsw. Because this exceeds the maximum allowed oxygen exposure depth, the dive must be aborted and the divers must return to the surface.

Example 2. A diver on a compass swim notes that his depth gauge reads 32 fsw. He recalls checking his watch 5 minutes earlier and at that time his depth gauge read 18 fsw. As his excursion time is less than 15 minutes, he has not exceeded the excursion limit for 40 fsw. He may continue the dive, but he must maintain his depth at 20 fsw or less and make no additional excursions.

NOTE **If the diver is unsure how long he was below 20 fsw, the dive must be aborted.**

18-4.6 **Single-Depth Limits.** The term Single-Depth Limits does not mean that the entire dive must be spent at one depth, but refers to the time limit applied to the dive based on the maximum depth attained during the dive.

18-4.6.1 **Single-Depth Limits Definitions.** The following definitions apply when using the Single-Depth Limits:

- *Oxygen time* is calculated as the time interval between when the diver begins breathing from the closed-circuit oxygen UBA (on-oxygen time) and the time when he discontinues breathing from the closed-circuit oxygen UBA (off-oxygen time).

- The *depth* for the dive used to determine the allowable exposure time is determined by the maximum depth attained during the dive. For intermediate depth, the next deeper depth limit will be used.

18-4.6.2 **Depth/Time Limits.** The Single-Depth Limits are provided in Table 18-5. No excursions are allowed when using these limits.

Example. Twenty-two minutes (oxygen time) into a compass swim, a dive pair descends to 28 fsw to avoid the propeller of a passing boat. They remain at this depth for 8 minutes. They now have two choices for calculating their allowed oxygen time: (1) they may return to 20 fsw or shallower and use the time below 25 fsw as an excursion, allowing them to continue their dive on the Transit with Excursion Limits to a maximum time of 240 minutes; or (2) they may elect to remain at 28 fsw and use the 30-fsw Single-Depth Limits to a maximum dive time of 80 minutes.

18-4.7 **Exposure Limits for Successive Oxygen Dives.** If an oxygen dive is conducted after a previous closed-circuit oxygen exposure, the effect of the previous dive on the exposure limit for the subsequent dive is dependent on the Off-Oxygen Interval.

18-4.7.1 **Definitions for Successive Oxygen Dives.** The following definitions apply when using oxygen exposure limits for successive oxygen dives.

- *Off-Oxygen Interval*. The interval between off-oxygen time and on-oxygen time is defined as the time from when the diver discontinues breathing from his closed-circuit oxygen UBA on one dive until he begins breathing from the UBA on the next dive.

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- *Face mask squeeze* can occur when the diver fails to equalize air in the mask by nasal exhalation. In a full face mask, malfunctioning air supply or valving can cause face mask squeeze.

- *Suit squeeze* is caused by a pocket of air in a dry suit that becomes trapped under a fold or fitting and pinches the skin in the fold area.

- *Tooth squeeze* is caused by a pocket of air in a filling.

19-4.1.1 **Treating Squeeze During Descent.** To treat squeeze during descent:

1. Stop descent.
2. If efforts to equalize pressure fail, ascend a few feet.
3. Avoid clearing on ascent.
4. Avoid a forceful Valsalva
5. If further efforts to equalize pressure fail, abort the dive.
6. If the diver reports dizziness, ventilate the diver, abort the dive, and evaluate the need to send down the standby diver to assist.
7. Report the squeeze to the medical personnel trained in diving medicine for appropriate treatment.

19-4.1.2 **Treating Reverse Squeeze During Ascent.** Reverse squeeze occurs when gas trapped in a cavity cannot escape as it expands during ascent. To treat reverse squeeze of the middle ear or sinus during ascent:

1. Stop ascent and, if clearing does not occur spontaneously, descend 2 to 4 feet.
2. Ascend slowly and in stages to allow additional time for equalization.
3. Avoid forceful Valsalva.
4. Evaluate the need to send down the standby diver to assist if difficulty persists. Vertigo may develop.
5. Upon surfacing, report the problem to the medical personnel trained in diving medicine for appropriate treatment.

19-4.1.3 **Preventing Squeeze.** Sinus and ear squeeze are best prevented by not diving with nasal and sinus congestion. If decongestants must be used, check with medical personnel trained in diving medicine to obtain medication that will not cause drowsiness and possibly add to symptoms caused by the narcotic effect of nitrogen.

19-4.1.4 Refer to Chapter 3 for more information on the signs and symptoms of the various types of squeeze

19-4.2 Gastrointestinal Distention as a Result of Gas Expansion. Divers may occasionally experience abdominal pain during ascent because of gas expansion in the stomach or intestines. This condition is caused by gas being generated in the intestines during a dive, or by swallowing air (aerophagia). These pockets of gas will usually work their way out of the system through the mouth or anus. If not, distention will occur.

19-4.2.1 **Treating Intestinal Gas Expansion.** If the pain begins to pass the stage of mild discomfort, ascent should be halted and the diver should descend slightly to relieve the pain. The diver should then attempt to gently burp or release the gas anally. Overzealous attempts to belch should be avoided as they may result in swallowing more air. Abdominal pain following fast ascents shall be evaluated by a Diving Medical Officer.

19-4.2.2 **Preventing Intestinal Gas Expansion.** To avoid intestinal gas expansion:

1. Do not dive with an upset stomach or bowel.

2. Avoid eating foods that are likely to produce intestinal gas.

3. Avoid a steep, head-down angle during descent to minimize the amount of air swallowed.

19-4.3 Ear Barotrauma. Simple ear squeeze is discussed in paragraph 19-4.1. More serious forms of ear barotrauma are rupture of the eardrum or round or oval window.

19-4.3.1 **Eardrum Rupture.** Ear squeeze may result in eardrum rupture. When rupture occurs, this pain will diminish rapidly. If eardrum rupture is suspected, the dive shall be aborted. Vertigo and/or nausea may occur if water enters the middle ear. Suspected cases of eardrum rupture shall be referred to medical personnel. Antibiotics and pain medication taken orally may be required. Never administer medications directly into the canal of a ruptured eardrum unless done in direct consultation with an ear, nose, and throat medical specialist.

19-4.3.2 **Inner Ear Barotrauma.** The round window and oval window are membranes that separate fluid in the inner ear from the middle ear. Inner ear barotrauma involves the rupture of one of these membranes and may be associated with the diver who had difficulty clearing his ears (vigorous Valsalva). However, a rupture may arise for no apparent reason. Often symptoms of inner ear barotrauma will become evident on the bottom or after the diver reaches the surface. Symptoms may include vertigo, hearing loss, or tinnitus. Any hearing loss occurring within 72 hours of a hyperbaric exposure should be evaluated for inner ear barotrauma.

CHAPTER 21

Recompression Therapy

21-1 INTRODUCTION

21-1.1 **Purpose.** This chapter covers recompression therapy. Recompression therapy is indicated for treating omitted decompression, decompression sickness, and arterial gas embolism.

21-1.2 **Scope.** The procedures outlined in this chapter are to be performed only by personnel properly trained to use them. Because these procedures cover symptoms ranging from pain to life-threatening disorders, the degree of medical expertise necessary to carry out treatment properly will vary. Certain procedures, such as starting IV fluid lines and inserting chest tubes, require special training and should not be attempted by untrained individuals. Treatment tables can be executed without consulting a Diving Medical Officer (DMO), although a DMO should always be contacted at the earliest possible opportunity. Four treatment tables require special consideration:

- Treatment Table 4 is a long, arduous table that requires constant evaluation of the stricken diver.
- Treatment Table 7 and Treatment Table 8 allow prolonged treatments for severely ill patients based on the patient’s condition throughout the treatment.
- Treatment Table 9 can only be prescribed by a Diving Medical Officer.

21-1.3 **Diving Supervisor’s Responsibilities.** Experience has shown that symptoms of severe decompression sickness or arterial gas embolism may occur following seemingly normal dives. This fact, combined with the many operational scenarios under which diving is conducted, means that treatment of severely ill individuals will be required occasionally when qualified medical help is not immediately on scene. Therefore, it is the Diving Supervisor’s responsibility to ensure that every member of the diving team:

1. Is thoroughly familiar with all recompression procedures.
2. Knows the location of the nearest, certified recompression facility.
3. Knows how to contact a qualified Diving Medical Officer if one is not at the site.

21-1.4 **Emergency Consultation.** Modern communications allow access to medical expertise from even the most remote areas. Emergency consultation is available 24 hours a day with:

- Primary:

  Navy Experimental Diving Unit (NEDU)
  321 Bullfinch Road
  Panama City, FL 32407-7015
  Commercial (850) 230-3100 or (850) 235-1668, DSN 436-4351

- Secondary:

  Navy Diving Salvage and Training Center (NDSTC)
  350 South Craig Rd.
  Panama City, FL 32407-7015
  Commercial (850) 234-4651, DSN 436-4651

21-1.5 **Applicability of Recompression.** The recompression procedures described in this chapter are designed to handle most situations that will be encountered operationally. They are applicable to both surface-supplied and scuba diving, whether on air, nitrogen-oxygen, helium-oxygen, or 100 percent oxygen. For example, the treatment of arterial gas embolism has little to do with the gas being breathed at the time of the accident. Because all possible conditions cannot be anticipated, additional medical expertise should be sought in all cases of decompression sickness or arterial gas embolism that do not show substantial improvement on standard treatment tables. Treatment of decompression sickness during saturation dives is covered separately in Chapter 15 of this manual. Periodic evaluation of U.S. Navy recompression treatment procedures has shown they are effective in relieving symptoms over 90 percent of the time when used as published. Deviation from these protocols shall be made only with the recommendation of a Diving Medical Officer.

21-1.6 **Recompression Treatment for Non-Diving Disorders.** In addition to individuals suffering from diving disorders, U.S. Navy recompression chambers are also permitted to conduct hyperbaric oxygen (HBO_2) therapy to treat individuals suffering from cyanide poisoning, carbon monoxide poisoning, gas gangrene, smoke inhalation, necrotizing soft-tissue infections, or arterial gas embolism arising from surgery, diagnostic procedures, or thoracic trauma. If the chamber is to be used for treatment of non-diving related medical conditions other than those listed above, authorization from MED-21 shall be obtained before treatment begins (BUMEDINST 6320.38). Any treatment of a non-diving related medical condition shall be done under the cognizance of a Diving Medical Officer.

The guidelines given in Table 21-1 for conducting HBO_2 therapy are taken from the Undersea and Hyperbaric Medical Society's *Hyperbaric Oxygen (HBO_2) Therapy Committee Report—1996: Approved Indications for Hyperbaric Oxygen Therapy*. For each condition, the guidelines prescribe the recommended Treatment

- Do not ignore seemingly minor symptoms. They can quickly become major symptoms.
- Follow the selected treatment table unless changes are recommended by a Diving Medical Officer.
- If multiple symptoms occur, treat for the most serious condition.

21-1.9 **In-Water or Air Recompression.** Recompression in a facility equipped for oxygen breathing is preferred. However, the procedures covered here also address situations where either no chamber is available or where only air is available at the recompression facility. In-water or air recompression treatments are used only when the delay in transporting the patient to a recompression facility having oxygen would cause greater harm.

21-2 PRESCRIBING AND MODIFYING TREATMENTS

Not all Medical Officers are DMOs. The DMO shall be a graduate of the Diving Medical Officer course taught at the Naval Diving and Salvage Training Center (NDSTC). DMOs shall have subspecialty codes of 16U0 or 16U1 (Undersea Medical Officer). Saturation Diving Medical Officers have an Additional Qualification Designator (AQD) of 6UD and Submarine Medical Officers an AQD of 6UM. Medical Officers who only complete the short diving medicine course at NDSTC do not receive DMO subspecialty codes, but are considered to have the same privileges as DMOs when treating diving accidents, with the exception that they are not granted the privilege of modifying treatment protocols. Only DMOs with appropriate subspeciality codes cited above may modify the treatment protocols as warranted by the patient’s condition with the concurrence of the Commanding Officer or Officer in Charge. Other physicians may assist and advise treatment and care of diving casualties but may not modify recompression procedures.

21-3 OMITTED DECOMPRESSION

Certain emergencies, such as uncontrolled ascents, an exhausted air supply, or bodily injury, may interrupt or prevent required decompression. If the diver shows symptoms of decompression sickness or arterial gas embolism, immediate treatment using the appropriate oxygen or air recompression treatment table is essential. Even if the diver shows no symptoms, omitted decompression must be addressed in some manner to avert later difficulty. Table 21-3 summarizes management of asymptomatic Omitted Decompression.

21-3.1 **Planned and Unplanned Omitted Decompression.** Omitted decompression may or may not be planned. Planned omitted decompression results when a condition develops at depth that will require the diver to surface before completing all of the decompression stops and when there is time to consider all available options, ready the recompression chamber, and alert all personnel as to the planned evolution. Equipment malfunctions, diver injury, or sudden severe storms are examples of these situations. In unplanned omitted decompression, the diver suddenly appears at the surface without warning or misses decompression for some unfore-

***Table 21-3.** Management of Asymptomatic Omitted Decompression.*

Depth at Which Omission Began	Decompression Status	Eligible for Sur-D?	Surface Interval (Note 4)	Action	
				ChamberAvailable (Note 3)	**No Chamber Available**
20 fsw or shallower	No Decompression	N/A	N/A	Observe on surface for 1 hour.	
	Decompression Stops Required	Yes	Less than 5 minutes	Use Surface Decompression Tables.	Perform Chamber stops in water. (Note 1)
		No	Less than 1 minute	Return to depth of stop. Increase stop time 1 minute. Resume decompression.	
		No.	Greater than 1 minute.	Return to depth of stop. Multiply 20- and 10-foot stop times by 1.5. ***OR:*** Treatment Table 5 (1A) for surface interval less than 5 minutes. ***OR:*** Treatment Table 6 (2A) for surface interval greater than 5 minutes.	
Deeper than 20 fsw	No-Decompression	N/A	N/A	Observe on surface for 1 hour.	
	Decompression Stops Required	Yes	Less than 5 minutes.	Use Surface Decompression Tables	Perform chamber stops in water (Note 1)
	Decompression Stops Required (Less than 30 minutes missed)	No No	Less than 5 minutes. Greater than 5 minutes.	Treatment Table 5 (1A) (Note 2) Treatment Table 6 (2A) (Note 2)	Descend to depth of first stop. Follow the schedule to 30 fsw. Multiply 30, 20, and 10 fsw stops by 1.5.
	Decompression Stops Required (Greater than 30 minutes)	No	Any	Treatment Table 6 (2A) (Note 2)	

Notes:

1. Sur-D Air only.
2. If a diver missed a stop deeper than 60 feet and oxygen is available, first compress to the depth of the first missed stop. Double this stop, then decompress to 60 feet using the appropriate decompression schedule doubling all stop times. Decompress from 60 feet on Treatment Table 5 or 6 as appropriate. If oxygen is unavailable, treat on a full Treatment Table 1A or 2A as appropriate.
3. Using a recompression chamber is strongly preferred over in-water recompression for returning a diver to pressure. Compress to depth as fast as possible not to exceed 100 fsw/min.
4. For surface decompression, the 5 minute surface interval starts after leaving the 30 foot stop or 30 fsw if no in-water stops are required till the diver reaches 40 fsw in the chamber.

seen reason. In either instance, the Surface Decompression Tables may be used to remove the diver from the water, if the surfacing time occurs such that water stops are either not required or have already been completed. When the conditions that permit using the Surface Decompression Tables are not fulfilled, the diver's decompression will be compromised. Special care shall be taken to detect signs of decompression sickness. The diver must be returned to pressure as soon as possible.

21-3.2 **Treating Omitted Decompression with Symptoms.** If the diver develops symptoms of decompression sickness during the surface interval, treat in accordance with the procedures in paragraph 21-4 (no chamber available) or paragraph 21-5 (chamber available). If the diver has no symptoms of decompression sickness or

21-5.4.5.9 ***Sleeping, Resting, and Eating.*** At least two tenders should be available when using Treatment Table 7, and three may be necessary for severely ill patients. Not all tenders are required to be in the chamber, and they may be locked in and out as required following appropriate decompression tables. The patient may sleep anytime except when breathing oxygen deeper than 30 feet. While asleep, the patient's pulse, respiration, and blood pressure should be monitored and recorded at intervals appropriate to the patient's condition. Food may be taken at any time and fluid intake should be maintained as outlined in paragraph 21-5.5.7.

21-5.4.5.10 ***Ancillary Care.*** Patients on Treatment Table 7 requiring intravenous and/or drug therapy should have these administered in accordance with paragraph 21-5.5.7 and paragraph 21-5.5.7.1.

21-5.4.5.11 ***Life Support.*** Before committing to a Treatment Table 7, the life-support considerations in paragraph 21-5.6 must be addressed. Do not commit to a Treatment Table 7 if the internal chamber temperature cannot be maintained at 85°F (29.4°C) or less (paragraph 21-5.6.5).

21-5.4.5.12 ***Abort Procedures.*** In some cases, a Treatment Table 7 may have to be terminated early. If extenuating circumstances dictate early decompression and less than 12 hours have elapsed since treatment was begun, decompression may be accomplished using the appropriate 60-foot Air Decompression Table as modified below. The 60-foot Air Decompression Tables may be used even if time was spent between 60 and 165 feet (e.g., on Table 4 or 6A), as long as at least 3 hours have elapsed since the last excursion below 60 feet. If less than 3 hours have elapsed, or if any time was spent below 165 feet, use the Air Decompression Table appropriate to the maximum depth attained during treatment. All stops and times in the Air Decompression Table should be followed, but oxygen-breathing periods should be started for all chamber occupants as soon as a depth of 30 feet is reached. All chamber occupants should continue oxygen-breathing periods of 25 minutes on 100 percent oxygen, followed by 5 minutes on air, until the total time breathing oxygen is one-half or more of the total decompression time.

If more than 12 hours have elapsed since treatment was begun, the decompression schedule of Treatment Table 7 shall be used. In extreme emergencies, the abort recommendations (paragraph 21-8) may be used if more than 12 hours have elapsed since beginning treatment.

21-5.4.6 **Treatment Table 8.** Treatment Table 8 is an adaptation of a Royal Navy Treatment Table 65 mainly for treating deep uncontrolled ascents (see Volume 3) when more than 60 minutes of decompression have been missed. Compress symptomatic patient to depth of relief not to exceed 225 fsw. Initiate Treatment Table 8 from depth of relief. The Table 8 schedule from 60 feet is the same as Treatment Table 7.

21-5.4.7 **Treatment Table 9.** Treatment Table 9 is a hyperbaric oxygen treatment table using 90 minutes of oxygen at 45 feet. This table is recommended by the Diving Medical Officer cognizant of the patient's medical condition. Treatment Table 9 is used for the following:

- Residual symptoms from AGE/DCS
- Carbon monoxide or cyanide poisoning
- Smoke inhalation
- Medical hyperbaric oxygen therapy

This table may also be recommended by the cognizant Diving Medical Officer when initially treating a severely injured patient whose medical condition precludes long absences from definitive medical care.

21-5.5 **Tending the Patient.** When conducting a recompression treatment, at least one qualified tender shall be inside the chamber. The inside tender shall be familiar with all treatment procedures and the signs, symptoms, and treatment of all diving-related disorders.

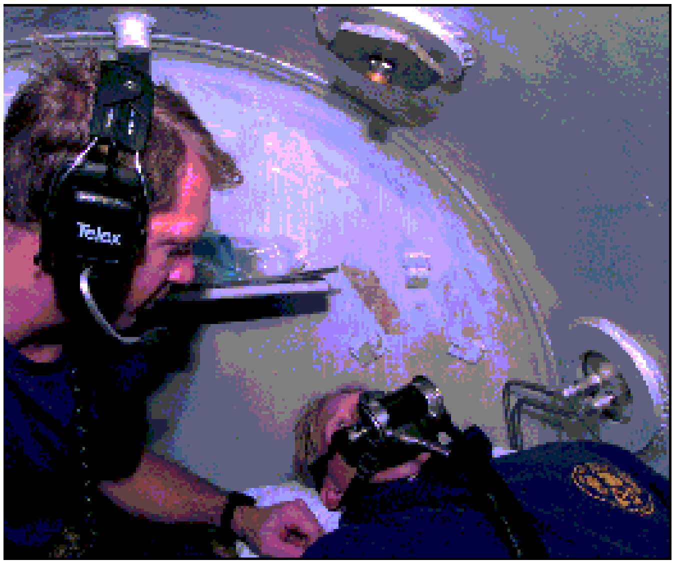


Figure 21-1. Inside Tender

21-5.5.1 **DMO or DMT Inside Tender.** If it is known before the treatment begins that involved medical aid must be administered to the patient, or if the patient is suspected of suffering from arterial gas embolism, a Diving Medical Technician or Diving Medical Officer should accompany the patient inside the chamber. However, recompression treatment must not be delayed.

21-5.5.2 **Use of DMO.** If only one Diving Medical Officer is present, the Medical Officer's time in the chamber should be kept to a minimum because effectiveness in directing the treatment is greatly diminished when inside the chamber. If periods in the chamber are necessary, visits should be kept within no-decompression limits if possible.

21-5.5.2a **Non-Diver Inside Tender - Medical.** Non-diving medical personnel may be qualified as Inside Tenders. Qualifications may be achieved through Navy Diver Inside Tender PQS. Prerequisites: Current diving physical exam, conformance to Navy physical standards and diver candidate pressure test.

21-5.5.2b **Emergency Management.** Emergency situations that require specialized medical care should always have the best qualified person provide it. The best qualified person may be a surgeon, repiratory therapist, IDC, etc. Since these are emergency exposures, no special medical or physical prerequisites exist. A qualified Inside Tender is required inside the chamber to handle any system related requirements.

21-5.5.3 **Patient Positioning.** Inside the chamber, the tender ensures that the patient is lying down and positioned to permit free blood circulation to all extremities. The tender closes and secures the inner lock door and pressurization begins at 20 fpm.

21-5.5.4 **Equalizing During Descent.** Descent rates may have to be decreased as necessary to allow the patient to equalize; however, it is vital to attain treatment depth in a timely manner for a suspected arterial gas embolism patient.

21-5.5.5 **Inside Tender Responsibilities.** During the early phases of treatment, the inside tender must monitor the patient constantly for signs of relief. Drugs that mask signs of the illness should not be given. Observation of these signs is the principal method of diagnosing the patient’s illness. Furthermore, the depth and time of their relief designates the treatment table to be used. The inside tender is also responsible for:

- Releasing the door latches (dogs) after a seal is made
- Communications with outside personnel
- Providing first aid as required by the patient
- Administering treatment gas to the patient at treatment depth
- Providing normal assistance to the patient as required
- Ensuring that sound attenuators for ear protection are worn during compression and ventilation portions of recompression treatments

21-5.5.6 **Oxygen Breathing and Toxicity During Treatments.** During prolonged treatments on Treatment Tables 4, 7, or 8, pulmonary oxygen toxicity may develop. Acute CNS oxygen toxicity may develop on any oxygen treatment table. Refer to paragraph 19-2.4 for further discussion of oxygen toxicity during in-water dives.

21-5.5.6.1 ***Central Nervous System Oxygen Toxicity.*** When employing the oxygen treatment tables, tenders must be particularly alert for the early warning signs of CNS oxygen toxicity. The warning signs can be remembered readily by using the mnemonic VENTIDC (Vision, Ears, Nausea, Twitching\Tingling, Irritability, Dizziness, Convulsions). For additional information, refer to paragraph 19-2.4.2.

21-5.5.6.1.1 ***Procedures in the Event of Oxygen Toxicity.*** At the first sign of CNS oxygen toxicity, the patient should be removed from oxygen and allowed to breathe chamber air. Fifteen minutes after all symptoms have subsided, resume oxygen breathing at the point of interruption. If symptoms of CNS oxygen toxicity develop again or if the first symptom is a convulsion, take the follow action:

For Treatment Tables 5, 6, and 6A:

1. Remove the mask

2. After all symptoms have completely subsided, decompress 10 feet at a rate of 1 fsw/min. For a convulsion, begin travel when the patient is fully relaxed and breathing normally.

3. Resume oxygen breathing at the shallower depth at the point of interruption.

4. If another oxygen symptom occurs, contact a Diving Medical Officer to modify oxygen breathing schedule to meet requirements.

For Treatment Tables 4, 7, and 8:

1. Remove the mask.

2. Consult with a Diving Medical Officer for administering further oxygen breathing. No compensatory lengthening of the table is required for interruption in oxygen breathing

21-5.5.6.1.2 ***Interruptions Due to Oxygen Toxicity.*** CNS oxygen toxicity is unlikely in resting individuals at depths of 50 feet or shallower and very unlikely at 30 feet or shallower, regardless of the level of activity. However, patients with severe Type II decompression sickness or arterial gas embolism symptoms may be abnormally sensitive to CNS oxygen toxicity. Convulsions unrelated to oxygen toxicity may also occur and may be impossible to distinguish from oxygen seizures. Inserting an airway device or bite block is unnecessary while the patient is convulsing; it is not only difficult but may cause harm if attempted. Figure 21-7, Figure 21-8, and Figure 21-9 explain how to handle interruptions in oxygen breathing on Treatment Tables 5, 6, and 6A. Treatment Tables 4, 7, and 8 do not require compensatory lengthening or alteration if oxygen breathing must be interrupted.

21-5.5.6.2 ***Pulmonary Oxygen Toxicity.*** Pulmonary oxygen toxicity is unlikely to develop on Treatment Tables 5, 6, or 6A. On Treatment Tables 4, 7, or 8, the large amounts of oxygen that may have to be administered may result in end-inspiratory discomfort, progressing to substernal burning and severe pain on inspiration. Substernal burning is normally cause for discontinuing oxygen breathing in patients who are responding well to treatment. However, if a significant neurological deficit remains and improvement is continuing (or if deterioration occurs when oxygen breathing is interrupted), oxygen breathing should be continued as long as considered beneficial or until pain limits inspiration. If oxygen breathing must be continued beyond the period of substernal burning, or if the 2-hour air breaks on Treatment Tables 4, 7, or 8 cannot be used because of deterioration upon the discontinuance of oxygen, the oxygen breathing periods should be changed to 20 minutes on oxygen, followed by 10 minutes breathing chamber air. The Diving Medical Officer may tailor the above guidelines to suit individual patient response to treatment.

21-5.5.7 **Ancillary Care and Adjunctive Treatments.** Drug therapy should be administered only after consultation with a Diving Medical Officer. Chamber tenders shall be adequately trained and be capable of administering prescribed treatments. Always ensure patients are adequately hydrated. Fully conscious patients may be given fluid by mouth to maintain adequate hydration. One to two liters of water, juice, or non-carbonated drink, over the course of a Treatment Table 5 or 6, is usually sufficient. Patients with Type II symptoms, or symptoms of arterial gas embolism, should be considered for IV fluids. Stuporous or unconscious patients should always be given IV fluids, using large-gauge plastic catheters. If trained personnel are present, an IV should be started as soon as possible and kept dripping at a rate of 75 to 100 cc/hour, using isotonic fluids (Lactated Ringer's Solution, Normal Saline) until specific instructions regarding the rate and type of fluid administration are given by qualified medical personnel. Avoid solutions containing only Dextrose (D5W) as they may contribute to edema as the sugar is metabolized. In some cases, the bladder may be paralyzed. The victim's ability to void shall be assessed as soon as possible. If the patient cannot empty a full bladder, a urinary catheter shall be inserted as soon as possible by trained personnel. Always inflate catheter balloons with liquid, not air. Adequate fluid is being given when urine output is at least 0.5cc/kg/hr. A gauge of proper hydration is a clear colorless urine.

21-5.5.7.1 ***Steroids.*** There is no consensus on the usefulness of adjunctive therapy, other than IV fluids. The most frequently recommended adjunctive therapy is dexamethasone (Decadron), based on the following reasons:

- It decreases tissue swelling (edema)
- It decreases tissue inflammation
- It decreases leaking of blood vessels
- It helps prevent histamine release

General opinion is that spinal cord and brain edema cause many late-appearing neurologic problems in DCS. Research suggests that dexamethasone is not useful during treatment of AGE. In this case steroids may be useful but their efficiency has not been proven. They do not become effective, however, for 4 to 6 hours after intravenous introduction. Therefore, administer these drugs early in the treatment. Do not delay recompression while preparing these drugs. For cerebral edema, the initial recommended dose is 30 mg/kg IV bolus, followed by a constant infusion of 5.4 mg/kg/hr of methylprednisolone. Continue infusion for 23 hours. No benefit has been documented if steroid treatment was not started within 8 hours of symptoms.

21-5.5.7.2 ***Lidocaine.*** Several studies suggest that Lidocaine used in antiarrhymic doses (loading dose 1.5 mg/kg drip rate 1 mg/min) may be useful. Its mechanism of action for treating DCS has been hypothesized as:

- Reduction of cerebral metabolic rate
- Preservation of cerebral blood flow
- Reduction leukocyte adherence to damaged endothelium

NOTE **Steroids or other drugs can be used only upon the prescription by and under supervision of a Diving Medical Officer.**

21-5.5.8 **Sleeping and Eating.** The only time the patient should be kept awake during recompression treatments is during oxygen breathing periods at depths greater than 30 feet. Travel between decompression stops on Treatment Tables 4, 7, and 8 is not a contra-indication to sleeping. While asleep, vital signs (pulse, respiratory rate, blood pressure) should be monitored as the patient's condition dictates. Any significant change would be reason to arouse the patient and ascertain the cause. Food may be taken by chamber occupants at any time. Adequate fluid intake should be maintained as discussed in paragraph 21-5.5.7.

21-5.6 **Recompression Chamber Life-Support Considerations.** The short treatment tables (Oxygen Treatment Tables 5, 6, 6A; Air Treatment Tables 1A and 2A) can be accomplished easily without significant strain on either the recompression chamber facility or support crew. The long treatment tables (Tables 3, 4, 7, and 8) will require long periods of decompression and may tax both personnel and hardware severely.

21-5.6.1 **Minimum Manning Requirements.** The minimum team for conducting any recompression operation shall consist of three individuals. In case of emergency, the recompression chamber can be manned with two individuals.

1. The Diving Supervisor is in complete charge at the scene of the operation, keeping individual and overall times on the operation, logging progress, and communicating with personnel inside the chamber.

2. The Outside Tender is responsible for the operation of gas supplies, ventilation, pressurization, and exhaust of the chamber.

3. The Inside Tender is familiar with the diagnosis and treatment of diving-related sicknesses.

21-5.6.2 **Optimum Manning Requirements.** The optimum team for conducting recompression operations consists of four individuals:

1. The Diving Supervisor is in complete charge at the scene of the operation.

2. The Outside Tender #1 is responsible for the operation of the gas supplies, ventilation, pressurization, and exhaust of the chamber.

3. The Outside Tender #2 is responsible for keeping individuals' and overall times on the operation, logging progress as directed by the Diving Supervisor, and communicating with personnel inside the chamber.

4. The Inside Tender is familiar with the diagnosis and treatment of diving-related sicknesses.

21-5.6.2.1 ***Additional Personnel.*** If the patient has symptoms of serious decompression sickness or arterial gas embolism, the team will require additional personnel. If the treatment is prolonged, a second team may have to relieve the first team. Patients with serious decompression sickness and gas embolism would initially be accompanied inside the chamber by a Diving Medical Technician or Diving Medical Officer, if possible. However, treatment should not be delayed to comply with this recommendation.

21-5.6.2.2 ***Required Consultation by a Diving Medical Officer.*** A Diving Medical Officer shall be consulted, if at all possible, before committing the patient to a Treatment Table 4, 7, or 8. The Diving Medical Officer may be on scene or in communication with the Diving Supervisor.

21-5.6.3 **Oxygen Control.** All treatment schedules listed in this chapter are usually performed with a chamber atmosphere of air. To accomplish safe decompression, the oxygen percentage should not be allowed to fall below 19 percent. Oxygen may be added to the chamber by ventilating with air or by bleeding in oxygen from an oxygen breathing system. If a portable oxygen analyzer is available, it can be used to determine the adequacy of ventilation and/or addition of oxygen. If no oxygen analyzer is available, ventilation of the chamber in accordance with paragraph 21-5.6.6 will ensure adequate oxygenation. Chamber oxygen percentages as high as 25 percent are permitted. If the chamber is equipped with a life-support system so that ventilation is not required and an oxygen analyzer is available, the oxygen level should be maintained between 19 percent and 25 percent. If chamber oxygen goes above 25 percent, ventilation with air should be used to bring the oxygen percentage down.

21-5.6.4 **Carbon Dioxide Control.** Ventilation of the chamber in accordance with paragraph 21-5.6.6 will ensure that carbon dioxide produced metabolically does not cause the chamber carbon dioxide level to exceed 1.5 percent SEV (11.4 mmHg).

21-5.6.4.1 ***Carbon Dioxide Monitoring.*** Chamber carbon dioxide should be monitored with electronic chamber carbon dioxide monitors. Monitors generally read CO_2 percentage once chamber air has been exhausted to the surface. The CO_2 percent reading at the surface 1 ata must be corrected for depth. To keep chamber CO_2 below 1.5 percent SEV (11.4 mmHg), the surface CO_2 monitor values should remain below 0.78 percent with chamber depth at 30 feet, 0.53 percent with chamber depth at 60 feet, and 0.25 percent with the chamber at 165 feet. If the CO_2 analyzer is within the chamber, no correction to the CO_2 readings is necessary.

21-5.6.4.2 ***Carbon Dioxide Scrubbing.*** If the chamber is equipped with a carbon dioxide scrubber, the absorbent should be changed when the partial pressure of carbon dioxide in the chamber reaches 1.5 percent SEV (11.4 mmHg). If absorbent cannot be changed, supplemental chamber ventilation will be required to maintain chamber CO_2 at acceptable levels. With multiple or working chamber occupants, supplemental ventilation may be necessary to maintain chamber CO_2 at acceptable levels.

21-5.6.4.3 ***Carbon Dioxide Absorbent.*** CO_2 absorbent may be used beyond the expiration date, when used in a recompression chamber scrubber unit, when the recompression chamber is equipped with a CO_2 monitor. When employed in a recompression chamber that has no CO_2 monitor, CO_2 absorbent in an opened but resealed bucket may be used until the expiration date on the bucket is reached. Pre-packed, double-bagged canisters shall be labeled with the expiration date from the absorbent bucket.

21-5.6.5 **Temperature Control.** If possible, internal chamber temperature should be maintained at a level comfortable to the occupants. Cooling can usually be accomplished by chamber ventilation in accordance with paragraph 21-5.6.6. If the chamber is equipped with a heater/chiller unit, temperature control can usually be maintained for chamber occupant comfort under any external environmental conditions. Usually, recompression chambers will become hot and must be cooled continuously. Chambers should always be shaded from direct sunlight. The maximum durations for chamber occupants will depend on the internal chamber temperature as listed in Table 21-4. Never commit to a treatment table that will expose the chamber occupants to greater temperature/time combinations than listed in Table 21-4 unless qualified medical personnel who can evaluate the trade-off between the projected heat stress and the anticipated treatment benefit are consulted. A chamber temperature below 85°F (29.4°C) is always desirable, no matter which treatment table is used.

Table 21-4. *Maximum Permissible Recompression Chamber Exposure Times at Various Temperatures.*

Internal Temperature	Maximum Tolerance Time	Permissible Treatment Tables
Over 104°F (40°C)	Intolerable	No treatments
95-104°F (34.4-40°C)	2 hours	Table 5, 9
85-94°F (29.4-34.4°C)	6 hours	Tables 5, 6, 6A, 1A, 9
Under 85°F (29.4°C)	Unlimited	All

NOTE
Internal chamber temperature can be kept considerably below ambient by venting or by using an installed chiller unit. Internal chamber temperature can be measured using electronic, bimetallic, alcohol, or liquid crystal thermometers. **Never use a mercury thermometer in or around hyperbaric chambers**. Since chamber ventilation will produce temperature swings during ventilation, the above limits should be used as averages when controlling temperature by ventilation. **Always shade chamber from direct sunlight**.

21-5.6.5.1 ***Patient Hydration.*** Successful treatment of decompression sickness depends upon adequate hydration. Thirst is an unreliable indicator of the water intake necessary to compensate for heavy sweating, and isolation of the patient within the recompression chamber makes it difficult to assess his overall fluid balance. By providing adequate hydration and following the temperature/time guidelines in Table 21-4, heat exhaustion and heat stroke can be avoided. If the chamber temperature is above 85°F (29.4°C), tenders should monitor patients for signs of thermal stress. If the chamber temperature is above 85°F, chamber occupants should drink approximately one liter of water hourly; below 85°F they should drink an average of one-half liter hourly. Clear colorless urine in patients and tenders is a good indication of adequate hydration.

21-5.6.6 **Chamber Ventilation.** Ventilation is the usual means of controlling oxygen level, carbon dioxide level, and temperature. Ventilation using air is required for chambers without carbon dioxide scrubbers and atmospheric analysis. A ventilation rate of two acfm for each resting occupant, and four acfm for each active occupant, should be used. Chamber ventilation procedures are presented in paragraph 22-5.4. These procedures are designed to assure that the effective concentration of carbon dioxide will not exceed 1.5 percent SEV (11.4 mmHg) and that, when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent.

21-5.6.7 **Access to Chamber Occupants.** Recompression treatments usually require access to occupants for passing in items such as food, water, and drugs and passing out such items as urine, excrement, and trash. Never attempt a treatment longer than a Treatment Table 6 unless there is access to inside occupants. When doing a Treatment Table 4, 7, or 8, a double-lock chamber is mandatory because additional personnel may have to be locked in and out during treatment.

21-5.6.8 **Inside Tenders.** For Type I decompression sickness, one qualified inside tender is required. For Type II decompression sickness, medical personnel may have to be locked into the chamber as the patient's condition dictates. If one Diving Medical Officer is on site, the Medical Officer should lock in and out as the patient's condition dictates, but should not commit to the entire treatment unless absolutely necessary. Once committed to remain in the chamber, the Diving Medical Officer will not be able to aid the treatment as well and consultation with other medical personnel becomes more difficult.

21-5.6.8.1 ***Oxygen Breathing.*** During treatments, all chamber occupants may breathe 100 percent oxygen at depths of 45 feet or shallower without locking in additional personnel. Tenders should not fasten the oxygen masks to their heads, but should hold them on their faces. When deeper than 45 feet, at least one chamber occupant must breathe air.

21-5.6.8.1.1 ***Table 4.*** On Table 4, tenders are required to breathe oxygen for 2 hours before leaving 30 feet and for 2 additional hours during decompression from 30 feet to the surface.

21-5.6.8.1.2 ***Table 5.*** On Table 5, oxygen should be breathed by the tender during the final 30-minute ascent to the surface. If the tender has had a previous hyperbaric exposure, an additional 20 minutes of oxygen breathing is required at 30 feet prior to ascent. (See Table 21-6.)

21-5.6.8.1.3 ***Table 6.*** For an unmodified Table 6 or when there has been only a single extension at 60 or 30 feet, the tender breathes 100 percent oxygen for the final 30 minutes at 30 feet and during ascent to the surface. If there has been more than one extension, oxygen breathing is done for the last 60-minute period at 30 feet and during ascent to the surface. If the tender has had a dive/hyperbaric exposure within the past 12 hours, an additional 60-minute oxygen breathing period at 30 feet is required. (See Table 21-6.)

21-5.6.8.1.4 ***Table 6A.*** For an unmodified Table 6A or when there has been only a single extension at 60 or 30 feet, the tender breathes 100 percent oxygen for the final 60 minutes at 30 feet and during ascent to the surface. If there has been more than one extension, oxygen breathing is done for 90 minutes at 30 feet and during ascent to the surface. If the tender has had a dive/hyperbaric exposure within the past 12 hours, an additional 60-minutes of oxygen at 30 feet is required. (See Table 21-6.)

21-5.6.8.1.5 ***Table 9.*** On Table 9, the tender breathes 100 percent oxygen during the last 15 minutes at 45 feet and during ascent to the surface, regardless of the ascent rate used.

21-5.6.8.1.6 ***Tending Frequency.*** Normally, tenders should allow a surface interval of at least 12 hours between consecutive treatments on Tables 1A, 2A, 3, 5, 6, and 6A, and at least 48 hours between consecutive treatments on Tables 4, 7, and 8. If necessary, however, tenders may repeat Treatment Tables 5, 6, or 6A within this 12-hour surface interval if oxygen is breathed at 30 feet and shallower as outlined above. Minimum surface intervals for Tables 1A, 2A, 3, 4, and 7 shall be strictly observed.

21-5.7 **Loss of Oxygen During Treatment.** Loss of oxygen breathing capability during oxygen treatments is a rare occurrence. However, should this occur, the following should be done:

If repair can be effected within 15 minutes:

- Maintain depth until repair is completed.
- After O_2 is restored, resume treatment at point of interruption.

If repair can be effected after 15 minutes but before 2 hours:

- Maintain depth until repair is completed.
- After O_2 is restored: If original table was Table 5, 6, or 6A, complete treatment with maximum number of O_2 extensions.

21-5.7.1 **Compensation.** If Table 4, 7, or 8 is being used, no compensation in decompression is needed if O_2 lost. If decompression must be stopped because of worsening symptoms in the affected diver, then stop decompression. When oxygen is restored, continue treatment from where it was stopped.

21-5.7.2 **Switching to Air Treatment Table.** If O_2 breathing cannot be restored in 2 hours switch to comparable air Treatment Table at current depth for decompression if 60 fsw or shallower. Rate of ascent must not exceed 1 fpm between stops. If an increase in treatment depth deeper than 60 feet is needed, use Treatment Table 4.

21-5.8 **Use of High Oxygen Mixes.** High oxygen N_2O_2/HeO_2 mixtures may be administered during treatment when 100 percent oxygen cannot be tolerated. The premixed gases shown in Table 21-5 may be used over the depth range of 0-225 fsw.

Table 21-5. *High Oxygen Treatment Gas Mixtures.*

Depth (fsw)	Mix (HeO_2 or N_2O_2)	ppO_2
0–60	100%	1.00–2.82
61–165	50/50	1.42–3.0
166–225	64/36 (HeO_2)	2.17–2.8

High-oxygen mixtures can be used for treating patients at depth when no significant improvement was made at 60 fsw. High-oxygen mixtures may also be used for patients experiencing pulmonary oxygen toxicity at 60 fsw and shallower.

Ideally, the ppO_2 of the treatment gas used should be 1.5 to 3.0 ata. Using nitrogen as the background gas is an acceptable practice for treating DCS/AGE. Recent studies suggest that using helium as the background gas may be more beneficial. Using HeO_2 reduces the amount of nitrogen dissolved in the patient's tissue and facilitates the off-gassing of nitrogen.

21-5.9 **Treatment at Altitude - Tender Considerations.** Divers serving as inside tenders during hyperbaric treatments at altitude are performing a dive at altitude and therefore require more decompression than at sea level. Tenders locking into the chamber for brief periods should be managed according to the Diving At Altitude procedures (paragraph 9-12). Tenders remaining in the chamber for the full treatment table must breathe oxygen during the terminal portion of the treatment to satisfy their decompression requirement.

The additional oxygen breathing required at altitude on TT5, TT6, and TT6A is given in Table 21-6. The requirement pertains both to tenders equilibrated at altitude and to tenders flown directly from sea level to the chamber location.

Table 21-6. *Tender Oxygen Breathing Requirements.*[1]

		Altitude		
Treatment Table (TT)		**Surface to 2499 ft.**	**2500 ft. – 7499 ft.**	**7500 ft. – 10,000 ft.**
TT5[2]	without extension	:00	:00	:00
	with extension @ 30 fsw	:00	:00	:20
TT6[2]	up to one extension @ 60 fsw or 30 fsw	:30	:60	:90
	more than one extension	:60	:90	:120
TT6A[2]	up to one extension @ 60 fsw or 30 fsw	:60	:120	:150[3]
	more than one extension	:90	:150[3]	:180[3]

Note 1 All tender O_2 breathing times in table are conducted at 30 fsw. In addition, tenders will breathe O_2 on ascent from 30 fsw to the surface.

Note 2 If the tender had a previous hyperbaric exposure within 12 hours, use the following guidance for administering O_2:
For TT5, add an additional 20 minute O_2 breathing period to the times in the table.
For TT6 or TT6A, add an additional 60 minute O_2 breathing period to the times in the table.

Note 3 In some instances, tender's oxygen breathing obligation exceeds the table stay time at 30 fsw. Extend the time at 30 fsw to meet these obligations **if** patient's condition permits. Otherwise, adminster O_2 to the tender to the limit allowed by the treatment table and observe the tender on the surface for 1 hour for symptoms of DCS.

Contact NEDU for guidance on tender oxygen administration for other treatment tables.

21-6 POST-TREATMENT CONSIDERATIONS

Tenders on Tables 5, 6, 6A, 1A, 2A, or 3 should have a minimum of a 12-hour surface interval before no-decompression diving and a minimum of a 24-hour surface interval before dives requiring decompression stops. Tenders on Tables 4, 7, and 8 should have a minimum of a 48-hour surface interval prior to diving.

21-6.1 Post-Treatment Observation Period. After a treatment, patients treated on a Treatment Table 5 should remain at the recompression chamber facility for 2 hours. Patients who have been treated for Type II decompression sickness or who required a Treatment Table 6 for Type I symptoms and have had complete relief should remain at the recompression chamber facility for 6 hours. These times may be shortened upon the recommendation of a Diving Medical Officer, provided the patient will be with personnel who are experienced at recognizing recurrence of symptoms and can return to the recompression facility within 30 minutes. All patients should remain within 60 minutes of a recompression facility for 24 hours and should not be left alone during that period.

21-6.2 Post-Treatment Transfer. Patients with residual symptoms should be transferred to appropriate medical facilities as directed by qualified medical personnel. If ambulatory patients are sent home, they should always be accompanied by someone familiar with their condition who can return them to the recompression facility should the need arise. Patients completing treatment do not have to remain in the vicinity of the chamber if the Diving Medical Officer feels that transferring them to a medical facility immediately is in their best interest.

21-6.3 **Inside Tenders.** Treatment table profiles place the inside tender(s) at risk for decompression sickness. After completing treatments, inside tenders should remain in the vicinity of the recompression chamber for 1 hour. If they were tending for Treatment Table 4, 7, or 8, inside tenders should also remain within 60 minutes of a recompression facility for 24 hours.

21-6.4 **Flying After Treatments.** Patients with residual symptoms should fly only with the concurrence of a Diving Medical Officer. Patients who have been treated for decompression sickness or arterial gas embolism and have complete relief should not fly for 72 hours after treatment, at a minimum.

21-6.4.1 **Emergency Air Evacuation.** Some patients will require air evacuation to another treatment or medical facility immediately after surfacing from a treatment. They will not meet surface interval requirements as described above. Such evacuation is done only on the recommendation of a Diving Medical Officer. Aircraft pressurized to one ata should be used if possible, or unpressurized aircraft flown as low as safely possible (no more than 1,000 feet is preferable). Have the patient breathe 100 percent oxygen during transport, if available.

21-6.4.2 **Tender Surface Interval.** Tenders on Tables 5, 6, 6A, 1A, 2A, or 3 should have a 24-hour surface interval before flying. Tenders on tables 4, 7, and 8 should not fly for 72 hours.

21-6.5 **Treatment of Residual Symptoms.** After completion of the initial recompression treatment and after a surface interval sufficient to allow complete medical evaluation, additional recompression treatments may be instituted. For persistent Type II symptoms, daily treatment on Table 6 may be used, but twice-daily treatments on Treatment Tables 5 or 9 may also be used. The treatment table chosen for re-treatments must be based upon the patient's medical condition and the potential for pulmonary oxygen toxicity. Patients surfacing from Treatment Table 6A with extensions, 4, 7, or 8 may have severe pulmonary oxygen toxicity and may find breathing 100 percent oxygen at 45 or 60 feet to be uncomfortable. In these cases, daily treatments at 33 feet may also be used. As many oxygen breathing periods (30 minutes on oxygen followed by 5 minutes on air) should be administered as can be tolerated by the patient. Ascent to the surface is at 20 feet per minute. A minimum oxygen breathing time is 90 minutes. A practical maximum bottom time is 3 to 4 hours at 33 feet. Treatments should not be administered on a daily basis for more than 5 days without a break of at least 1 day. These guidelines may have to be modified by the Diving Medical Officer to suit individual patient circumstances and tolerance to oxygen as measured by decrements in the patient's vital capacity.

21-6.5.1 **Additional Recompression Treatments.** Additional recompression treatments are indicated as long as they are prescribed by a Diving Medical Officer. In treating residual symptoms, no response to recompression may occur on the first one or two treatments. In these cases, the Diving Medical Officer is the best judge as to the number of treatments. Consultation with NEDU or NDSTC may be appropriate (phone numbers are listed in paragraph 21-1.4). As the delay time between completion of initial treatment and the beginning of follow-up hyperbaric treatments increases, the probability of benefit from additional treatments decreases. However, improvement has been noted in patients who have had delay times of up to 1 week. Therefore, a long delay is not necessarily a reason to preclude follow-up treatments. Once residual symptoms respond to additional recompression treatments, such treatments should be continued until no further benefit is noted. In general, treatment may be discontinued if there is no further sustained improvement on two consecutive treatments.

21-6.6 **Returning to Diving after Treatment Table 5.** Divers who meet all of the criteria for treatment using Treatment Table 5, as outlined in paragraph 21-5.4.1 and who have had complete relief, may return to normal diving activity 7 days after surfacing from the Treatment Table 5. If there is any doubt about the presence or absence of Type II symptoms, the diver should be examined by a Diving Medical Officer before resumption of diving.

21-6.6.1 **Returning to Diving After Treatment Table 6.** Divers who had symptoms of arterial gas embolism, Type II DCS, or Type I DCS requiring a Treatment Table 6 should not dive for at least 4 weeks and should resume diving only upon the recommendation of a Diving Medical Officer.

21-6.6.2 **Returning to Diving After Treatment Table 4 or 7.** A diver having cardiorespiratory and/or CNS symptoms severe enough to warrant Treatment Table 4 or 7 should not dive for a minimum of 3 months, and not until a thorough review of his case by a Diving Medical Officer has established that return to normal diving activity can be accomplished safely.

21-7 NON-STANDARD TREATMENTS

The treatment recommendations presented in this chapter should be followed as closely as possible unless it becomes evident that they are not working. Only a Diving Medical Officer may then recommend changes to treatment protocols or use treatment techniques other than those described in this chapter. Any modifications to treatment tables shall be approved by the Commanding Officer. The standard treatment procedures in this chapter should be considered minimum treatments. Treatment procedures should never be shortened unless emergency situations arise that require chamber occupants to leave the chamber early, or the patient's medical condition precludes the use of standard U.S. Navy treatment tables.

21-8 RECOMPRESSION TREATMENT ABORT PROCEDURES

Once recompression therapy is started, it should be completed according to the procedures in this chapter unless the diver being treated dies or unless continuing the treatment would place the chamber occupants in mortal danger.

21-8.1 **Death During Treatment.** If it appears that the diver being treated has died, a qualified medical personnel shall be consulted before the treatment is aborted. If this is done, then the tenders may be decompressed by completing the treatment table, by following the air decompression schedule (as modified below), or contact NEDU or NDSTC for decompression procedures for the total time since treatment began and the maximum depth attained. The shortest procedure should be used. The exception is Treatment Table 7; the appropriate abort procedure for Table 7 is discussed in paragraph 21-5.4.5.12.

21-8.2 **Oxygen Breathing Periods During Abort Procedure.** The air decompression schedule used in recompression treatment aborts is modified by having all chamber occupants begin breathing oxygen as soon as a depth of 30 feet or shallower is reached. Oxygen-breathing periods of 25 minutes on oxygen, followed by 5 minutes on air, are continued until the total time on oxygen is one-half or more of the total decompression time. This procedure may be used even if gases other than air (i.e., nitrogen-oxygen or helium-oxygen mixtures) were breathed during treatment. Upon surfacing, chamber occupants are treated as if they had surfaced from a normal dive.

21-8.3 **Impending Natural Disasters or Mechanical Failures.** Impending natural disasters or mechanical failures may require aborting treatments. For instance, the ship where the chamber is located may be in imminent danger of sinking or a fire or explosion may have severely damaged the chamber system to such an extent that completing the treatment is impossible. In these cases, the abort procedure described above could be used for all chamber occupants (including the stricken diver) if time is available. If time is not available, the following may be done:

1. If deeper than 60 feet, go immediately to 60 feet.
2. Once the chamber is 60 feet or shallower, put all chamber occupants on continuous 100 percent oxygen.
3. Follow as much of the air decompression schedule (for maximum depth and total time) as possible, breathing 100 percent oxygen continuously.
4. When no more time is available, bring all chamber occupants to the surface (try not to exceed 10 feet per minute) and keep them on 100 percent oxygen during evacuation, if possible.
5. Immediately evacuate all chamber occupants to the nearest recompression facility and treat according to Figure 21-5. If no symptoms occurred after the treatment was aborted, follow Treatment Table 6.

21-9 EMERGENCY MEDICAL EQUIPMENT

Every diving activity shall maintain emergency medical equipment that will be available immediately for use at the scene of a diving accident (Figure 21-2). This equipment is to be in addition to any medical supplies maintained in a medical treatment facility and shall be kept in a kit small enough to carry into the chamber, or in a locker in the immediate vicinity of the chamber.

21-9.1 **Primary Emergency Kit.** Because some sterile items may become contaminated as a result of a hyperbaric exposure, it is desirable to have a primary kit for imme-

Figure 21-2. Emergency Medical Equipment for TRCS.

diate use inside the chamber and a secondary kit from which items that may become contaminated can be locked into the chamber only as needed. The lists of contents presented here are not meant to be restrictive but are considered the minimum requirement. Additional items may be added to suit local medical preferences.

21-9.2 **Emergency Kits.** The Primary Emergency Kit is described in Table 21-7; the Secondary Emergency Kit is described in Table 21-8.

21-9.2.1 **Primary Emergency Kit.** The primary emergency kit contains diagnostic and therapeutic equipment that is available immediately when required. This kit shall be inside the chamber during all treatments.

Table 21-7. *Primary Emergency Kit.*

Diagnostic Equipment

- Flashlight
- Stethoscope
- Otoscope (Ophthalmoscope)
- Sphygmomanometer (Aneroid type only, case vented for hyperbaric use)
- Reflex hammer
- Tuning Fork (256 cps)
- Sterile safety pins or swab sticks which can be broken for sensory testing
- Tongue depressors
- Thermometer (non-mercury type, high and low reading preferably)

Emergency Treatment Equipment and Medications

- Oropharyngeal airways (#4 and #5 Geudel)
- Self-Inflating Clear Bag-Mask ventilator with medium adult mask
  NOTE: Some of these units do not have sufficient bag volume to provide adequate ventilation. Use a Laerdal Resusci Folding Bag II (Adult) or equivalent.
- Suction apparatus
- Nonflexible plastic suction tips (Yankauer Suction Tip)
- Large-bore needle and catheter (12 or 14 gauge) for cricothyrotomy or relief of tension pneumothorax
- Chest tube
- Small Penrose drain, Heimlich valve, or other device to provide one-way flow of gas out of the chest
- Christmas tree adapter (to connect one-way valve to chest tube)
- Adhesive tape (2-inch waterproof)
- Elastic-Wrap bandage for a tourniquet (2- and 4-inch)
- Tourniquet
- Bandage Scissors
- #11 knife blade and handle
- Curved Kelly forceps
- 10% povidone-iodine swabs or wipes
- 1% lidocaine solution
- #21 ga. 1½-inch needles on 5 cc syringes
- Cravets
- 20 cc syringe

NOTE: One Primary Emergency Kit is required per chamber system (i.e., TRCS requires one).

Table 21-8. *Secondary Emergency Kit.*

Emergency Airway Equipment)

- Cuffed endotracheal tubes with adapters (7-9.5mm)
- Syringe and sterile water for cuff inflation (10 cc)
- Malleable stylet (approx. 12" in length)
- Laryngoscope blades (McIntosh #3 and #4, Miller #2 and #3)
- Sterile lubricant
- Soft-rubber suction catheters
- #32F and #34F latex rubber nasal airways
- 5% or 2% lidocaine ointment

Intravenous Infusion Therapy

- Catheter and needle unit, intravenous (16- and 18-gauge - 4 ea)
- Intravenous infusion sets (4)
- Intravenous infusion extension sets with injection ports (2)
- 3-way stopcocks
- Lactated Ringer's Solution (3 ea. 1 - liter bag)
- Normal saline (2 ea. 1 - liter bag)

Miscellaneous

- Nasogastric tube
- Urinary catheterization set with collection bag (Foley type)
- Straight and curved hemostats (2 ea)
- Blunt straight surgical scissors
- Syringes (2, 5, 10 and 30 cc)
- Sterile needles (18-, 20-, and 22- gauge)
- Wound closure instrument tray
- Needle driver
- Assorted suture material (with and without needles)
- Assorted scalpel blades and handle
- Surgical soap
- Sterile towels
- Sterile gloves (6-8)
- Gauze roller bandage, 1-inch and 2-inch, sterile
- 10% povidone-iodine swabs or wipes
- Cotton Balls
- Gauze pads, sterile, 4-inch by 4-inch
- Band aids
- Splints

NOTE 1: Only commands having recompression chambers with a Medical Officer or ACLS trained Diving Medical Technician/Independent Duty Corpsman assigned shall maintain a portable monitor-defibrillator and those drugs required by the American Heart Association for ACLS.

NOTE 2: Whenever possible, preloaded syringe injection sets should be obtained to avoid the need to vent multidose vials or prevent implosion of ampules. Sufficient quantities should be maintained to treat one injured diver.

NOTE 3: One Secondary Emergency Kit is required per chamber system (i.e., TRCS requires one).

NOTE 4**:** A portable oxygen supply with an E cylinder (approximately 669 liters of oxygen) is recommended whenever possible in the event the patient needs to be transported to another facility**.**

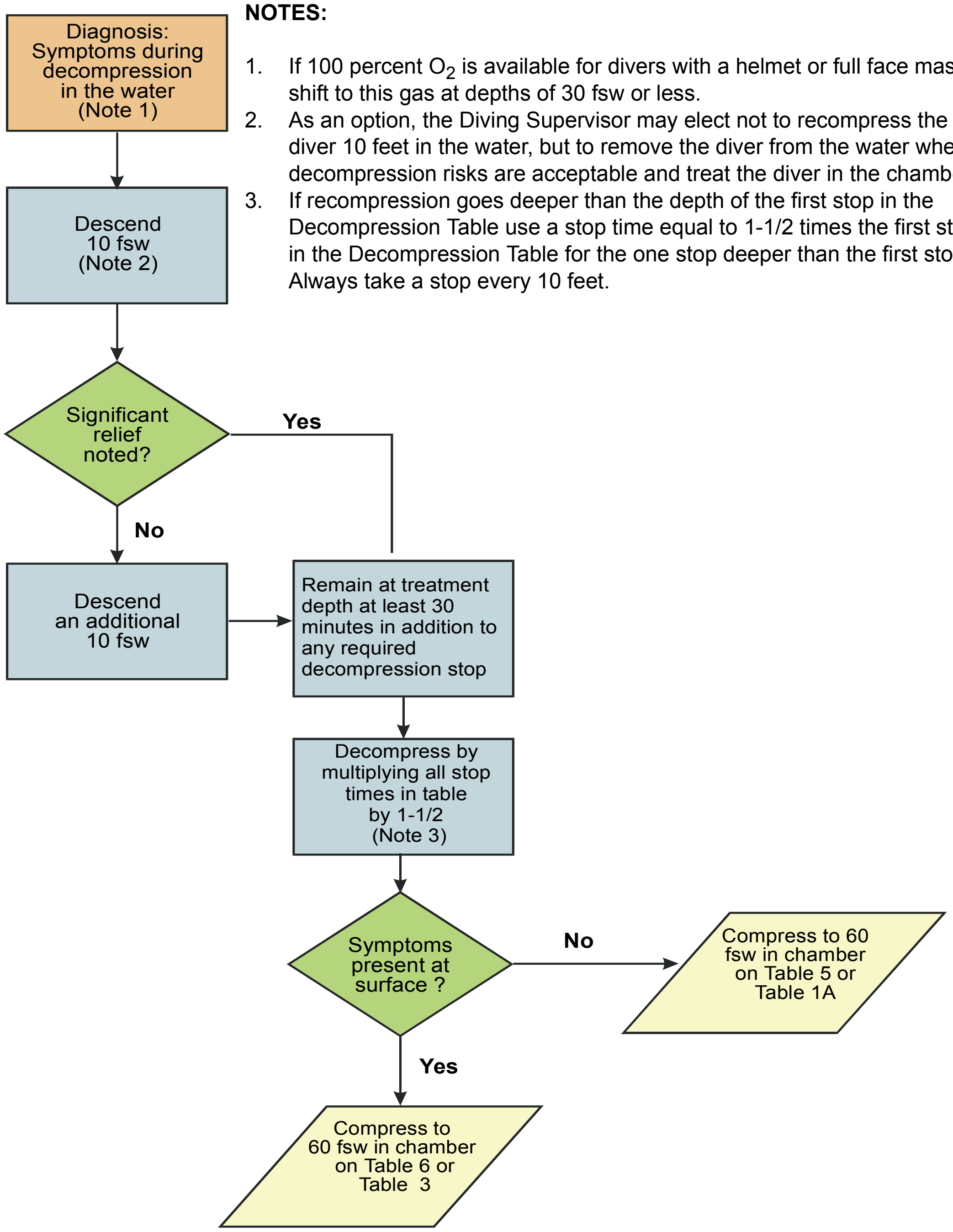
21-9.2.2 **Secondary Emergency Kit.** The secondary emergency kit contains equipment and medicine that does not need to be available immediately, but can be locked-in when required. This kit shall be stored in the vicinity of the chamber.

21-9.2.3 **Portable Monitor-Defibrillator.** Only commands having recompression chambers with a Medical Officer or ACLS trained Diving Medical Technician/Independent Duty Corpsman assisted shall maintain a portable monitor-defibrillator and those drugs required by the American Heart Association for ACLS. These drugs need to be in sufficient quantities to support an event requiring Advanced Cardiac Life Support. These drugs/equipment are not required to be in every dive kit when multiple chambers/kits are present in a single command.

21-9.3 **Use of Emergency Kits.** Unless adequately sealed against increased atmospheric pressure, sterile supplies should be resterilized after each pressure exposure, or, if not exposed, at six-month intervals. Drugs shall be replaced when their expiration date is reached. Not all drug ampules will withstand pressure. Stoppered multidose vials should be vented with a needle during pressurization and then discarded if not used.

21-9.3.1 **Modification of Emergency Kits.** Because the available facilities may differ on board ship, at land-based diving installations, and at diver training or experimental units, the responsible Diving Medical Officer or Diving Medical Technician will have to modify the emergency kits to suit the local needs. Both kits should be taken to the recompression chamber or scene of the accident. Each kit is to contain a list of contents. Each time the kit is opened, it shall be inventoried and each item checked for proper working order and then re-sterilized. Sterile supplies are to be provided in duplicate so that one set can be autoclaved while the other resides in the kit. The kits on-hand are inventoried, unopened, at four-month intervals. Normally, use of the emergency kit is to be restricted to the medical personnel. Concise instructions for administrating each drug are to be provided in the kit along with current American Heart Association Advanced Cardiac Life-Support Protocols. In untrained hands, many of the items can be dangerous. Remember that as in all treatments YOUR FIRST DUTY IS TO DO NO HARM.

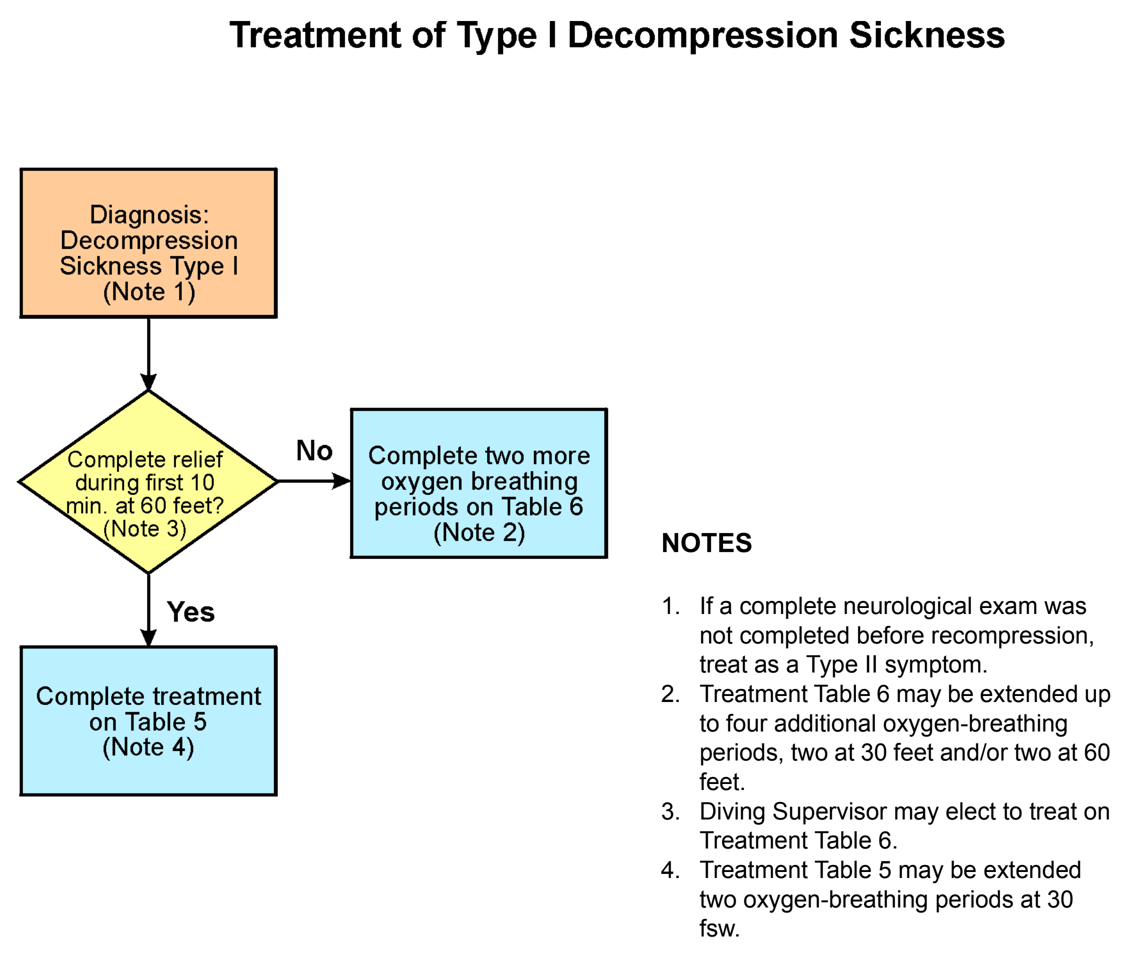
Treatment of Decompression Sickness Occurring While at a Decompression Stop in the Water



NOTES:

1. If 100 percent O_2 is available for divers with a helmet or full face mask, shift to this gas at depths of 30 fsw or less.
2. As an option, the Diving Supervisor may elect not to recompress the diver 10 feet in the water, but to remove the diver from the water when decompression risks are acceptable and treat the diver in the chamber.
3. If recompression goes deeper than the depth of the first stop in the Decompression Table use a stop time equal to 1-1/2 times the first stop in the Decompression Table for the one stop deeper than the first stop. Always take a stop every 10 feet.

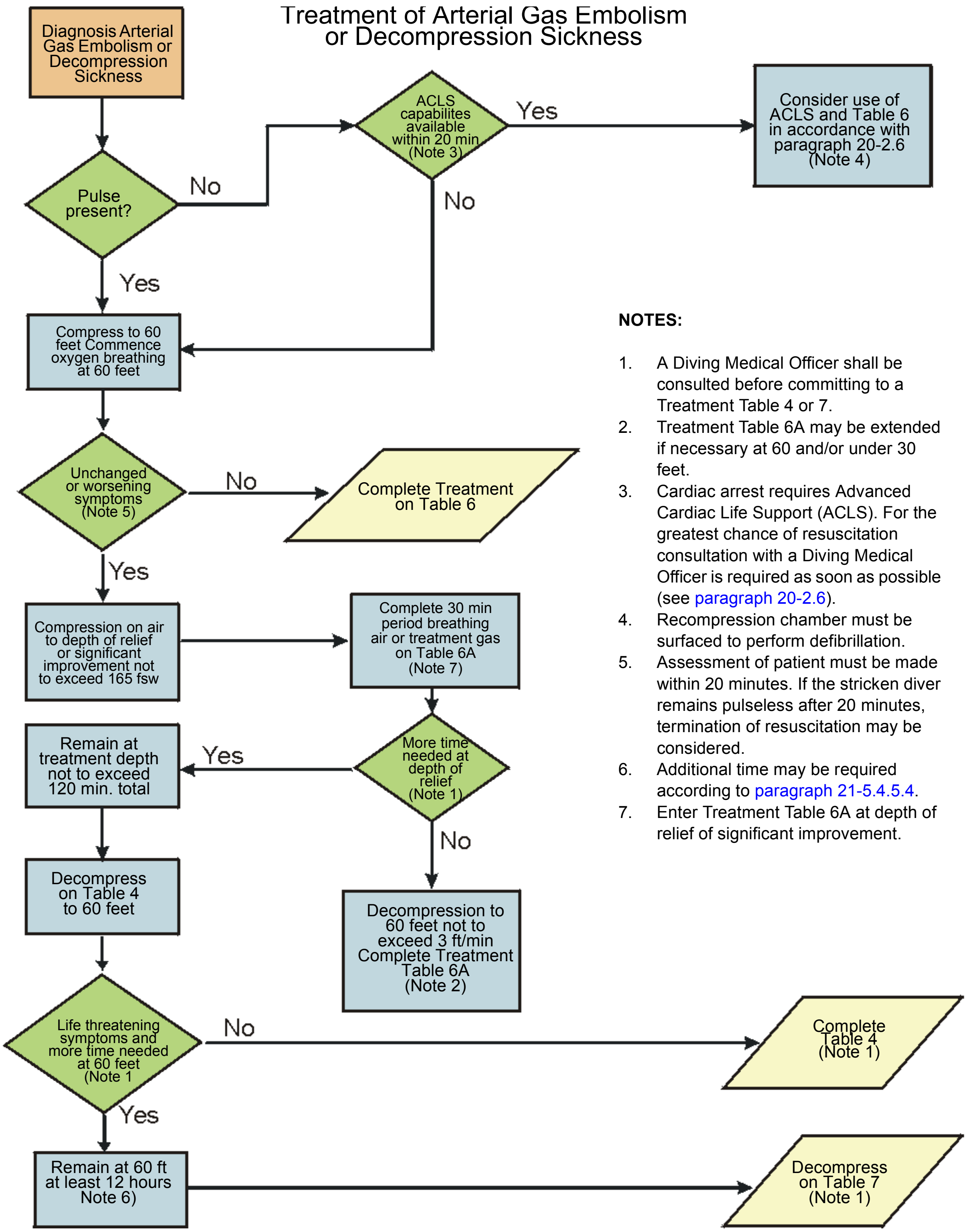
Figure 21-3. Treatment of Decompression Sickness Occurring while at Decompression Stop in the Water.


Treatment of Type I Decompression Sickness

NOTES

1. If a complete neurological exam was not completed before recompression, treat as a Type II symptom.
2. Treatment Table 6 may be extended up to four additional oxygen-breathing periods, two at 30 feet and/or two at 60 feet.
3. Diving Supervisor may elect to treat on Treatment Table 6.
4. Treatment Table 5 may be extended two oxygen-breathing periods at 30 fsw.

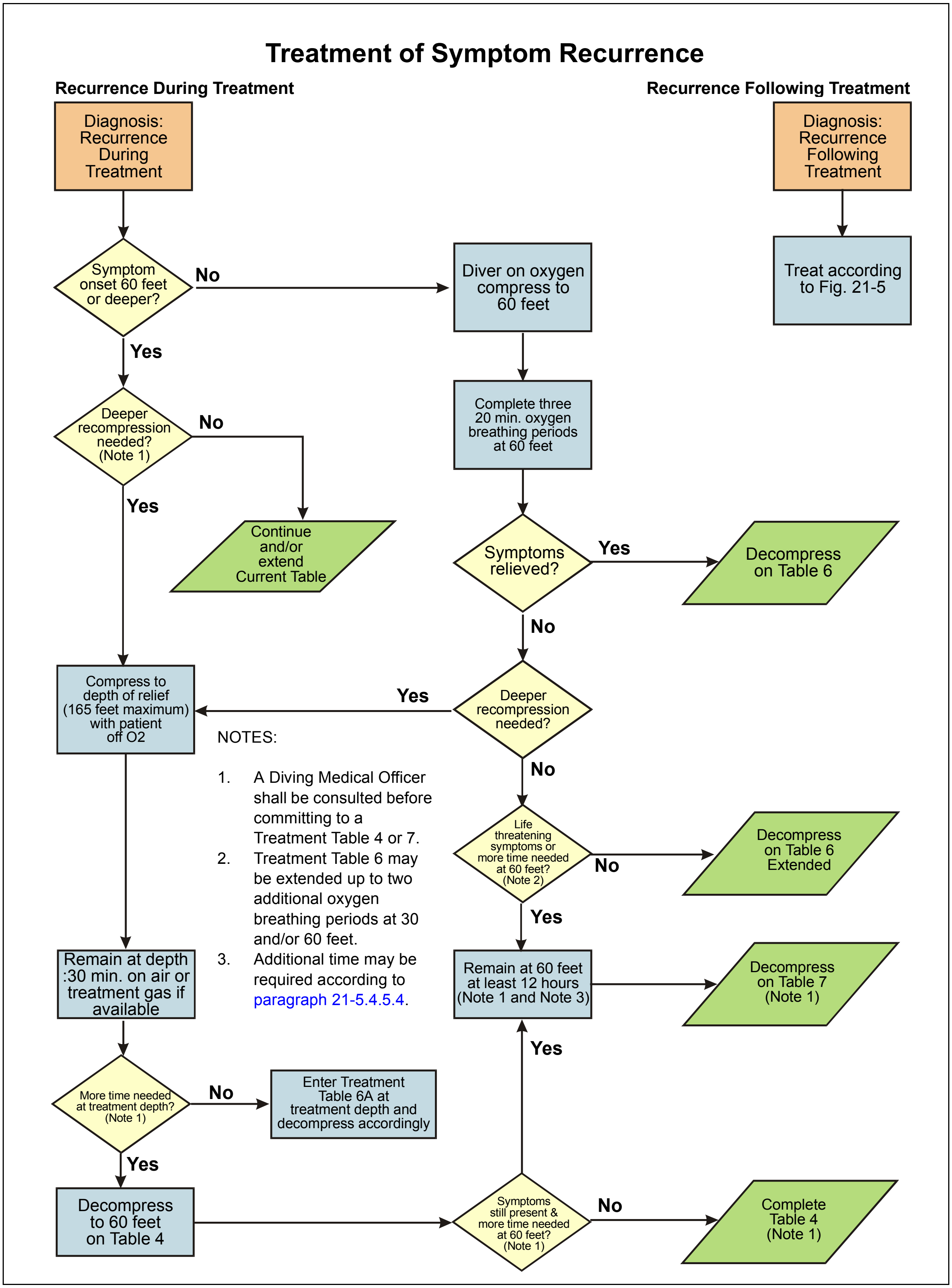
Figure 21-4. Decompression Sickness Treatment from Diving or Altitude Exposures.



NOTES:

1. A Diving Medical Officer shall be consulted before committing to a Treatment Table 4 or 7.
2. Treatment Table 6A may be extended if necessary at 60 and/or under 30 feet.
3. Cardiac arrest requires Advanced Cardiac Life Support (ACLS). For the greatest chance of resuscitation consultation with a Diving Medical Officer is required as soon as possible (see paragraph 20-2.6).
4. Recompression chamber must be surfaced to perform defibrillation.
5. Assessment of patient must be made within 20 minutes. If the stricken diver remains pulseless after 20 minutes, termination of resuscitation may be considered.
6. Additional time may be required according to paragraph 21-5.4.5.4.
7. Enter Treatment Table 6A at depth of relief of significant improvement.

Figure 21-5. Treatment of Arterial Gas Embolism or Decompression Sickness.



NOTES:

1. A Diving Medical Officer shall be consulted before committing to a Treatment Table 4 or 7.
2. Treatment Table 6 may be extended up to two additional oxygen breathing periods at 30 and/or 60 feet.
3. Additional time may be required according to paragraph 21-5.4.5.4.

Figure 21-6. Treatment of Symptom Recurrence.

Treatment Table 5

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 21-5.5.6.1.1)
5. Treatment Table may be extended two oxygen-breathing periods at the 30-foot stop. No air break required between oxygen-breathing periods or prior to ascent.
6. Tender breathes 100 percent O_2 during ascent from the 30-foot stop to the surface. If the tender had a previous hyperbaric exposure in the previous 12 hours, an additional 20 minutes of oxygen breathing is required prior to ascent.

Treatment Table 5 Depth/Time Profile

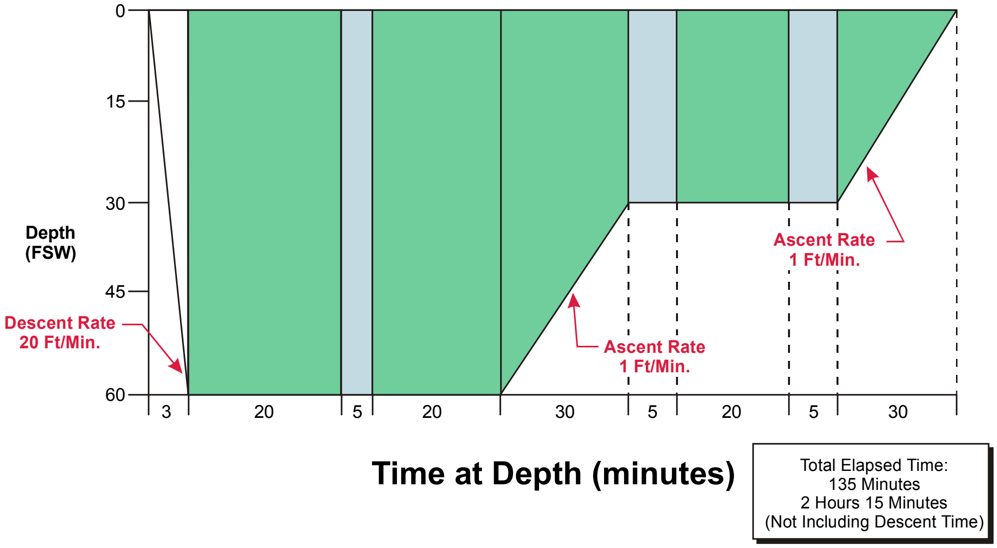


Figure 21-7. Treatment Table 5.

Treatment Table 6

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 21-5.5.6.1.1).
5. Table 6 can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (15 minutes on air and 60 minutes on oxygen), or both.
6. Tender breathes 100 percent O_2 during the last 30 min. at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 feet. If there has been more than one extension, the O_2 breathing at 30 feet is increased to 60 minutes. If the tender had a hyperbaric exposure within the past 12 hours an additional 60-minute O_2 period is taken at 30 feet.

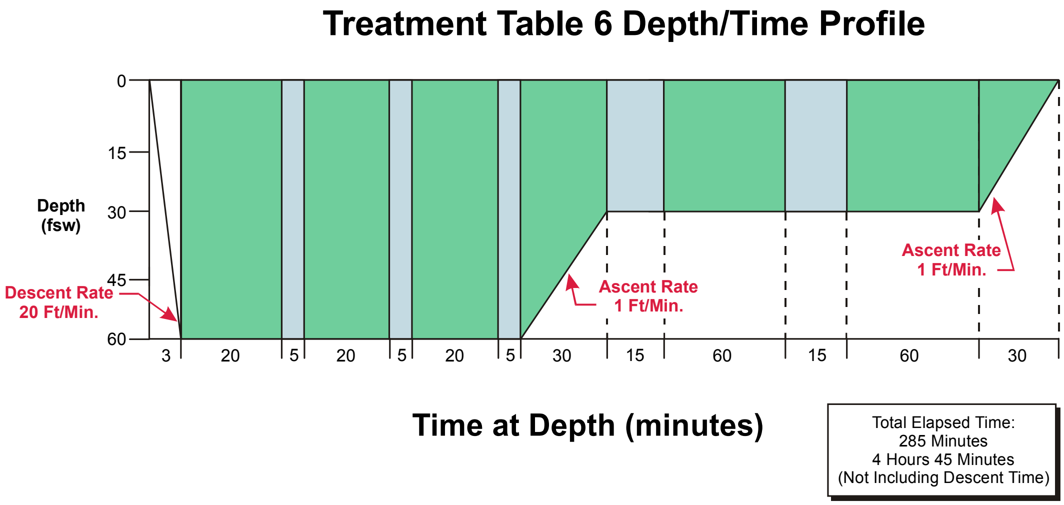


Figure 21-8. Treatment Table 6.

Treatment Table 6A

1. Descent rate - 20 ft/min.
2. Ascent rate - 165 fsw to 60 fsw not to exceed 3 ft/min, 60 fsw and shallower, not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time at treatment depth does not include compression time.
4. Table begins with initial compression to depth of 60 fsw. If initial treatment was at 60 feet, up to 20 minutes may be spent at 60 feet before compression to 165 fsw. Contact a Diving Medical Officer.
5. If a chamber is equipped with a high-O_2 treatment gas, it may be administered at 165 fsw and shallower, not to exceed 3.O ata O_2 in accordance with paragraph 21-5.7. Treatment gas is administered for 25 minutes interrupted by 5 minutes of air. Treatment gas is breathed during ascent from the treatment depth to 60 fsw.
6. Deeper than 60 feet, if treatment gas must be interrupted because of CNS oxygen toxicity, allow 15 minutes after the reaction has entirely subsided before resuming treatment gas. The time off treatment gas is counted as part of the time at treatment depth. If at 60 feet or shallower and oxygen breathing must be interrupted because of CNS oxygen toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 21-5.5.6.1.1).
7. Table 6A can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (60-minutes on oxygen and 15 minutes on air), or both.
8. Tenders breathes 100 percent O_2 during the last 60 minutes at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 fsw. If there has been more than one extension, the O_2 breathing at 30 fsw is increased to 90 minutes. If the tender had a hyperbaric exposure within the past 12 hours, an additional 60 minute O_2 breathing period is taken at 30 fsw.
9. If significant improvement is not obtained within 30 minutes at 165 feet, consult with a Diving Medical Officer before switching to Treatment Table 4.

Treatment Table 6A Depth/Time Profile

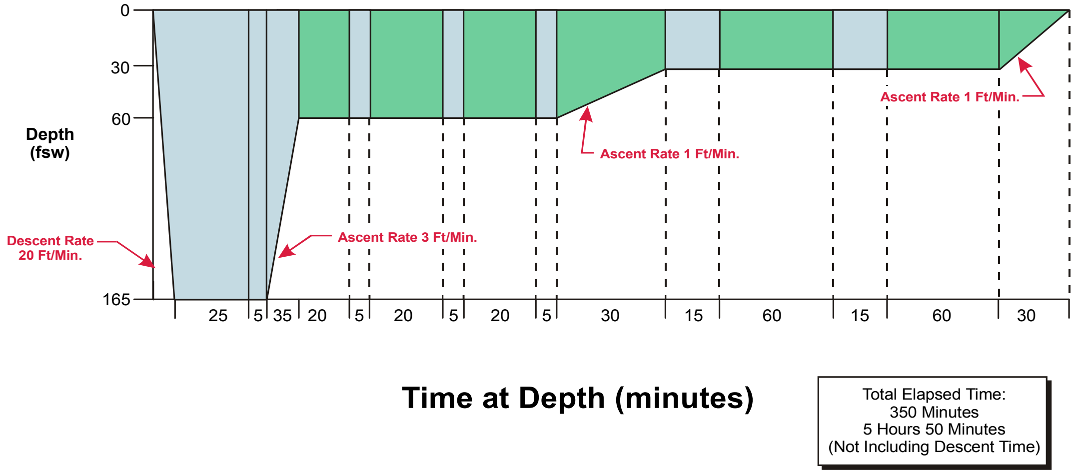
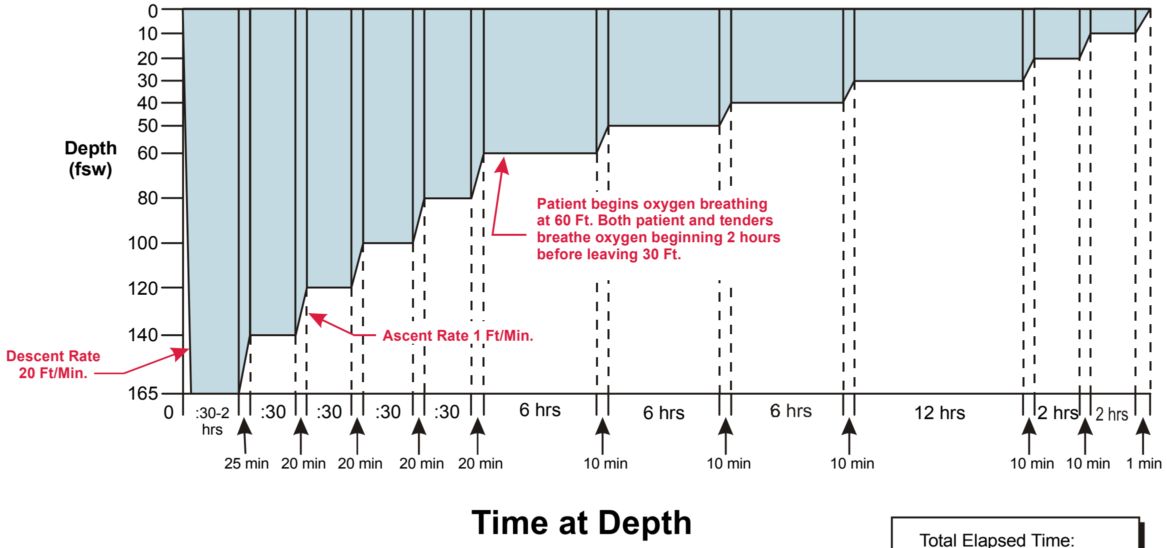


Figure 21-9. Treatment Table 6A.

Treatment Table 4

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet includes compression.
4. If only air is available, decompress on air. If oxygen is available, patient begins oxygen breathing upon arrival at 60 feet with appropriate air breaks. Both tender and patient breathe oxygen beginning 2 hours before leaving 30 feet. (see paragraph 21-5.4.4.2).
5. Ensure life-support considerations can be met before committing to a Table 4. (see paragraph 21-5.6) Internal chamber temperature should be below 85° F.
6. If oxygen breathing is interrupted, no compensatory lengthening of the table is required.
7. If switching from Treatment Table 6A or 3 at 165 feet, stay a maximum of 2 hours at 165 feet before decompressing.
8. If the chamber is equipped with a high-O_2 treatment gas, it may be administered at 165 fsw, not to exceed 3.0 ata O_2. Treatment gas is administered for 25 minutes interupted by 5 minutes of air.

Treatment Table 4 Depth/Time Profile



Total Elapsed Time:
39 Hours 6 Minutes
(30 Minutes at 165 fsw) to
40 Hours 36 Minutes
(2 Hours at 165 fsw)

Figure 21-10. Treatment Table 4.

Treatment Table 7

1. Table begins upon arrival at 60 feet. Arrival at 60 feet is accomplished by initial treatment on Table 6, 6A or 4. If initial treatment has progressed to a depth shallower than 60 feet, compress to 60 feet at 20 ft/min to begin Table 7.
2. Maximum duration at 60 feet is unlimited. Remain at 60 feet a minimum of 12 hours unless overriding circumstances dictate earlier decompression.
3. Patient begins oxygen breathing periods at 60 feet. Tender need breathe only chamber atmosphere throughout. If oxygen breathing is interrupted, no lengthening of the table is required.
4. Minimum chamber O_2 concentration is 19 percent. Maximum CO_2 concentration is 1.5 percent SEV (11.4 mmHg). Maximum chamber internal temperature is 85°F (paragraph 21-5.6.5).
5. Decompression starts with a 2-foot upward excursion from 60 to 58 feet. Decompress with stops every 2 feet for times shown in profile below. Ascent time between stops is approximately 30 seconds. Stop time begins with ascent from deeper to next shallower step. Stop at 4 feet for 4 hours and then ascend to the surface at 1 ft/min.
6. Ensure chamber life-support requirements can be met before committing to a Treatment Table 7.
7. A Diving Medical Officer shall be consulted before committing to this treatment table.

Treatment Table 7 Depth/Time Profile

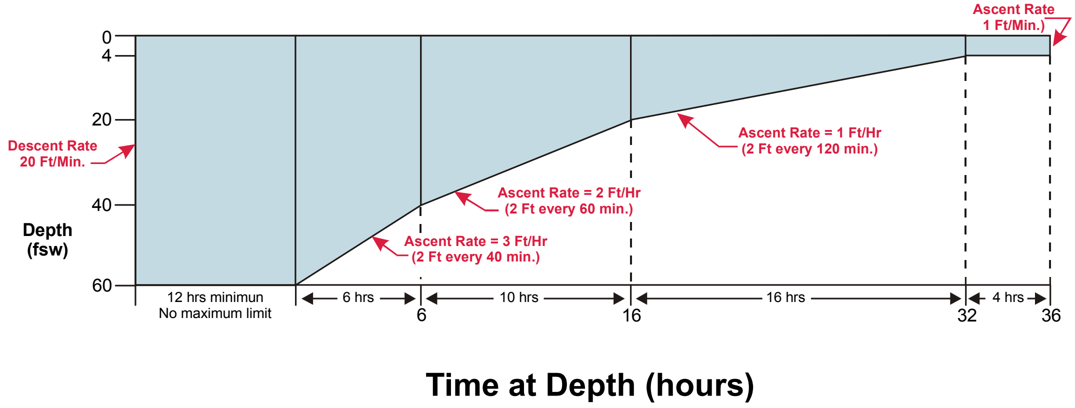


Figure 21-11. Treatment Table 7.

Treatment Table 8

1. Enter the table at the depth which is exactly equal to or next greater than the deepest depth attained in the recompression. The descent rate is as fast as tolerable.
2. The maximum time that can be spent at the deepest depth is shown in the second column. The maximum time for 225 fsw is 30 minutes; for 165 fsw, 3 hours. For an asymptomatic diver, the maximum time at depth is 30 minutes for depths exceeding 165 fsw and 2 hours for depths equal to or shallower than 165 fsw.
3. Decompression is begun with a 2-fsw reduction in pressure if the depth is an even number. Decompression is begun with a 3-fsw reduction in pressure if the depth is an odd number. Subsequent stops are carried out every 2 fsw. Stop times are given in column three. The stop time begins when leaving the previous depth. Ascend to the next stop in approximately 30 seconds.
4. Stop times apply to all stops within the band up to the next quoted depth. For example, for ascent from 165 fsw, stops for 12 minutes are made at 162 fsw and at every two-foot interval to 140 fsw. At 140 fsw, the stop time becomes 15 minutes. When traveling from 225 fsw, the 166-foot stop is 5 minutes; the 164-foot stop is 12 minutes. Once begun, decompression is continuous. For example, when decompressing from 225 feet, ascent is not halted at 165 fsw for 3 hours. However, ascent may be halted at 60 fsw and shallower for any desired period of time.
5. While deeper than 165 fsw, helium-oxygen mixture with 16-21 percent oxygen may be breathed by mask to reduce narcosis. At 165 fsw and shallower, a HeO_2 or N_2O_2 mix with a ppO_2 not to exceed 3.0 ata may be given to the diver as a treatment gas. At 60 fsw and shallower, pure oxygen may be given to the diver as a treatment gas. For all treatment gases (HeO_2, N_2O_2, and O_2), a schedule of 25 minutes on gas and 5 minutes on chamber air should be followed for a total of four cycles. Additional oxygen may be given at 60 fsw after a 2-hour interval of chamber air. See Treatment Table 7 for guidance.
6. A high-O_2 treatment mix can be used at treatment depth and during decompression. If high O_2 breathing is interrupted, no lengthening of the table is required.
7. To avoid loss of the chamber seal, ascent may be halted at 4 fsw and the total remaining stop time of 240 minutes taken at this depth. Ascend directly to the surface upon completion of the required time.
8. Total ascent time from 225 fsw is 56 hours, 29 minutes. For a 165-fsw recompression, total ascent time is 53 hours, 52 minutes, and for a 60-fsw recompression, 36 hours, 0 minutes.

Depth (fsw)	Max Time at Initial Treatment Depth (hours)	2-fsw Stop TImes (minutes)
225	0.5	5
165	3	12
140	5	15
120	8	20
100	11	25
80	15	30
60	Unlimited	40
40	Unlimited	60
20	Unlimited	120

Figure 21-12. Treatment Table 8.

Treatment Table 9

1. Descent rate - 20 ft/min.
2. Ascent rate - 20 ft/min. Rate may be slowed to 1 ft/min depending upon the patient's medical condition.
3. Time at 45 feet begins on arrival at 45 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, oxygen breathing may be restarted 15 minutes after all symptoms have subsided. Resume schedule at point of interruption (see paragraph 21-5.5.6.1.1).
5. Tender breathes 100 percent O_2 during last 15 minutes at 45 feet and during ascent to the surface regardless of ascent rate used.
6. If patient cannot tolerate oxygen at 45 feet, this table can be modified to allow a treatment depth of 30 feet. The oxygen breathing time can be extended to a maximum of 3 to 4 hours.

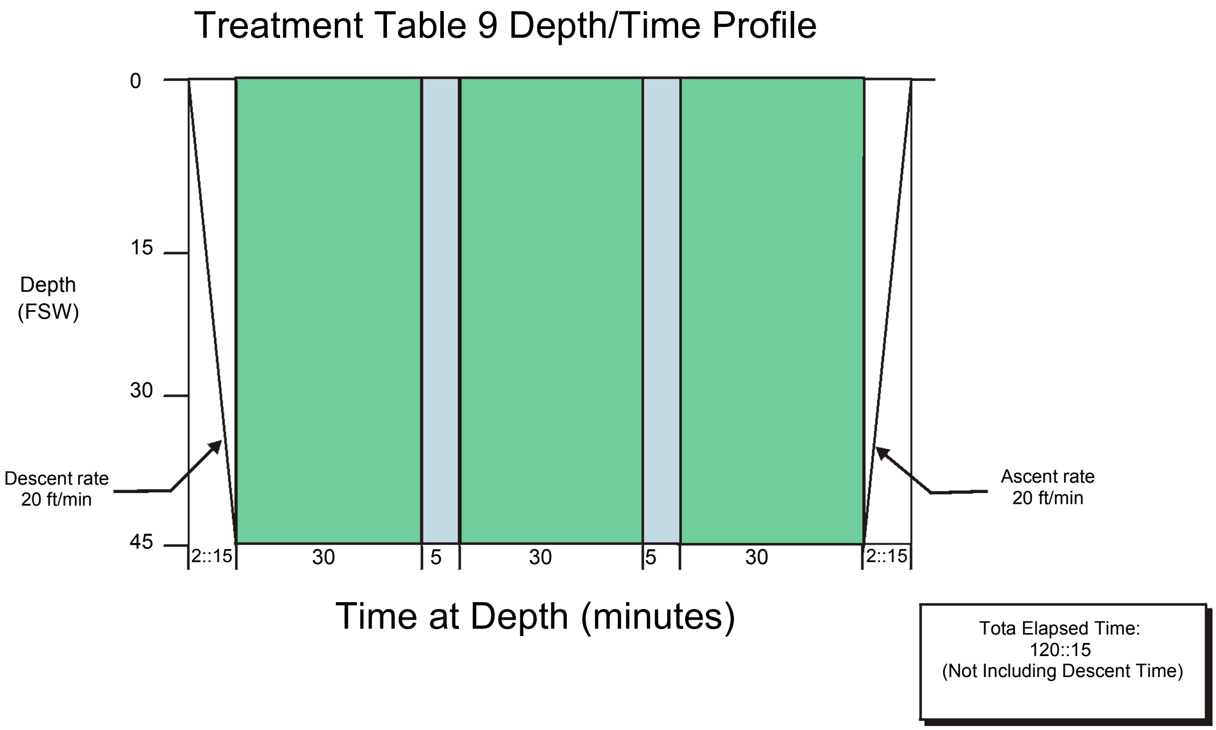


Figure 21-13. Treatment Table 9.

Air Treatment Table 1A

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 100 feet includes time from the surface.

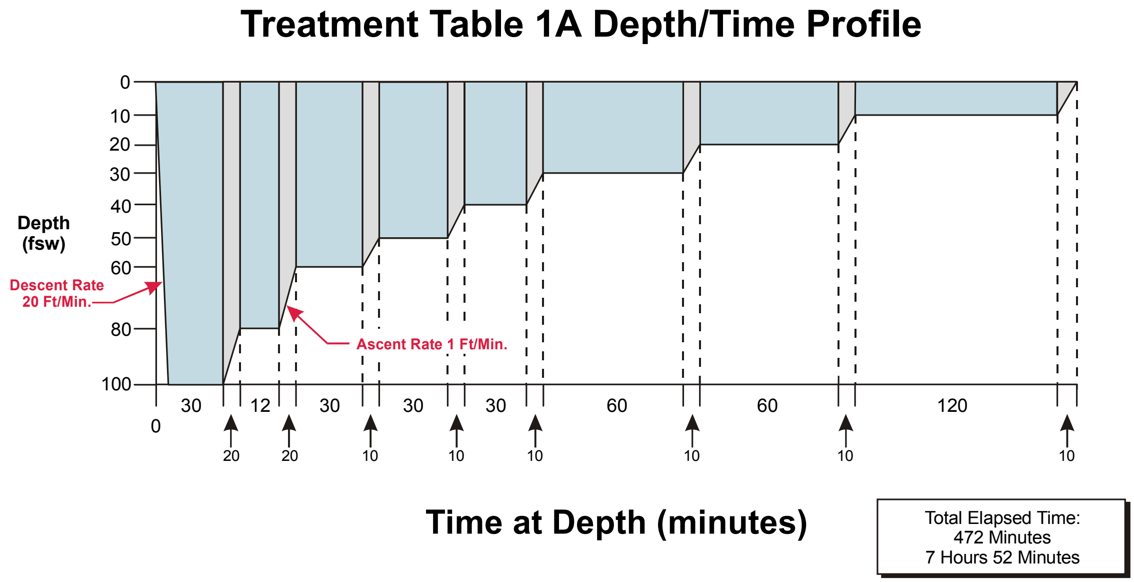


Figure 21-14. Air Treatment Table 1A.

Air Treatment Table 2A

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet includes time from the surface.

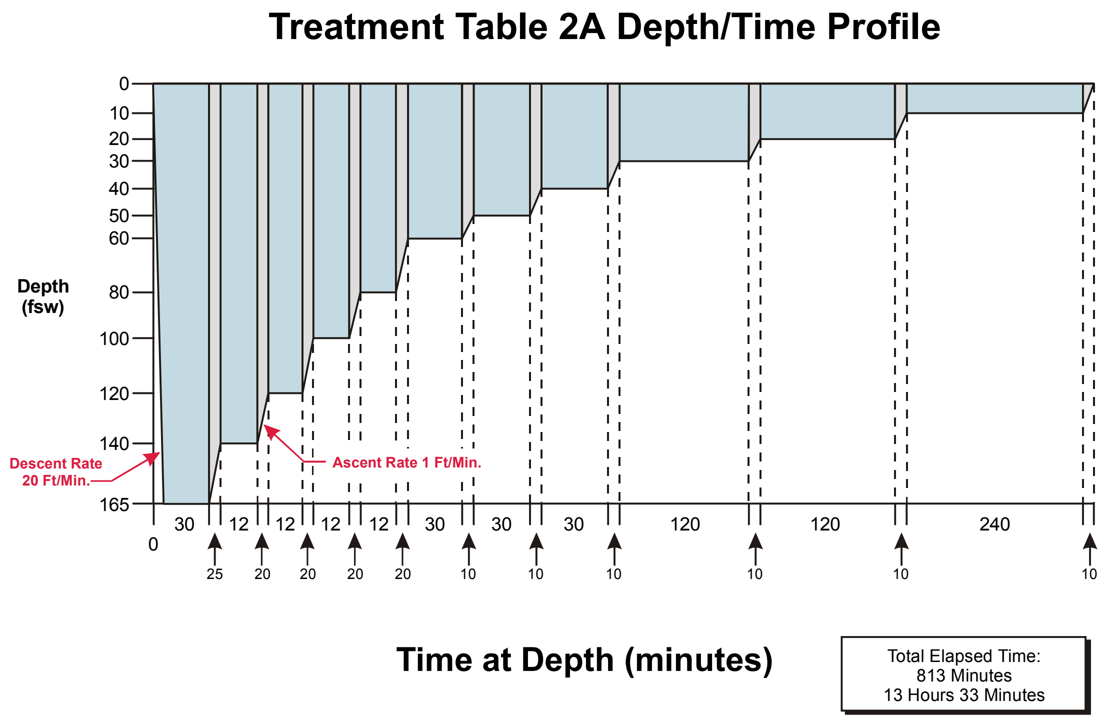


Figure 21-15. Air Treatment Table 2A.

Air Treatment Table 3

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet-includes time from the surface.

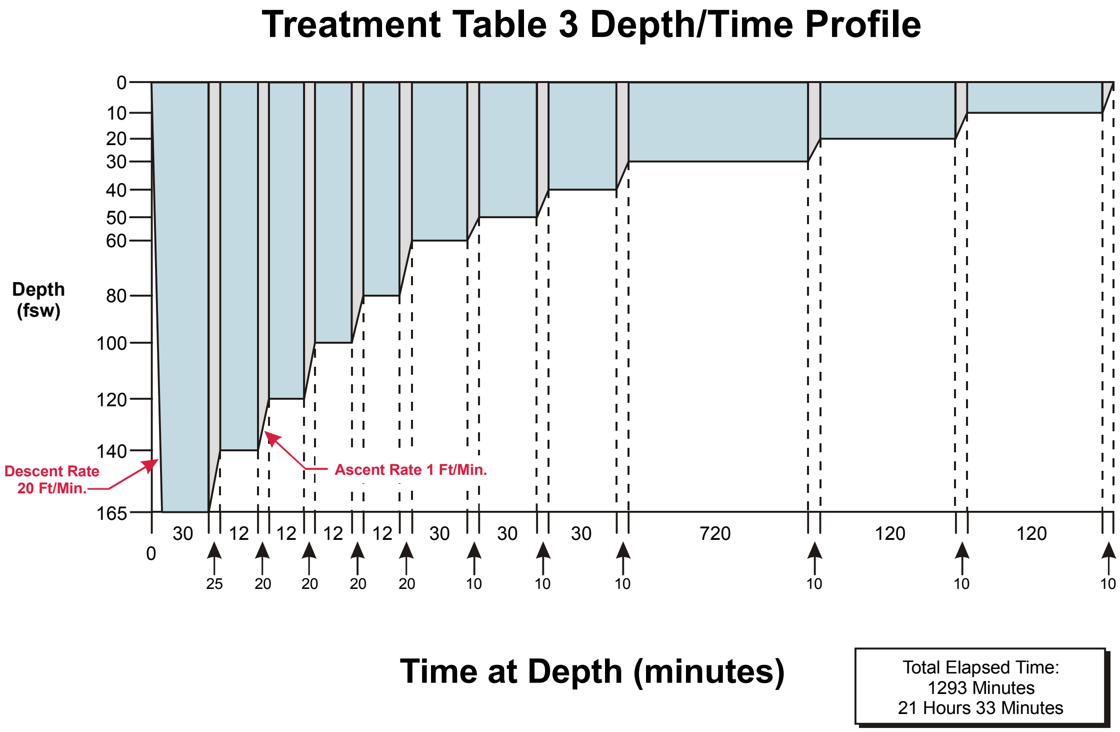


Figure 21-16. Air Treatment Table 3.

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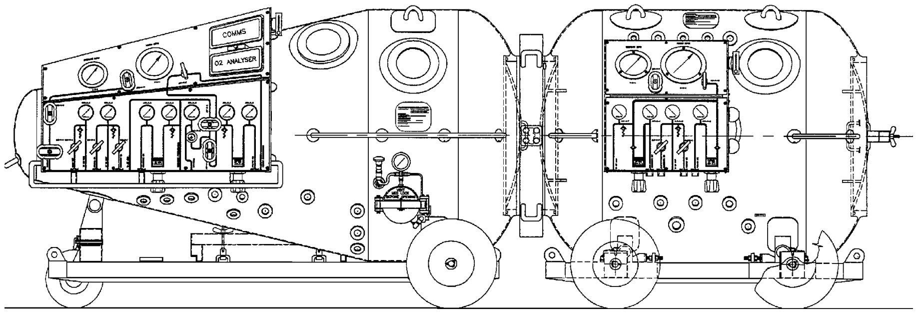
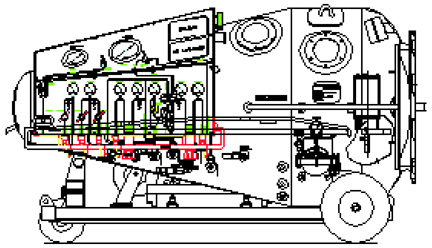


Figure 22-5. Transportable Recompression Chamber System (TRCS).

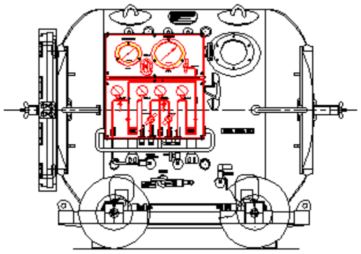


Height	52″ with wheel, 48″ without wheels
Width	50.7″
Weight	1,268 lbs.
Internal Volume	45 cu. ft.
Door Opening	26″
View Ports	3 @ 6″ dia. Clear Opening
Medical Lock	5.75″ dia. x 11.8″ long
Mating Flange	Male per NATO STANG 1079
Life Support Scrubber	Air driven, replaceable scrubber, canister fits in Med Lock
BIBS	2 masks – oxygen and air supply (with capability for N_2O_2 or HeO_2) – overboard dump
Atmospheric Monitoring	Oxygen and Carbon Dioxide Analyzer
Gas Supply	Primary and secondary air and O_2
Communications	Battery-powered speaker/headset phone
Furnishing	Patient litter, attendants seat

Design Pressure	110 psig
Design Temperature	0-125°F
Length	95.7″

Figure 22-6. Transportable Recompression Chamber (TRC).

22-2.5 **Standard Features.** Recompression chambers must be equipped with a means for delivering breathing oxygen to the personnel in the chamber. The inner lock should be provided with connections for demand-type oxygen inhalators. Oxygen can be furnished through a high-pressure manifold connected with supply cylinders outside the chamber.



Height	52.9″
Width	54.8″
Weight	1,367 lbs.
Internal Volume	45.5 cu. ft.
Door Opening	2 doors – 26″
View Ports	2 @ 6″ dia. Clear Opening
Mating Flange	Rotating Female per NATO STANG 1079
Life Support Scrubber	Air-driven, replaceable scrubber, canister fits in TRC Med Lock
BIBS	2 masks – oxygen and air supply – overboard dump
Atmospheric Monitoring	Oxygen and Carbon Dioxide Analyzer
Gas Supply	Primary and secondary air and O_2
Communications	Sound-powered phone
Design Pressure	110 psig
Design Temperature	0-125°F
Length	69.9″

Figure 22-7. Transfer Lock (TL).

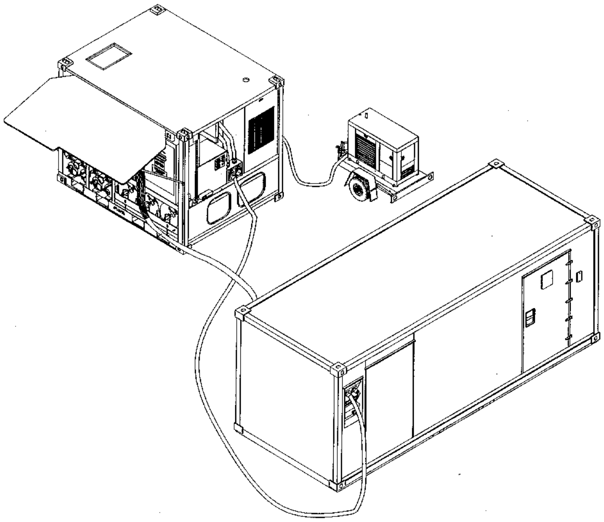


Figure 22-8. Fly Away Recompression Chamber (FARCC).

22-2.5.1 **Labeling.** All lines should be identified and labeled to indicate function, content and direction of flow. The color coding in Table 22-1 should be used.

22-2.5.2 **Inlet and Exhaust Ports.** Optimum chamber ventilation requires separation of the inlet and exhaust ports within the chamber. Exhaust ports must be provided with a guard device to prevent accidental injury when they are open.

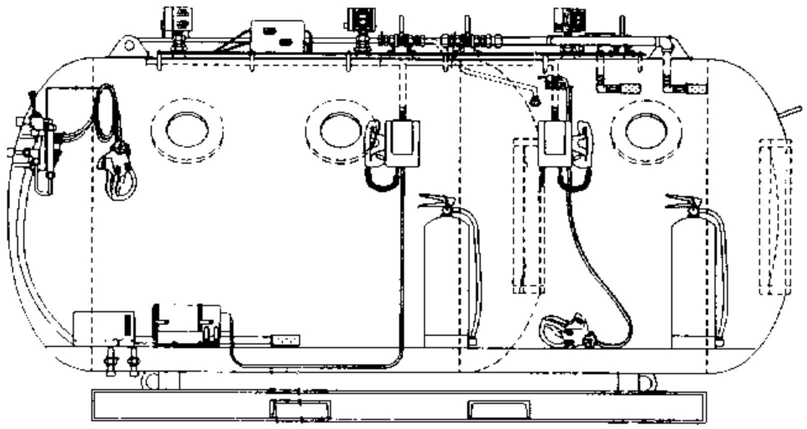


Figure 22-9. Fly Away Recompression Chamber.

22-2.5.3 **Pressure Gauges.** Chambers must be fitted with appropriate pressure gauges. These gauges, marked to read in feet of seawater (fsw), must be calibrated or compared as described in the applicable Planned Maintenance System (PMS) to ensure accuracy in accordance with the instructions in Chapter 4.

22-2.5.4 **Relief Valves.** Recompression chambers should be equipped with pressure relief valves in each manned lock. Chambers that do not have latches (dogs) on the doors are not required to have a relief valve on the outer lock. The relief valves shall be set in accordance with PMS. In addition, all chambers shall be equipped with a gag valve, located between the chamber pressure hull and each relief valve. This gag valve shall be a quick acting, ball-type valve, sized to be compatible with the relief valve and its supply piping. The gag valve shall be safety wired in the open position

22-2.5.5 **Communications System.** Chamber communications are provided through a diver's intercommunication system, with the dual microphone/speaker unit in the chamber and the surface unit outside. The communication system should be arranged so that personnel inside the chamber need not interrupt their activities to operate the system. The backup communications system may be provided by a set of standard sound-powered telephones. The press-to-talk button on the set inside the chamber can be taped down, thus keeping the circuit open.

22-2.5.6 **Lighting Fixtures.** Consideration should be given to installation of a low-level lighting fixture (on a separate circuit), which can be used to relieve the patient of

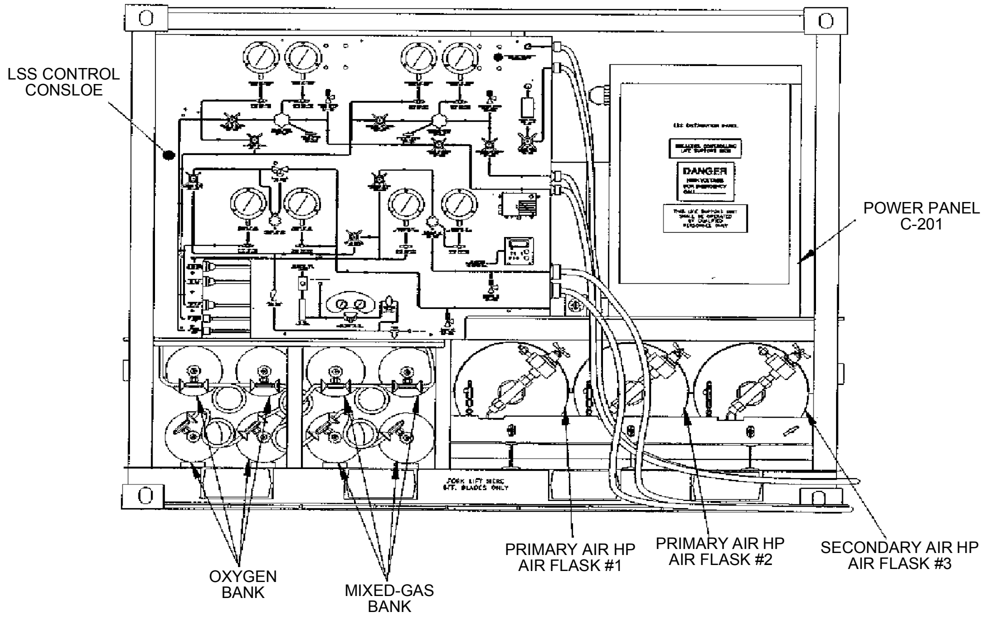


Figure 22-10. Fly Away Recompression Chamber Life Support Skid.

Table 22-1. *Recompression Chamber Line Guide.*

Function	Designation	Color Code
Helium	HE	Buff
Oxygen	OX	Green
Helium-Oxygen Mix	HE-OX	Buff & Green
Nitrogen	N	Light Gray
Nitrogen Oxygen Mix	N-OX	Light Gray & Green
Exhaust	E	Silver
Air (Low Pressure)	ALP	Black
Air (High Pressure)	AHP	Black
Chilled Water	CW	Blue & White
Hot Water	HW	Red & White
Potable Water	PW	Blue
Fire Fighting Material	FP	Red

the heat and glare of the main lights. Emergency lights for both locks and an external control station are mandatory. No electrical equipment, other than that authorized within the scope of certification or as listed in the NAVSEA Authorized for Navy Use (ANU) List, is allowed inside the chamber. Because of the possibility of fire or explosion when working in an oxygen or compressed air atmosphere, all electrical wiring and equipment used in a chamber shall meet required specifications.

22-3 STATE OF READINESS

Since a recompression chamber is emergency equipment, it must be kept in a state of readiness. The chamber shall be well maintained and equipped with all necessary accessory equipment. A chamber is not to be used as a storage compartment. The chamber and the air and oxygen supply systems shall be checked prior to each use with the Predive Checklist and in accordance with PMS instructions. All diving personnel shall be trained in the operation of the recompression chamber equipment and should be able to perform any task required during treatment.

22-4 GAS SUPPLY

A recompression chamber system must have a primary and a secondary air supply system that satisfies Table 22-2. The purpose of this requirement is to ensure the recompression chamber system, at a minimum, is capable of conducting a TT6A.

22-4.1 **Capacity.**

Either system may consist of air banks and/or a suitable compressor. The primary recompression chamber support system must be capable of pressurizing the inner lock to a depth of 165 feet.

- Primary System Capacity:

C_p = $(5 \times V_{il}) + (10 \times V_{ol}) + RV$

Where:

C_p = minimum capacity of primary system in SCF

V_{il} = volume of inner lock

V_{ol} = volume of outer lock

5 = atmospheres equivalent to 165 fsw

10 = twice the atmospheres equivalent to 165 fsw

RV = required ventilation. See paragraph 22-5.4 for Category A and B ventilation requirements. Not used for Category C, D, and E.

- Secondary System Requirement:

C_s = $(5 \times V_{il}) + (5 \times V_{ol}) + RV$

Where:

C_s = minimum capacity of secondary system in SCF

V_{il} = volume of inner lock

V_{ol} = volume of outer lock

5 = atmospheres equivalent to 165 fsw

RV = required ventilation. For Category A, B, and C, use 4,224 for ventilation rate of 70.4 scfm for one hour. For Category D and E, calculate air or NITROX required for two patients and one tender to breathe BIBS (when not on O_2) during one TT6A with maximum extensions.

Table 22-2. *Recompression Chamber Air Supply Requirements.*

Recompression Chamber Configuration	Primary Air Requirement	Secondary Air Requirement
CATEGORY A: No BIBS overboard dump No CO_2 scrubber No air BIBS No O_2 and CO_2 monitor	Sufficient air to press the IL once and the OL twice to 165 fsw and vent during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY B: BIBS overboard dump No CO_2scrubber No air BIBS $O_2$and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 fsw and vent for CO_2 during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm
CATEGORY C: BIBS overboard dump CO_2 scrubber No air BIBS O_2 and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 fsw.'	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm
CATEGORY D: BIBS overboard dump CO_2 scrubber Air BIBS O_2 and CO_2 monitor	Sufficient air to press the IL once and the OL twice to 165 fsw. (For TRCS, sufficient air to power CO_2 scrubbers must be included)	Sufficient air to press the IL and OL once to 165 fsw and enough air for one tender and two patients (when not on O_2) to breathe air BIBS during one TT6A with maximum extensions.
CATEGORY E: BIBS overboard dump CO_2 scrubber O_2 and CO_2monitor Spare CO_2scrubber Secondary power supply NITROX BIBS No Air BIBS	Sufficient air to press the IL once and the OL twice to 165 fsw.	Sufficient air to press the IL and OL once to 165 fsw and enough air/ NITROX for one tender and two patients (when not on O_2) to breathe air/NITROX BIBS during one TT6A with maximum extensions.
Notes: 1) Additional air source per PSOB will be requied for TT4, 7 or 8. 2) For chambers used to conduct Sur "D" sufficient air is required to conduct a TT6A in addition to any planned Sur "D"		

22-5 OPERATION

22-5.1 Predive Checklist. To ensure each item is operational and ready for use, perform the equipment checks listed in the Recompression Chamber Predive Checklist, Figure 22-11a.

22-5.2 Safety Precautions.

- Do not use oil on any oxygen fitting, air fitting, or piece of equipment.
- Do not allow oxygen supply tanks to be depleted below 100 psig.
- Ensure dogs are in good operating condition and seals are tight.
- Do not leave doors dogged (if applicable) after pressurization.
- Do not allow open flames, smoking materials, or any flammables to be carried into the chamber.

RECOMPRESSION CHAMBER PREDIVE CHECKLIST	
Equipment	**Initials**
Chamber	
System certified	
Cleared of all extraneous equipment	
Clear of noxious odors	
Doors and seals undamaged, seals lubricated	
Pressure gauges calibrated/compared	
Air Supply System	
Primary and secondary air supply adequate	
One-valve supply: Valve closed	
Two-valve supply: Outside valve open, inside valve closed, if applicable	
Equalization valve closed, if applicable	
Supply regulator set at 250 psig or other appropriate pressure	
Fittings tight, filters clean, compressors fueled	
Exhaust System	
One-valve exhaust: Valve closed and calibrated for ventilation	
Two-valve exhaust: Outside valve open, inside valve closed, if applicable	
Oxygen Supply System	
Cylinders full, marked as BREATHING OXYGEN, cylinder valves open	
Replacement cylinders on hand	
Built in breathing system (BIBS) masks installed and tested	
Supply regulator set in accordance with OPs	
Fittings tight, gauges calibrated	
Oxygen manifold valves closed	
BIBS dump functioning	

Figure 22-11a. Recompression Chamber Predive Checklist (sheet 1 of 2).

RECOMPRESSION CHAMBER PREDIVE CHECKLIST		
Equipment		**Initials**
Electrical System		
Lights		
Carbon dioxide analyzer calibrated		
Oxygen analyzer calibrated		
Temperature indicator calibrated		
Carbon dioxide scrubber operational		
Chamber conditioning unit operational		
Direct Current (DC) power supply		
Ground Fault Interrupter (GFI)		
Communication System		
Primary system tested		
Secondary system tested		
Fire Prevention System		
Tank pressurized for chambers with installed fire suppression systems		
Combustible material in metal enclosure		
Fire-retardant clothing worn by all chamber occupants		
Fire-resistant mattresses and blankets in chamber		
Means of extinguishing a fire		
Miscellaneous		
Inside Chamber:	CO_2-absorbent canister with fresh absorbent installed	
	Urinal	
	Primary medical kit	
	Ear protection sound attenuators/aural protectors (1 set per person) Must have a 1/16” hole drilled to allow for equalization.	
Outside Chamber:	Heater/chiller unit	
	Stopwatches for recompression treatment time, decompression time, personnel leaving chamber time, and cumulative time	
	Fresh CO_2 scrubber canister	
	U.S. Navy Diving Manual, Volume 5	
	Ventilation bill	
	Chamber log	
	Operating Procedures (OPs) and Emergency Procedures (EPs)	
	Secondary medical kit	
	Bedpan (to be locked in as required)	

Figure 22-11b. Recompression Chamber Predive Checklist (sheet 2 of 2).

- Do not permit electrical appliances to be used in the chamber unless listed in the Authorized for Navy Use (ANU).
- Do not perform unauthorized repairs or modifications on the chamber support systems.
- Do not permit products in the chamber that may contaminate or off-gas into the chamber atmosphere.

22-5.3 General Operating Procedures.

1. Ensure completion of Predive Checklist.
2. Diver and tender enter the chamber together.
3. Diver sits in an uncramped position.
4. Tender closes and dogs (if so equipped) the inner lock door.
5. Pressurize the chamber, at the rate and to the depth specified in the appropriate decompression or recompression table.
6. As soon as a seal is obtained or upon reaching depth, tender releases the dogs (if so equipped).
7. Ventilate chamber according to specified rates and energize CO_2 scrubber and chamber conditioning system.
8. Ensure proper decompression of all personnel.
9. Ensure completion of Postdive Checklist.

22-5.3.1 **Tender Change-Out.** During extensive treatments, medical personnel may prefer to lock-in to examine the patient and then lock-out, rather than remain inside throughout the treatment. Inside tenders may tire and need relief.

22-5.3.2 **Lock-In Operations.** Personnel entering the chamber go into the outer lock and close and dog the door (if applicable). The outer lock should be pressurized at a rate controlled by their ability to equalize, but not to exceed 75 feet per minute. The outside tender shall record the time pressurization begins to determine the decompression schedule for the occupants when they are ready to leave the chamber. When the pressure levels in the outer and inner locks are equal, the inside door (which was undogged at the beginning of the treatment) should open.

22-5.3.3 **Lock-Out Operations.** To exit the chamber, the personnel again enter the outer lock and the inside tender closes and dogs the inner door (if so equipped). When ready to ascend, the Diving Supervisor is notified and the required decompression schedule is selected and executed. Constant communications are maintained with the inside tender to ensure that a seal has been made on the inner door. Outer lock depth is controlled throughout decompression by the outside tender.

22-5.3.4 **Gag Valves.** The actuating lever of the chamber gag valves shall be maintained in the open position at all times, during both normal chamber operations and when the chamber is secured. The gag valves must be closed only in the event of relief valve failure during chamber operation. Valves are to be lock-wired in the open position with light wire that can be easily broken when required. A WARNING plate, bearing the inscription shown below, shall be affixed to the chamber in the vicinity of each gag valve and shall be readily viewable by operating personnel. The WARNING plates shall measure approximately 4 inches by 6 inches and read as follows:

WARNING
The gag valve must remain open at all times.
Close only if relief valve fails.

22-5.4 **Ventilation.** The basic rules for ventilation are presented below. These rules permit rapid computation of the cubic feet of air per minute (acfm) required under different conditions as measured at chamber pressure (the rules are designed to ensure that the effective concentration of carbon dioxide will not exceed 1.5 percent (11.4 mmHg) and that when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent).

1. When air is breathed, provide 2 cubic feet per minute (acfm) for each diver at rest and 4 cubic feet per minute (acfm) for each diver who is not at rest (i.e., a tender actively taking care of a patient).

2. When oxygen is breathed from the built-in breathing system (BIBS), provide 12.5 acfm for a diver at rest and 25 acfm for a diver who is not at rest. When these ventilation rates are used, no additional ventilation is required for personnel breathing air. These ventilation rates apply only to the number of people breathing oxygen and are used only when no BIBS dump system is installed.

3. If ventilation must be interrupted for any reason, the time should not exceed 5 minutes in any 30-minute period. When ventilation is resumed, twice the volume of ventilation should be used for the time of interruption and then the basic ventilation rate should be used again.

4. If a BIBS dump system is used for oxygen breathing, the ventilation rate for air breathing may be used.

5. If portable or installed oxygen and carbon dioxide monitoring systems are available, ventilation may be adjusted to maintain the oxygen level below 25 percent by volume and the carbon dioxide level below 1.5 percent surface equivalent (sev).

22-5.4.1 **Chamber Ventilation Bill.** Knowing how much air must be used does not solve the ventilation problem unless there is some way to determine the volume of air actually being used for ventilation. The standard procedure is to open the exhaust valve a given number of turns (or fraction of a turn), which will provide a certain number of cubic feet of ventilation per minute at a specific chamber depth, and to use the supply valve to maintain a constant chamber depth during the ventilation period. Determination of valve settings required for different amounts of ventilation at different depths is accomplished as follows.

WARNING **This procedure is to be performed with an unmanned chamber to avoid exposing occupants to unnecessary risks.**

1. Mark the valve handle position so that it is possible to determine accurately the number of turns and fractions of turns.

2. Check the basic ventilation rules above against probable situations to determine the rates of ventilation at various depths (chamber pressure) that may be needed. If the air supply is ample, determination of ventilation rates for a few depths (30, 60, 100, and 165 feet) may be sufficient. It will be convenient to know the valve settings for rates such as 6, 12.5, 25, or 37.5 cubic feet per minute (acfm).

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

   a. Calculate how long it will take to change the chamber pressure by 10 feet if the exhaust valve lets air escape at the desired rate close to the depth in question. Use the following formula.

$$T = \frac{V \times 60 \times \Delta P}{R \times (D + 33)}$$

Where:

T = time in seconds for chamber pressure to change 10 feet
V = internal volume of chamber (or of lock being used for test) in cubic feet (cf)
R = rate of ventilation desired, in cubic feet per minute as measured at chamber pressure (acfm)
P = Change in chamber pressure in fsw
D = depth in fsw (gauge)

Example: Determine how long it will take the pressure to drop from 170 to 160 feet in a 425-cubic-foot chamber if the exhaust valve is releasing 6 cubic feet of air per minute (measured at chamber pressure of 165 feet).

1. List values from example:

T = unknown
V = 425 cf
R = 6 acfm
P = 10 fsw

$D = 165 \text{ fsw}$

2. Substitute values and solve to find how long it will take for the pressure to drop:

$$\text{T} = \frac{425 \times 60 \times 10}{6(165 + 33)}$$

$$= 215 \text{ seconds}$$

$$\text{T} = \frac{215 \text{ seconds}}{60 \text{ seconds / minute}}$$

$$= 3.6 \text{ minutes}$$

b. Increase the empty chamber pressure to 5 feet beyond the depth in question. Open the exhaust valve and determine how long it takes to come up 10 feet (for example, if checking for a depth of 165 fsw, take chamber pressure to 170 feet and clock the time needed to reach 160 feet). Open the valve to different settings until you can determine what setting will approximate the desired time. Record the setting. Calculate the times for other rates and depths and determine the settings for these times in the same way. Make a chart or table of valve setting versus ventilation rate and prepare a ventilation bill, using this information and the ventilation rules.

22-5.4.2 Notes on Chamber Ventilation.

- The basic ventilation rules are not intended to limit ventilation. Generally, if air is reasonably plentiful, more air than specified should be used for comfort. This increase is desirable because it also further lowers the 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 would be ample for long periods of time.

- These rules assume that there is good circulation of air in the chamber during ventilation. If circulation is poor, the rules may be inadequate. Locating the inlet near one end of the chamber and the outlet near the other end improves ventilation.

- Coming up to the next stop reduces the standard cubic feet of gas in the chamber and proportionally reduces the quantity (scfm) of air required for ventilation.

- Continuous ventilation is the most efficient method of ventilation in terms of the amount of air required. However, it has the disadvantage of exposing the divers in the chamber to continuous noise. At the very high ventilation rates required for oxygen breathing, this noise can reach the level at which hearing loss becomes a hazard to the divers in the chamber. If high sound levels do occur, especially during exceptionally high ventilation rates, the chamber occupants must wear aural protectors (available as a stock item). A small hole should be drilled into the central cavity of the protector so that they do not produce a seal which can cause ear squeeze.

- The size of the chamber does not influence the rate (acfm) of air required for ventilation.
- Increasing depth increases the actual mass of air required for ventilation; but when the amount of air is expressed in volumes as measured at chamber pressure, increasing depth does not change the number of actual cubic feet (acfm) required.
- If high-pressure air banks are being used for the chamber supply, pressure changes in the cylinders can be used to check the amount of ventilation being provided.

22-6 CHAMBER MAINTENANCE

22-6.1 **Postdive Checklist.** To ensure equipment receives proper postdive maintenance and is returned to operational readiness, perform the equipment checks listed in the Recompression Chamber Postdive Checklist, Figure 22-12a.

22-6.2 **Scheduled Maintenance.** Proper care of a recompression chamber requires both routine and periodic maintenance. Every USN recompression chamber (with the exception of the TRCS) shall be pressure tested upon installation, at 2-year intervals thereafter, after a major overhaul or repair, and each time it is moved. This test shall be conducted in accordance with the pressure test for USN recompression chambers (Figure 22-13a) contained in this chapter. The completed test form shall be retained until retest is conducted. Chamber relief valves shall be tested in accordance with the Planned Maintenance System to verify setting. Each tested relief valve shall be tagged to indicate the valve set pressure, date of test, and testing activity. After every use or once a month, whichever comes first, the chamber shall receive routine maintenance in accordance with the Postdive Checklist. At this time, minor repairs shall be made and used supplies shall be restocked.

22-6.2.1 **Inspections.** At the discretion of the activity, but at least once a year, the chamber shall be inspected, both inside and outside. Any deposits of grease, dust, or other dirt shall be removed and, on steel chambers, the affected areas repainted.

22-6.2.2 **Corrosion.** Corrosion is removed best by hand or by using a scraper, 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.

RECOMPRESSION CHAMBER POSTDIVE CHECKLIST	
Equipment	**Initials**
Air Supply	
All valves closed	
Air banks recharged, gauged, and pressure recorded	
Compressors fueled and maintained per technical manual/PMS requirements	
View Ports and Doors	
View-ports checked for damage; replaced as necessary	
Door seals checked, replaced as necessary	
Door seals lightly lubricated with approved lubricant	
Door dogs and dogging mechanism checked for proper operation and shaft seals for tightness	
Chamber	
Inside wiped clean with Nonionic Detergent (NID) and warm fresh water	
All but necessary support items removed from chamber	
Blankets cleaned and replaced	
All flammable material in chamber encased in fire-resistant containers	
Primary medical kit restocked as required	
Chamber aired out	
Outer door closed	
CO_2 canister packed	
Deckplates lifted, area below deckplates cleaned, deckplates reinstalled	
Support Items	
Stopwatches checked and reset	
U.S. Navy Diving Manual, Operating Procedures (OPs), Emergency Procedures (EPs), ventilation bill and pencil available at control desk	
Secondary medical kit restocked as required and stowed	
Clothing cleaned and stowed	
All entries made in chamber log book	
Chamber log book stowed	

Figure 22-12a. Recompression Chamber Postdive Checklist (sheet 1 of 2).

RECOMPRESSION CHAMBER POSTDIVE CHECKLIST	
Equipment	**Initials**
Oxygen Supply	
BIBS mask removed, cleaned per current PMS procedures, reinstalled	
All valves closed	
System bled	
Breathing oxygen cylinders fully pressurized	
Spare cylinders available	
System free of contamination	
Exhaust System	
One-valve exhaust: valves closed	
Two-valve exhaust: inside valves closed	
Two-valve exhaust: outside valves opened	
Electrical	
All circuits checked	
Light bulbs replaced as necessary	
Pressure-proof housing of lights checked	
All power OFF	
Wiring checked for fraying	

Figure 22-12b. Recompression Chamber Postdive Checklist (sheet 2 of 2).

22-6.2.3 **Painting Steel Chambers.** Steel chambers shall be painted in accordance with approved NAVSEA procedures. The following paint shall be utilized on steel chambers:

- Inside:
  - Prime coat NSN 8010-01-302-3608.
  - Finish coat white NSN 8010-01-302-3606.
- Outside:
  - Prime coat NSN 8010-01-302-3608.
  - Exterior coats gray NSN 8010-01-302-6838 or white NSN 8010-01-302-3606.

PRESSURE TEST FOR USN RECOMPRESSION CHAMBERS

NOTE

All U.S. Navy Standard recompression chambers are restricted to a maximum pressure of 100 psig, regardless of design pressure rating.

A pressure test shall be conducted on every USN recompression chamber (except TRCS):

- When initially installed
- When moved and reinstalled
- After repairs/overhaul
- At two-year intervals at a given location

Performance of the test and the test results are recorded on a standard U.S. Navy Recompression Chamber Air Pressure and Leak Test form (attached).

The test is conducted as follows:

1. Pressurize the innermost lock to 100 fsw (45 psig). Using soapy water or an equivalent solution, leak test all shell penetration fittings, view-ports, dog seals, door dogs (where applicable), valve connections, pipe joints, and shell weldments.

2. Mark all leaks. Depressurize the lock and adjust, repair, or replace components as necessary to eliminate leaks.

  a. View-Port Leaks. Remove the view-port gasket (replace if necessary), wipe clean.

CAUTION

Acrylic view-ports should not be lubricated or come in contact with any lubricant. Acrylic view-ports should not come in contact with any volatile detergent or leak detector (non-ionic detergent is to be used for leak test). When reinstalling view-port, take up retaining ring bolts until the gasket just compresses evenly about the view-port. Do not overcompress the gasket.

  b. Weldment Leaks. Contact appropriate NAVSEA technical authority for guidance on corrective action.

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

4. Pressurize lock to 225 fsw (100 psig) and hold for 5 minutes.

5. Depressurize the lock to 165 fsw (73.4 psig). Hold for 1 hour. If pressure drops below 145 fsw (65 psig), locate and mark leaks. Depressurize chamber and repair leaks in accordance with Step 2 above and repeat this procedure until final pressure is at least 145 fsw (65 psig).

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

Figure 22-13a. Pressure Test for USN Recompression Chambers (sheet 1 of 3).

22-6.2.4 **Recompression Chamber Paint Process Instruction.** Painting shall be kept to an absolute minimum. Only the coats prescribed above are to be applied. Naval Sea Systems Command will issue a Recompression Chamber Paint Process Instruction (NAVSEA-00C3-PI-001) on request.

22-6.2.5 **Aluminum Chambers.** Only steel chambers are painted. Aluminum chambers are normally a dull, uneven gray color and corrosion can be easily recognized. Aluminum chambers will not be painted.

22-6.2.6 **Fire Hazard Prevention.** The greatest single hazard in the use of a recompression chamber is from explosive fire. Fire may spread two to six times faster in a pressurized chamber than at atmospheric conditions because of the high partial pressure of oxygen in the chamber atmosphere. The following precautions shall be taken to minimize fire hazard:

- Maintain the chamber oxygen percentage as close to 21 percent as possible and never allow oxygen percentage to exceed 25 percent.
- Remove any fittings or equipment that do not conform with the standard requirements for the electrical system or that are made of flammable materials. Permit no wooden deck gratings, benches, or shelving in the chamber.
- Use only mattresses designed for hyperbaric chambers. Use Durett Product or submarine mattress (NSN 7210-00-275-5878 or 5874). Other mattresses may cause atmospheric contamination. Mattresses should be enclosed in flameproof covers. Use 100% cotton sheets and pillow cases. Put no more bedding in a chamber than is necessary for the comfort of the patient. Never use blankets of wool or synthetic fibers because of the possibility of sparks from static electricity.
- Clothing worn by chamber occupants shall be made of 100% cotton. Diver swim trunks made of 65% polyester 35% cotton material is acceptable.
- Keep oil and volatile materials out of the chamber. If any have been used, ensure that the chamber is thoroughly ventilated before pressurization. Do not put oil on or in any fittings or high-pressure line. If oil is spilled in the chamber or soaked into any chamber surface or equipment, it must be completely removed. If lubricants are required, use only those approved and listed in *Naval Ships Technical Manual* (NSTM) NAVSEA S9086-H7-STM-000, Chapter 262. Regularly inspect and clean air filters and accumulators in the air supply lines to protect against the introduction of oil or other vapors into the chamber. Permit no one to wear oily clothing into the chamber.

- Permit no one to carry smoking materials, matches, lighters or any flammable materials into a chamber. A WARNING sign should be posted outside the chamber. Example:

> **WARNING**
> **Fire/Explosion Hazard. No matches, lighters, electrical appliances, or flammable materials permitted in chamber.**

22-6.2.6.1 ***Fire Extinguishing.*** All recompression chambers must have a means of extinguishing a fire in the interior. Examples of fire protection include wetted towels, a bucket of water, fire extinguisher, hand-held hose system, or suppression/deluge system. Refer to U.S. Navy Diving and Hyperbaric Systems Safety Certification Manual (SS521-AA-MAN-010) for specific requirements of fire protection systems. Only fire extinguishers listed on the NAVSEA Authorized for Navy Use (ANU) are to be used.

22-7 DIVER CANDIDATE PRESSURE TEST

All U.S. Navy diver candidates shall be physically qualified in accordance with the *Manual of the Medical Department*, Art. 15-66. Candidates shall also pass a pressure test before they are eligible for diver training. This test may be conducted at any Navy certified recompression chamber, provided it is administered by qualified chamber personnel.

22-7.1 Candidate Requirements. The candidate must demonstrate the ability to equalize pressure in both ears to a depth of 60 fsw. The candidate shall have also passed the screening physical readiness test in accordance with MILPERSMAN 1410380, Exhibit 5.

22-7.2 Procedure.

1. Candidates shall undergo a diving physical examination by a Navy Medical Officer in accordance with the *Manual of the Medical Department,* Art. 15-66, and be qualified to undergo the test.

2. The candidates and the tender enter the recompression chamber and are pressurized to 60 fsw on air, at a rate of 75 fpm or less as tolerated by the occupants.

3. If a candidate cannot complete the descent, the chamber is stopped and the candidate is placed in the outer lock for return to the surface.

4. Stay at 60 fsw for at least 10 minutes.

5. Ascend to the surface following standard air decompression procedures.

6. All candidates shall remain at the immediate chamber site for a minimum of 15 minutes and at the test facility for 1 hour. Candidates or tenders who must

return to their command via air travel must proceed in accordance with Chapter 9-13, paragraph 9-13.

22-7.2.1 References.

- *Navy Military Personnel Manual*, Art. 1220-100
- *Manual of the Medical Department*, Art. 15-66
- *SECNAVINST 12000.2A*

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APPENDIX 5A

Neurological Examination

5A-1 INTRODUCTION

This appendix provides guidance on evaluating diving accidents prior to treatment. Figure 5A-1a is a guide aimed at non-medical personnel for recording essential details and conducting a neurological examination. Copies of this form should be readily available. While its use is not mandatory, it provides a useful aid for gathering information.

5A-2 INITIAL ASSESSMENT OF DIVING INJURIES

When using the form in Figure 5A-1a, the initial assessment must gather the necessary information for proper evaluation of the accident.

When a diver reports with a medical complaint, a history of the case shall be compiled. This history should include facts ranging from the dive profile to progression of the medical problem. If available, review the diver's Health Record and completed Diving Chart or Diving Log to aid in the examination. A few key questions can help determine a preliminary diagnosis and any immediate treatment needed. If the preliminary diagnosis shows the need for immediate recompression, proceed with recompression. Complete the examination when the patient stabilizes at treatment depth. Typical questions should include the following:

1. What is the problem/symptom? If the only symptom is pain:
   - a. Describe the pain:
     - Sharp
     - Dull
     - Throbbing
   - b. Is the pain localized, or hard to pinpoint?
2. Has the patient made a dive recently?
3. What was the dive profile?
   - a. What was the depth of the dive?
   - b. What was the bottom time?
   - c. What dive rig was used?
   - d. What type of work was performed?
   - e. Did anything unusual occur during the dive?

4. How many dives has the patient made in the last 24 hours?

   a. Chart profile(s) of any other dive(s).

5. Were the symptoms first noted before, during. or after the dive? If after the dive, how long after surfacing?

6. If during the dive, did the patient notice the symptom while descending, on the bottom, or during ascent?

7. Has the symptom either increased or decreased in intensity since first noticed?

8. Have any additional symptoms developed since the first one?

9. Has the patient ever had a similar symptom?

10. Has the patient ever suffered from decompression sickness or gas embolism in the past?

    a. Describe this symptom in relation to the prior incident if applicable.

11. Does the patient have any concurrent medical conditions that might explain the symptoms?

To aid in the evaluation, review the diver's Health Record, including a baseline neurological examination, if available, and completed Diving Chart or Diving Log, if they are readily available.

5A-3 NEUROLOGICAL ASSESSMENT

There are various ways to perform a neurological examination. The quickest information pertinent to the diving injury is obtained by directing the initial examination toward the symptomatic areas of the body. These concentrate on the motor, sensory, and coordination functions. If this examination is normal, the most productive information is obtained by performing a complete examination of the following:

1. Mental status
2. Coordination
3. Motor
4. Cranial nerves
5. Sensory
6. Deep tendon reflexes

The following procedures are adequate for preliminary examination. Figure 5A-1a can be used to record the results of the examination.

NEUROLOGICAL EXAMINATION CHECKLIST

(Sheet 1 or 2)

(See text of Appendix 5A for examination procedures and definitions of terms.)

Patient's Name: ____________________________________Date/Time: ____________________________

Describe pain/numbness: ____

____

HISTORY

Type of dive last performed: _________________ Depth: _____________ How long: _________________

Number of dives in last 24 hours: ____

Was symptom noticed before, during or after the dive? ______________________________________

If during, was it while descending, on the bottom or ascending? ____________________________

Has symptom increased or decreased since it was first noticed? ____________________________

Have any other symptoms occurred since the first one was noticed? _________________________

Describe: ____

Has patient ever had a similar symptom before? ___________________When: ________________________

____

MENTAL STATUS/STATE OF CONSCIOUSNESS

____

____

COORDINATION

Walk: _________

Heel-to Toe: _________

Romberg: _________

Finger-to-Nose: _________

Heel Shin Slide: _________

Rapid Movement: _________

CRANIAL NERVES

Sense of Smell (I): ________

Vision/Visual Fld (II): _________

Eye Movements, Pupils (III, IV, VI): _________

Facial Sensation, Chewing (V): _________

Facial Expression Muscles (VI): _________

Hearing (VII): _________

Upper Mouth, Throat Sensation (IX): _________

Gag & Voice (X): _________

Shoulder Shrug (XI): _________

Tongue (XII): _________

STRENGTH (Grade 0 to 5)

UPPER BODY

Deltoids L ____ R ____

Latissimus L ____ R ____

Biceps L ____ R ____

Triceps L ____ R ____

Forearms L ____ R ____

Hands L ____ R ____

LOWER BODY

Hips

Flexion L ___ R ____

Extension L ___ R ____

Abduction L ___ R ____

Adduction L ___ R ____

Knees

Flexion L ___ R ____

Extension L ____ R ____

Figure 5A-1a. Neurological Examination Checklist (sheet 1 of 2).

NEUROLOGICAL EXAMINATION CHECKLIST

(Sheet 2 of 2)

REFLEXES

(Grade: Normal, Hypoactive, Hyperactive, Absent

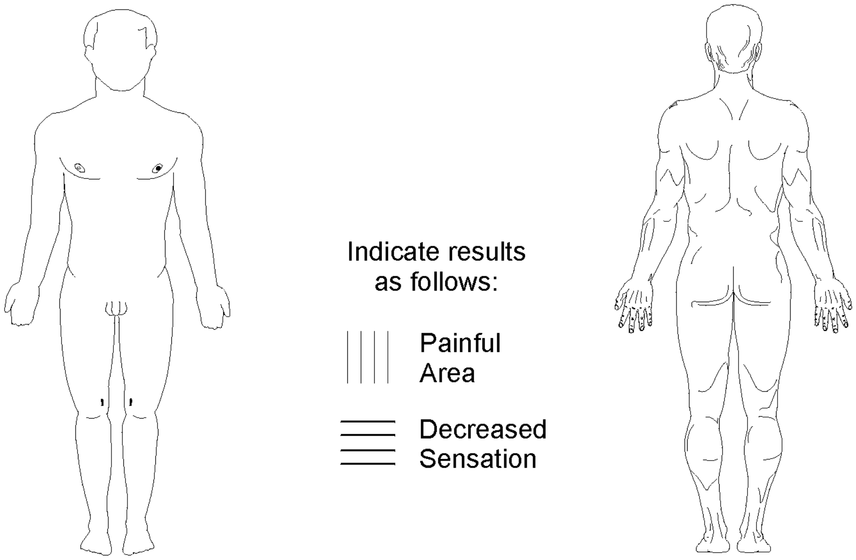
Biceps L ____ R ____
Triceps L ____ R ____
Knees L ____ R ____
Ankles L ____ R ____

Ankles
Dorsiflexion L ____ R ____
Plantarflexion L ____ R ____
Toes L ____ R ____

Sensory Examination for Skin Sensation

(Use diagram to record location of sensory abnormalities – numbness, tingling, etc.)

LOCATION



Indicate results as follows:

|||| Painful Area

≡ Decreased Sensation

COMMENTS

Examination Performed by: ____

Figure 5A-1b. Neurological Examination Checklist (sheet 2 of 2).

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