FM 20-11
C1

Change 1

Headquarters
Department of the Army
Washington, DC, 14 April 2000

Military Diving

1. Change FM 20-11, 20 January 1999, as follows:

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2. A bar (▌) marks new or changed material.

3. File this transmittal sheet in front of the publication.

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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 6-19)

WARNING Scuba equipment is not authorized for use in enclosed space diving. (Page 6-24)

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 8-28)

WARNING 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 masks. (Page 8-28)

WARNING If the diving equipment should fail, the diver shall immediately switch to the EGS and abort the dive. (Page 8-28)

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 8-30)

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 9-42)

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 6-45)

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 8-26)

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)**

List of Tables

Diving Supervisor elects to use surface-supplied MK 21 equipment. The compressor discharge capacity is 60 cubic feet per minute, and the air temperature on the deck of the ship is 80°F.

Apply the general gas law to determine whether the compressor can deliver the proper volume of air to both the working diver and the standby diver at the operating depth and temperature.

1. Calculate the absolute pressure at depth (P_2):

$$P_2 = \frac{130\ \text{fsw} + 33\ \text{fsw}}{33\ \text{fsw}}$$

$$= 4.93\ \text{ata}$$

2. Convert Fahrenheit temperatures to Rankine (absolute) temperatures:

Conversion formula:

$$°R = °F + 460$$

$$T_1 = 80°F + 460$$

$$= 540°R$$

$$T_2 = 40°F + 460$$

$$= 500°R$$

3. Rearrange the general gas law formula to solve for the volume of air at depth (V_2):

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1}$$

4. Substitute known values and solve:

$$V_2 = \frac{1\ \text{ata} \times 60\ \text{cfm} \times 500°R}{4.93\ \text{ata} \times 540°R}$$

$$= 11.26\ \text{acfm at bottom conditions}$$

Based upon an actual volume (displacement) flow requirement of 1.4 acfm for a deep-sea diver, the compressor capacity is sufficient to support the working and standby divers at 130 fsw.

Sample Problem 3. Find the actual cubic feet of air contained in a 700-cubic inch internal volume cylinder pressurized to 3,000 psi.

1. Simplify the equation by eliminating the variables that will not change. The temperature of the tank will not change so T_1 and T_2 can be eliminated from the formula in this problem:

   $P_1V_1 = P_2V_2$

2. Rearrange the formula to solve for the initial volume:

   $$V_1 = \frac{P_2V_2}{P_1}$$

   Where:

   P_1 = 14.7 psi

   P_2 = 3,000 psi + 14.7 psi

   V_2 = 700 in^3

3. Fill in the known values and solve for V_1:

   $$V_1 = \frac{3014.7 \text{ psia} \times 700 \text{ in}^3}{14.7 \text{ psi}}$$

   $$= 143,557.14 \text{ in}^3$$

4. Convert V_1 to cubic feet:

   $$V_1 = \frac{143,557.14 \text{ in}^3}{1728 \text{ in}^3} \quad (1728 \text{ in}^3 = 1 \text{ ft}^3)$$

   $$= 83.07 \text{ scf}$$

2-12 GAS MIXTURES

If a diver used only one gas for all underwater work, at all depths, then the general gas law would suffice for most of his necessary calculations. However, to accommodate use of a single gas, oxygen would have to be chosen because it is the only one that provides life support. But 100 percent oxygen can be dangerous to a diver as depth and breathing time increase. Divers usually breathe gases in a mixture, either air (21 percent oxygen, 78 percent nitrogen, 1 percent other gases) or oxygen with one of the inert gases serving as a diluent for the oxygen. The human body has a wide range of reactions to various gases under different conditions of pressure and for this reason another gas law is required to help compute the differences between breathing at the surface and breathing under pressure.

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.

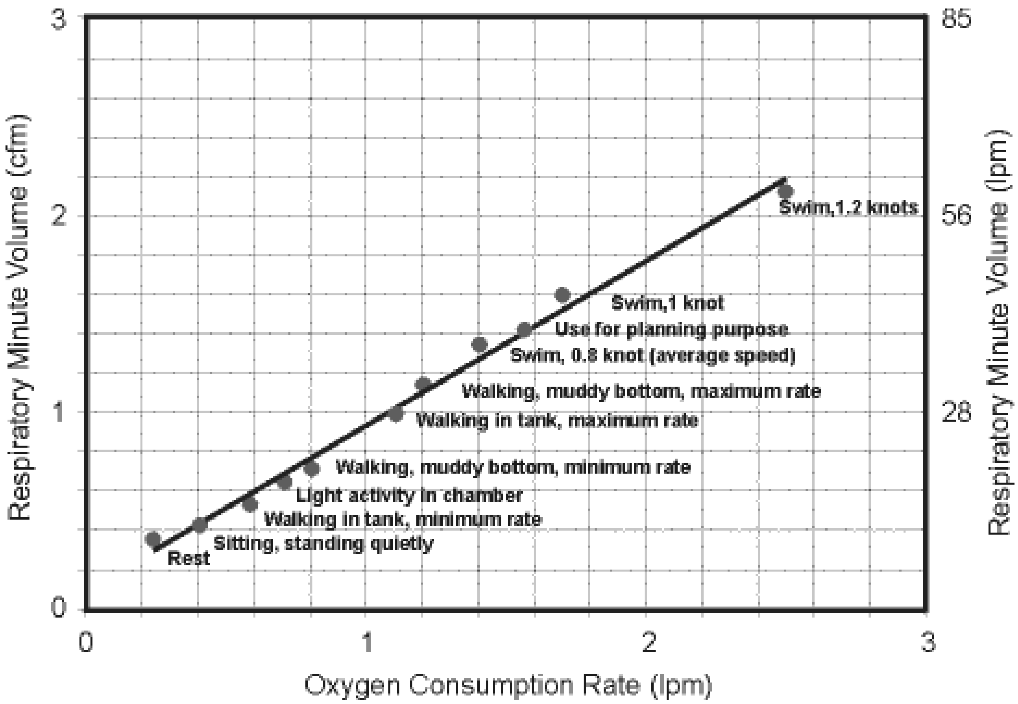
Carbon dioxide production depends only on the level of exertion and can be assumed to be independent of depth. Carbon dioxide production and RQ are used to compute ventilation rates for chambers and free-flow diving helmets. These factors may also be used to determine whether the oxygen supply or the 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.

Table 4-4. Diver's Compressed Helium Breathing Purity Requirements.

Constituent	Specification
Helium (percent by volume)	99.997%
Moisture (water vapor)	7 ppm (max)
Dew Point (not greater than)	-78°F
Hydrocarbons (as Methane)	1 ppm (max)
Oxygen	3 ppm (max)
Nitrogen + Argon	5 ppm (max)
Neon	23 ppm (max)
Hydrogen	1 ppm (max)
Reference: Military Specification MIL-PRF-27407B	

breathing-air source in service must be sampled approximately every 6 months (within the interval between 4 and 8 months following the last accomplishment), when contamination is suspected and after system overhaul.

Do not use a compressor that is suspected of producing contaminated air or that has failed an air sample analysis until the cause of the problem has been corrected and a satisfactory air sample analysis has been obtained validating the production of acceptable air.

Diving systems that do not have a high-pressure (HP) air compressor within the scope of certification shall only be charged with air produced by HP air compressors listed on the ANU list and must have all applicable PMS completed up to date, including air sample requirements. Examples of these types of systems include MK 3 LWDS, Roper Cart, and various diving boats. HP banks on these systems need not be sampled unless contamination is suspected.

Air drawn from submarine HP air storage banks for use as diver's breathing air shall be sampled in accordance with the PMS maintenance requirement card applicable to the system, i.e., dry deck shelter system, submarine escape trunk, scuba charging station. See paragraph 4-4.2 for additional information on system line-up for sampling compressors where a sampling connection cannot be made immediately downstream from the last air filtration device.

Table 4-1 shows the minimum purity requirements for diving air produced by ANU-approved and certified diving air compressors. Air sampling services may be procured locally from government or commercial air analysis facilities, or may be acquired by utilizing analysis services coordinated via Coastal Systems Station (CSS), Panama City, Florida.

NOTE **The most recent air sample analysis report shall be maintained on file for each air compressor (by compressor serial number) used to produce diver's breathing air.**

4-4.2 General Air Sampling Procedures. The following general information is provided to assist commands in managing air sample analysis programs.

Ensure all applicable PMS has been completed on the compressor and associated filtration system prior to taking an air sample.

Table 4-5. *Diver's Compressed Nitrogen Breathing Purity Requirements.*

Class I Oil Free, Type I Gaseous & Type II Liquid			
	Specification/Grade		
Constituent	**A**	**B**	**C**
Nitrogen	99.5%	99.5%	99.5%
Oxygen	0.05%	0.50%	0.50%
Moisture (water vapor)	.02 mg/l	.02 mg/l	*
Total Hydrocarbons	50 ppm	50 ppm	50 ppm
Odor	None	None	None

* Not a limiting characteristic

Note: Type I Nitrogen shall not contain any solid particles whose dimensions are greater than 50 microns. A 10 micron or better nominal filter at or close to the cylinder charging manifold will be used.

Reference: Federal Specification BB-N-411C

- When sampling from HP charging systems, separate samples should be taken from each compressor supplying the system. Samples from the compressors should be taken as close to the compressor as possible but down stream of the last compressor-mounted air treatment device (moisture separator, filter, etc.). Some systems do not have fittings that allow samples to be taken from the system at a location other than the charging connection. In this case, the storage flasks should be isolated from the system, the system purged with air from the compressor to be sampled and the sample taken at the charging connection.

- When sampling from a low-pressure (LP) breathing-air system, separate air samples shall be taken from each LP compressor connected to the system. Samples shall be taken from each LP compressor as close to the compressor as possible, but downstream of the last compressor installed air treatment device (moisture separator, filter, etc.). Some systems do not have fittings that allow samples to be taken at connections other than the diver’s manifold. In this case, a HP source should be isolated from the LP system, the system purged with air from the LP compressor to be sampled, and the sample obtained from the diver’s manifold.

NOTE Failure to purge the system line-up of air produced from other compressors or storage flasks will lead to an invalid air sample for the compressor being sampled.

- Ensure that the compressor being sampled has reached full operating status (proper operating temperature, oil pressure, and air pressure) and is properly lined up to deliver air to the sample kit.

- Ensure that the compressor's intake is clear of any potential sources of contamination (including consideration of ambient smog levels in areas where smog is a problem).

- Follow the procedures on applicable air sample MRC card.

- Follow the instructions for operation of the air sampling kit.

4-4.3 **CSS Air Sampling Services.** The following applies to centrally funded air sampling services coordinated by CSS. Due to limited funding, commands are requested to schedule all compressors and associated samples to be taken at the same time. CSS coordinates air sampling services with a commercial contractor. Commands are not authorized to communicate directly with the commercial contractor. Sampling services are provided at no cost to the command. To request air sampling services, fill out and fax Air Sampling services request to COAST-SYSTA (Attn: Air Sampling). Telephone numbers are listed in Appendix 1C.

- The user must provide the sample expiration date, the number and type (HP or LP) of samples required, a complete mailing address, user point of contact and phone number. Air sample kits will not be shipped until the required information is received.

- Allow a minimum of 5 working days after submitting a properly filled out request form for delivery of a sampling kit in CONUS. Kits will be sent via commercial air with a prepaid return mailer. Incomplete sample requests cannot be acted on and will result in delay of shipping of sample kit.

- Allow a minimum of 3 weeks after submitting a properly filled out request form for delivery of a sampling kit if overseas. Kits will be sent via certified priority mail for overseas/FPO-APO addressees with prepaid return mailing. Incomplete sample requests cannot be acted on and will result in delay of shipping of sample kit.

- Detailed instructions are included with each sample kit. It is imperative to follow those instructions and the instructions on the applicable compressor air sampling MRC card.

- Air samples shall be taken and returned to COASTSYSTA within 5 working days of receipt of the air sample kit to preclude incurring late fees.

- Air sample analysis reports for samples that meet air purity standards will be mailed to the command. Commands will be notified by quickest means possible of any samples that do not meet minimum purity requirements.

- The user will be contacted immediately by phone and/or message by COASTSYSTA if the sample fails to meet established purity standards. The user will discontinue use of the air source until cause of contamination is corrected. Corrective action must be taken prior to laboratory retest.

4-4.4 **Local Air Sampling Services.** Commands may use local government (e.g., shipyards, ship repair facilities, government research laboratories) or commercial laboratories to analyze diver's air samples. Commands are required to bear the cost of locally procured air sample services. Local sampling facilities must be able to analyze to U.S. Navy air purity standards.

4-5 DIVING COMPRESSORS

4-5.1 **Equipment Requirements.** Compressors used to supply diving air or transfer oxygen or mixed gases shall be listed in the NAVSEA/00C Authorized for Navy use (ANU) list or be an element of a certified diving system.

4-5.2 **Air Filtration System.** Military diving compressors shall be equipped with an air filtration system that is listed in the NAVSEA/00C Authorized for Navy use (ANU) list or be an element of a certified diving system. The term air filtration system as used here is inclusive, referring collectively to compressed gas system filters, moisture separators, air purification, air cooling, and dehydration equipment.

4-5.3 **Lubrication.** Compressors used to produce military diver's breathing air are normally of oil-lubricated, two-to-five-stage reciprocating type. Oil lubrication:

- 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

A malfunctioning oil-lubricated compressor poses a contamination risk to the diver's air supply. Contamination may occur due to excess oil mist being passed out of the compressor due to excess clearances, broken parts, or overfilling the oil sump.

Gaseous hydrocarbons and carbon monoxide may also be produced should a compressor overheat to the point of causing combustion of the lubricating oil and/or gaskets and other soft goods found in the compressor. Compressor overheating may be caused by a number of events including, but not limited to: loss of cooling water or air flow, low lube oil level, malfunction of stage unloader or relief valves,

CHAPTER 5

Dive Program Administration

5-1 INTRODUCTION

5-1.1 Purpose. The purpose of this chapter is to promulgate general policy for maintaining and retaining command smooth diving logs, personal diving logs, personal diving records, diving mishap reports, and failure analysis reports.

5-1.2 Scope. The record keeping and reporting instructions outlined in this chapter pertain to command smooth diving logs, individual diving logs, personal diving records, diving mishap reports, and failure analysis reports.

5-2 OBJECTIVES OF THE RECORD KEEPING AND REPORTING SYSTEM

There are five objectives in the diving record keeping and reporting system.

1. Establish a comprehensive operational record for each diving command. The Command Smooth Diving Log is a standardized operational record prepared in accordance with established military practice. This record establishes the diving history for each diving command and constitutes the basic operational record requirement under normal, uneventful circumstances.

2. Gather data for safety and trend analysis. Information about current diving operations conducted in the Navy, the incidence of Hyperbaric Treatments, and diving mishaps is provided to the Naval Safety Center through the Diving Reporting System and by message as required in OPNAVINST 5100.19C Section A-6. This information enables the Safety Center to identify safety-related problems associated with operating procedures and training.

3. Provide data for a personal record. OPNAVINST 3150.27 (series) requires each diver to maintain a personal diving log/history.

4. Report information about diving mishaps and casualties in accordance with the requirements of OPNAVINST 5100.19C Section A-6. Complete and accurate information enables the command to take appropriate action and prevent reoccurrence.

5. Report information about equipment deficiencies to the responsible technical agencies through the Failure Analysis Report (FAR) system.

5-3 RECORD KEEPING AND REPORTING DOCUMENTS

The documents established to meet the objectives of the record keeping and reporting system are:

- Command Smooth Diving Log (Figure 5-1a and Figure 5-1b)
- Dive Reporting System (DRS)
- Diver's Personal Dive Record (diskette or hard copy)
- Diving Mishap/Hyperbaric Treatment/Death Report, Symbol OPNAV 5102/5
- Diving Mishaps reported in accordance with OPNAVINST 5100.19 Series Appendix A-6
- Equipment Accident/Incident Information Sheet (Figure 5-2a and Figure 5-2b)
- Diving Life Support Equipment Failure Analysis Report (FAR) for MK 20 AGA, MK 21 surface-supplied diving system, and open-circuit scuba (NAVSEA Form 10560/4) (Figure 5-3)
- Failure Analysis Report for MK 16 UBA (NAVSEA Form 10560/1) (Figure 5-4) or Failure Analysis or Inadequacy Report for MK 25 (LAR V).

5-4 COMMAND SMOOTH DIVING LOG

The Command Smooth Diving Log is a chronological record of all dives conducted at that facility or command. It contains information on dives by personnel attached to the reporting command and dives by personnel temporarily attached to the command, such as personnel on TAD/TDY.

Dives conducted while temporarily assigned to another diving command shall be recorded in the host command's Smooth Diving Log. Additionally, record the dive in the Dive Reporting System (DRS) of the host command.

The OPNAVINST 3150.27 (series) requires commands to retain the official diving log for 3 years. The minimum data items in the Command Smooth Diving Log include:

- Date of dive
- Purpose of the dive
- Identification of divers and standby divers
- Times left and reached surface, bottom time
- Depth
- Decompression time
- Air and water temperature
- Signatures of Diving Supervisor or Diving Officer

5-5 RECOMPRESSION CHAMBER LOG

The Recompression Chamber Log is the official chronological record of procedures and events for an entire dive. It is mandatory that all U.S. Navy diving activities maintain a Recompression Chamber Log. The Diving Officer, Master Diver, and Diving Supervisor shall review and sign the log daily or at the end of their watches. The 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) <u>within a 24-hour period</u> 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
COMNAVSEASYSCOM (Code 00C3)		(703) 607-2766 DSN 327-2766	(703) 607-2757
MED-21		(202) 762-3444	
National Oceanic and Atmospheric Administration (NOAA)	HAZMAT	(206) 526-6317	(206) 526-6329
Naval Facilities Engineering Command Code 00CE		(202) 433-8770	
Naval Sea Systems Command Code 00C 00C1 00C2 00C3 00C4 00C5	 Director Finance Salvage Diving Certification Husbandry	DSN 327-XXXX (703) 607-2753 (703) 607-2762 (703) 607-2758 (703) 607-2766 (703) 607-1570 (703) 607-2761	(703) 607-2757 DSN 327-2757
Naval Sea Systems Command Code 92Q		(703) 602-0141	
NAVFAC 00CE		Comm: (202) 433-8599 DSN: 288-8599	
NAVFAC Code 00CE	Certification Acquisitions	(202) 433-8766 (202) 433-5280	
NAVFAC Ocean Facilities Program		(703) 325-0505 DSN 325-0505.	
Navy Diving Salvage and Training Center (NDSTC)		Comm.:: (850) 234-4651 DSN: 436-4651	
NCSC, Code 5110		DSN: 436-5414	
Navy Experimental Diving Unit		Comm: (850) 230-3100 or (850) 235-1668 DSN: 436-4351	

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Volume 2 - List of Tables

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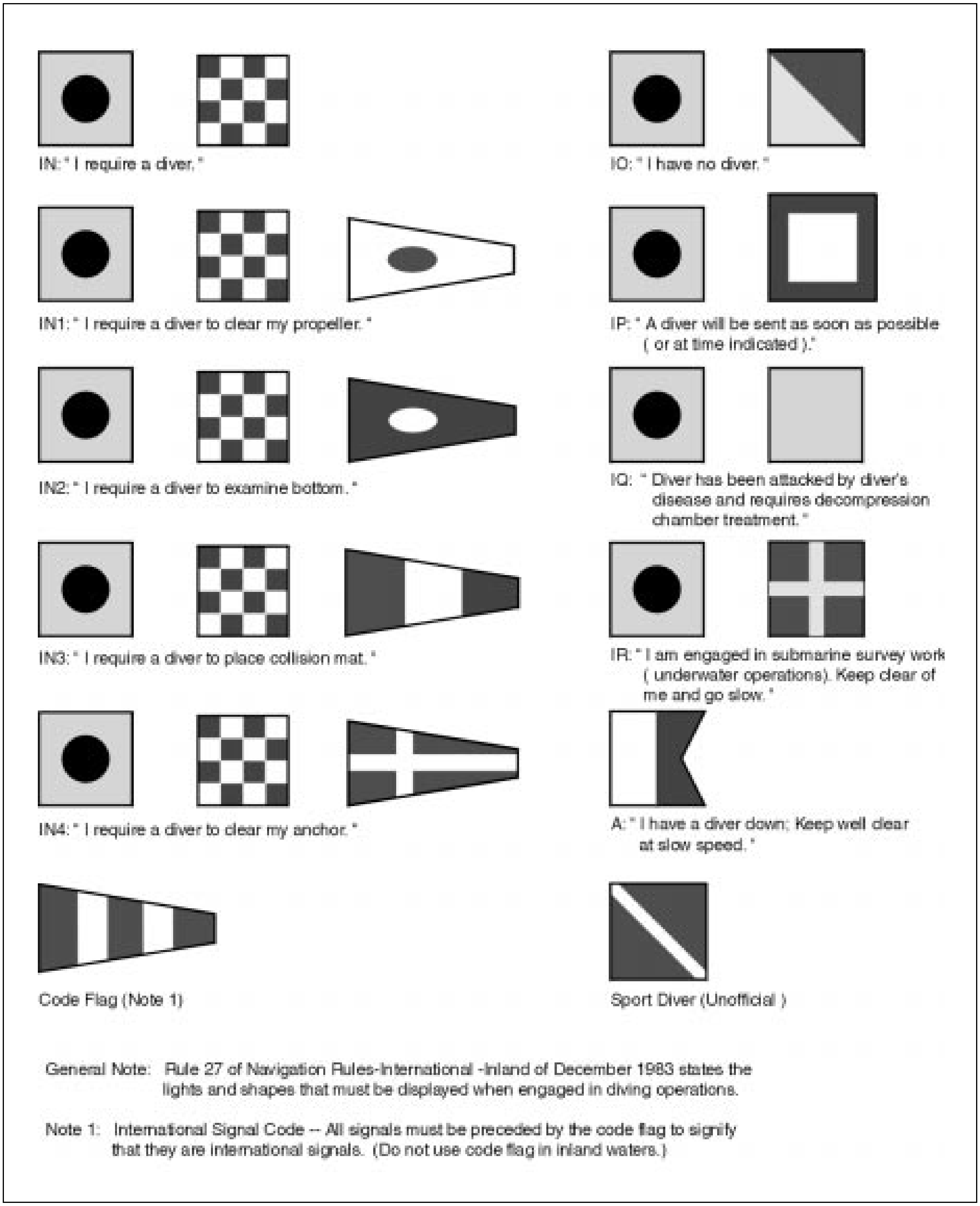


Figure 6-12. International Code Signal Flags.

1. Open-circuit scuba

2. MK 20 MOD 0 surface-supplied gear

3. MK 21 MOD 1 surface-supplied gear

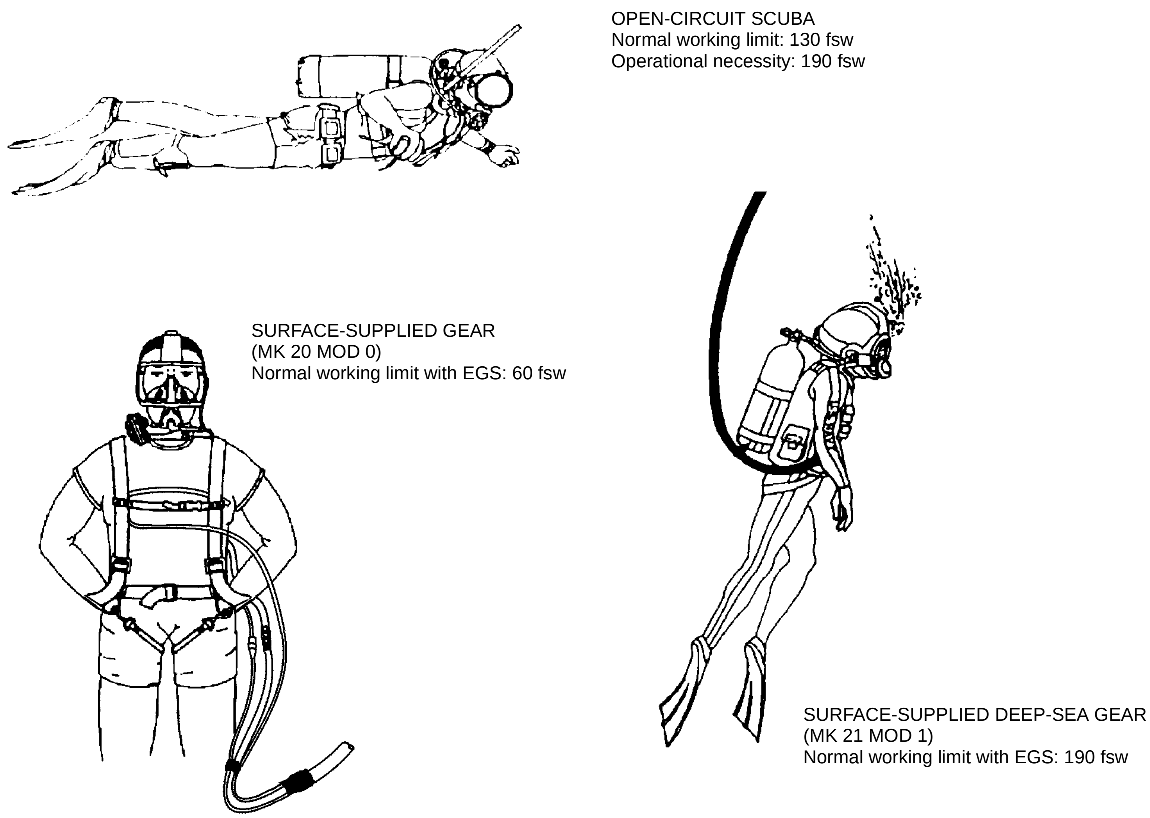


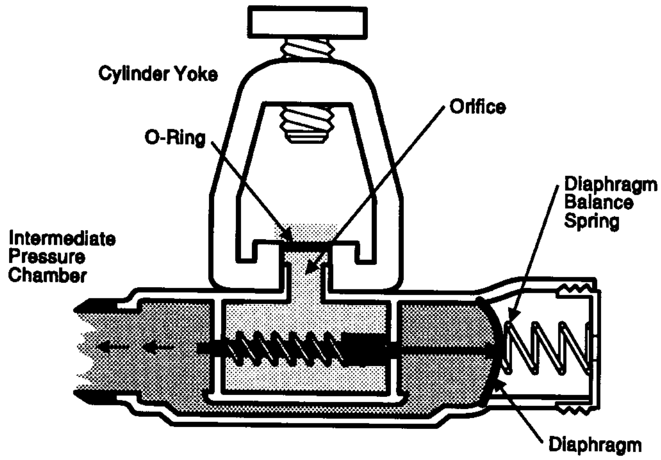
Figure 6-13. Air Diving Techniques. A choice of three air diving techniques are available: open circuit scuba, surface-supplied gear (MK 20 MOD 0), and surface-supplied deep-sea gear (MK 21 MOD 1).

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

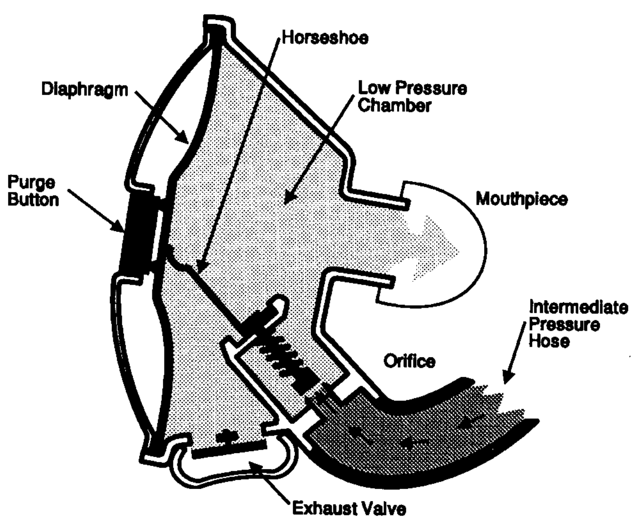
A dive of extended length, even in shallow water, may require an air supply exceeding that which could be provided by scuba. Specific depth limits have been established for each type of diving gear and shall not be exceeded without specific approval of the Chief of Naval Operations in accordance with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

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.

octopus hose is an alternative and preferred method to accomplish buddy breathing. An octupus is mandatory for standby diver and recommended for all SCUBA divers. 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 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.

7-2.2.2 **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).

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

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 SSD

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 8-6.2.3.

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 a steel 72 charges to a minimum of 1,800 psig or aluminum 80 charged to a minimum 1,900 psig with either a K- or J-valve and a first-stage regulator set at 135 ± 5 psi over bottom pressure. 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 helmet sideblock. A submersible pressure gauge is also required on the first-stage regulator.

When using an EGS whip 50 to 100 feet in length, set at manufacturer's recommended pressure, but not lower than 135 psi. If the diving scenario dictates leaving the EGS topside, adjust the first-stage regulator to 150 psig.

When conducting 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.

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 8-0 shows the MK 21 MOD 1 overbottom pressure requirements.

Table 8-0. *MK 21 MOD 1 Overbottom Pressure Requirements.*

	Pressure in psig		
Dive Depth	**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 overbottom 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:

   Bottom pressure at 175 fsw = $175 \times .445$ psi

   = 77.87 psig (round to 78)

2. Determine the overbottom pressure for the MK 21 MOD 1 system (see paragraph 8-2.2.3). 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:

$$\text{scf available} = \frac{P_f - (P_{mf} + \text{MMP})}{14.7} \times V \times N$$

   Where:

P_f	=	Flask pressure = 3,000 psig
P_{mf}	=	Minimum flask pressure = 200 psig
MMP	=	223 psig
V	=	Capacity of flasks = 8 cffv
N	=	Number of flasks = 4

$$\text{scf available} = \frac{3000 - (200 + 223)}{14.7} \times 8 \times 4$$
$$= 5609.79 \text{ scf (round down to 5609)}$$

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:

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

Where:

D	=	Depth (feet)
V	=	acfm needed per diver
N	=	Number of divers
T	=	Time at depth (minutes)

Bottom time: 30 minutes

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

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.

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

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

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

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.

$$\text{scf remaining} = \text{scf available} - \text{scf required}$$
$$= 5609 \text{ scf} - 804 \text{ scf}$$
$$= 4805 \text{ scf}$$

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 8-6.2.3.

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:

- Single scuba cylinder steel 72 with either a K- or J-valve, charged to a minimum of 1,800 psi or aluminum 80 charged to 1,900 psi.
- 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.

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 sideback 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 PORTABLE SURFACE-SUPPLIED DIVING SYSTEMS

8-4.1 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 (0.97 cu ft floodable volume each). Each flask holds 198 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.

8-4.1.1 **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.

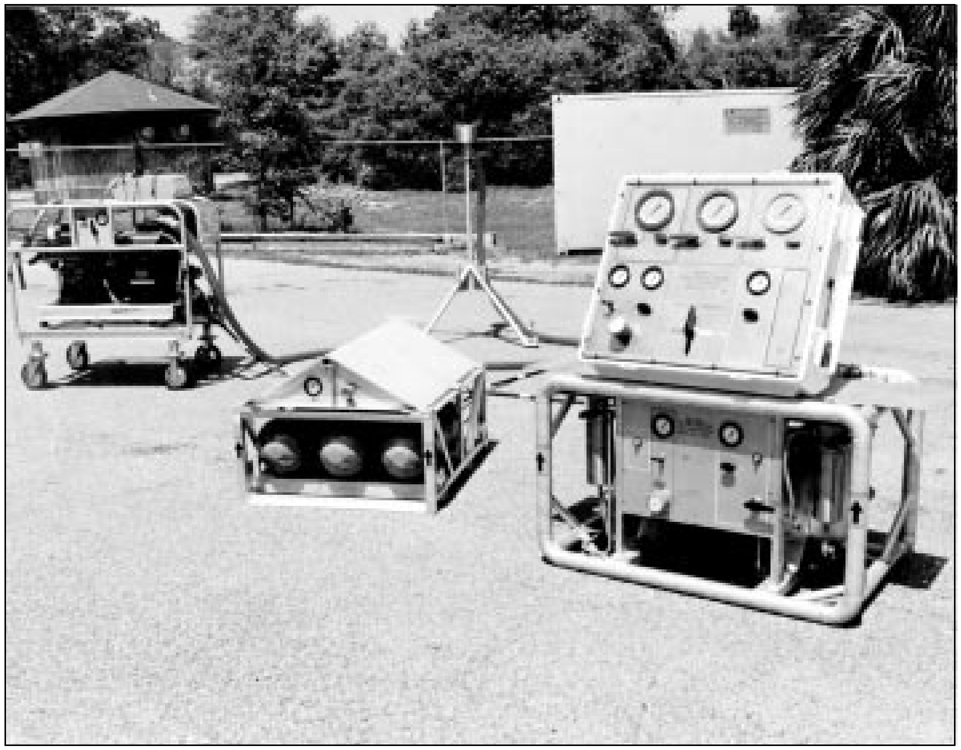


Figure 8-3. MK 3 MOD 0 Configuration 1.

8-4.1.2 **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.

8-4.1.3 **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.

8-4.2 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.

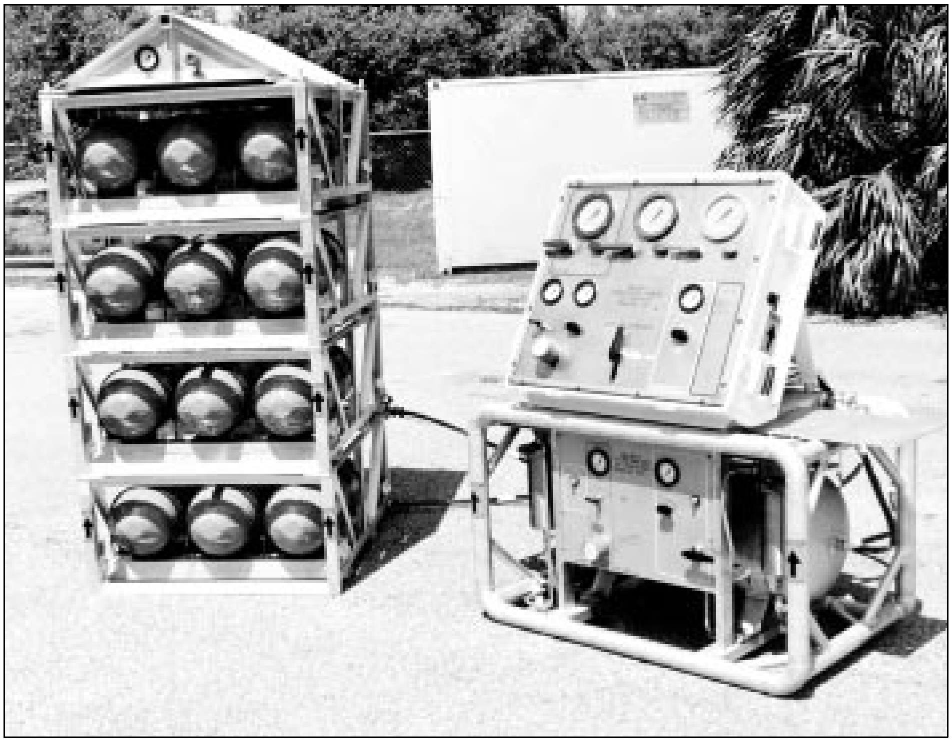


Figure 8-4. MK 3 MOD 0 Configuration 2.

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

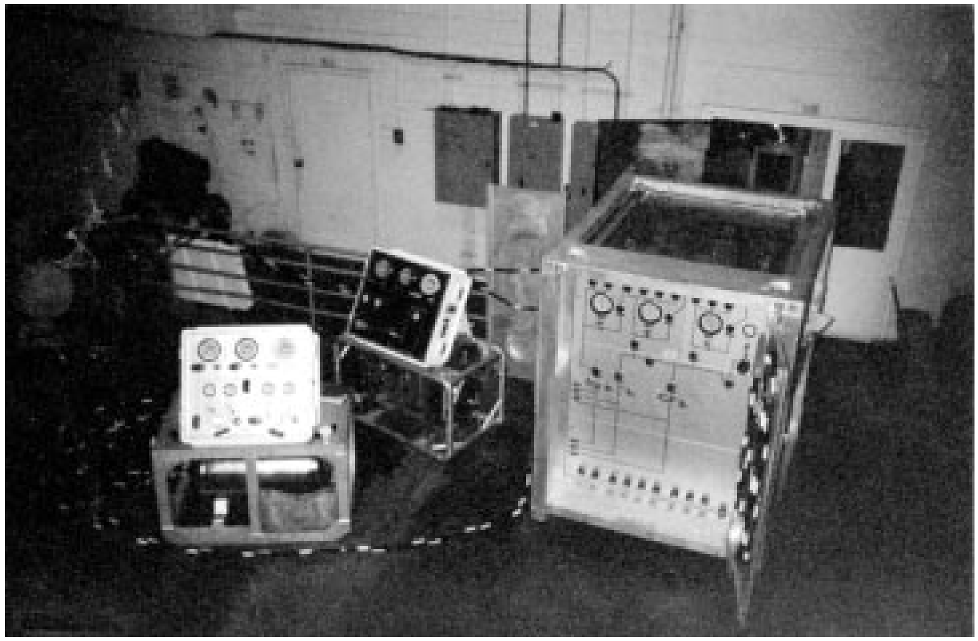


Figure 8-6. Flyaway Dive System (FADS) III.

8-4.3 **ROPER Diving Cart.** The ROPER diving cart is a trailer-mounted diving system, designed to suport 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 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.

8-4.4 **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

Figure 8-7. ROPER Cart.

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.*

8-4.5 **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.

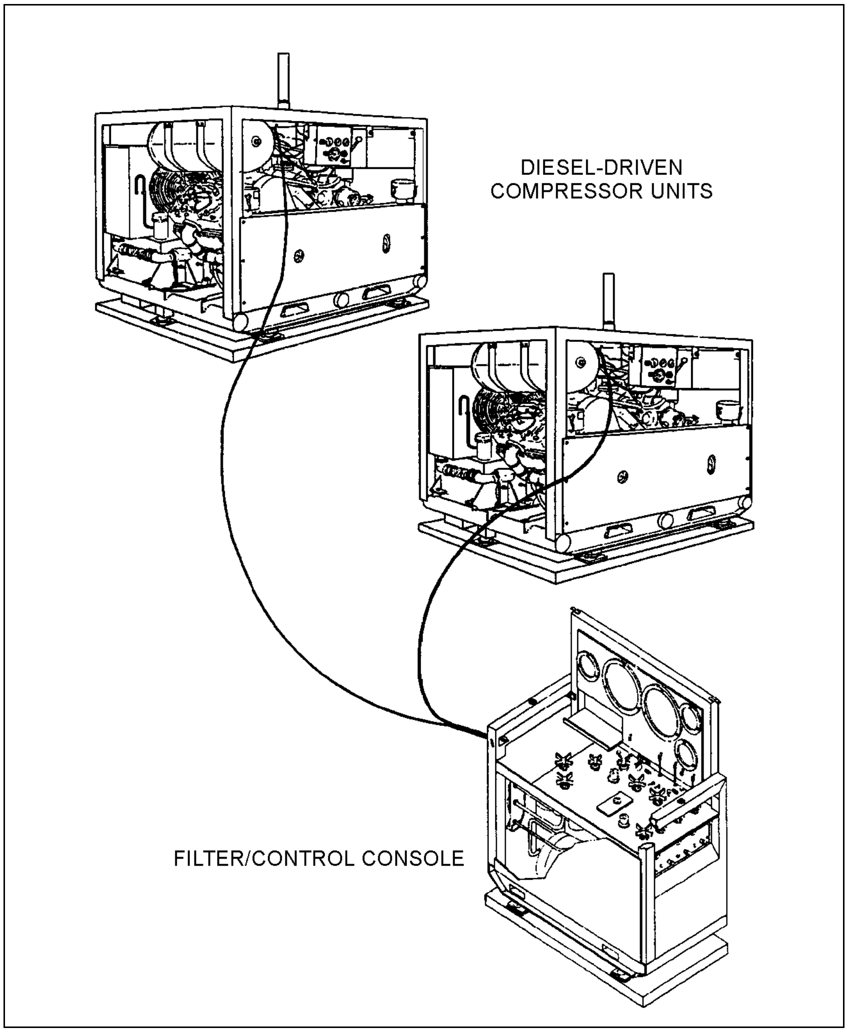


Figure 8-8. Flyaway Air Diving System (FADS) I.

- **High pressure air compressor (HPAC)**. Diesel-driven INGERSOLL RAND 10T2, 3,000 psi, 15 scfm, skid-mounted.

- **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.

8-4.6 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.

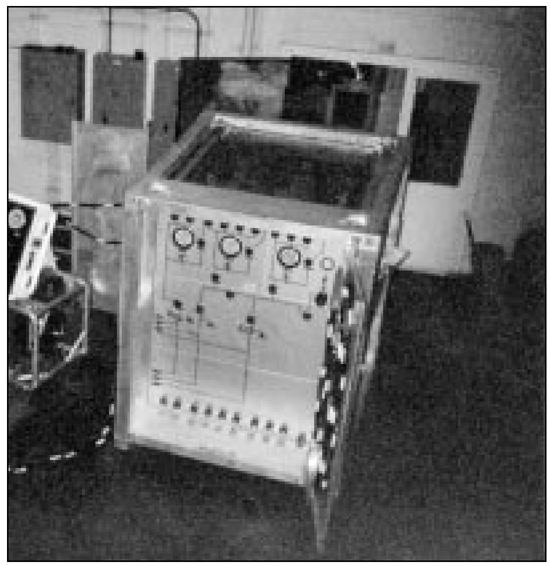


Figure 8-9. Air Supply Rack Assembly (ASRA) of FADS III.

8-5 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

Table 8-1. 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 60-130 fsw. For dives from 131-190 fsw, 165 psi over-bottom pressure shall be used.

- **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.

8-6.1.5 **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.

8-6.2 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 8-1). 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.

8-6.2.1 **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.

8-6.2.2 **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.

8-6.2.2.1 ***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.

8-6.2.2.2 ***Compressor Capacity Requirements.*** Air compressors must meet the flow and pressure requirements outlined in paragraph 8-6.1.2 and 8-6.1.3. 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.

8-6.2.2.3 ***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

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 WATER	DECOMPRESSION TIME CHAMBER	TIME WATER	TIME 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.

Table 9-8. *U.S. Navy Standard Air Decompression Table (Continued).*

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 decom-pression time (min:sec)
			Decompression stops (feet/meters)																				
	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

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 decom-pression time (min:sec)
	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)	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 decom-pression time (min:sec)
			Decompression stops (feet/meters)																				
	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) 60 / 18.2	50 / 15.2	40 / 12.1	30 / 9.1	Surface Interval	Time at 40-foot chamber stop (min) on oxygen	Surface	Total decompression time (min:sec)
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						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) 60 / 18.2	50 / 15.2	40 / 12.1	30 / 9.1	Surface Interval	Time at 40-foot chamber stop (min) on oxygen	Surface	Total decompression time (min:sec)
120 36.5	15	4:00								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

Surface Interval: TOTAL TIME FROM LAST WATER STOP TO FIRST CHAMBER STOP NOT TO EXCEED 5 MINUTES

Surface: 1-MINUTE 20 SECONDS ASCENT FROM 40 FEET IN CHAMBER TO SURFACE

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

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 (MILSTD 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 MILSTD 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).

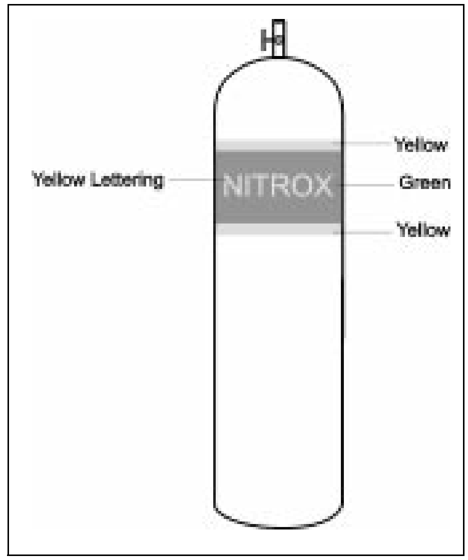


Figure 10-2. NITROX Scuba Bottle Markings.

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. MILSTD 1330.D 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. MILSTD 1330 is applicable to anything with an oxygen level higher than 25 percent by volume. Therefore, MILSTD 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 MILSTD 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 MILSTD 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 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.

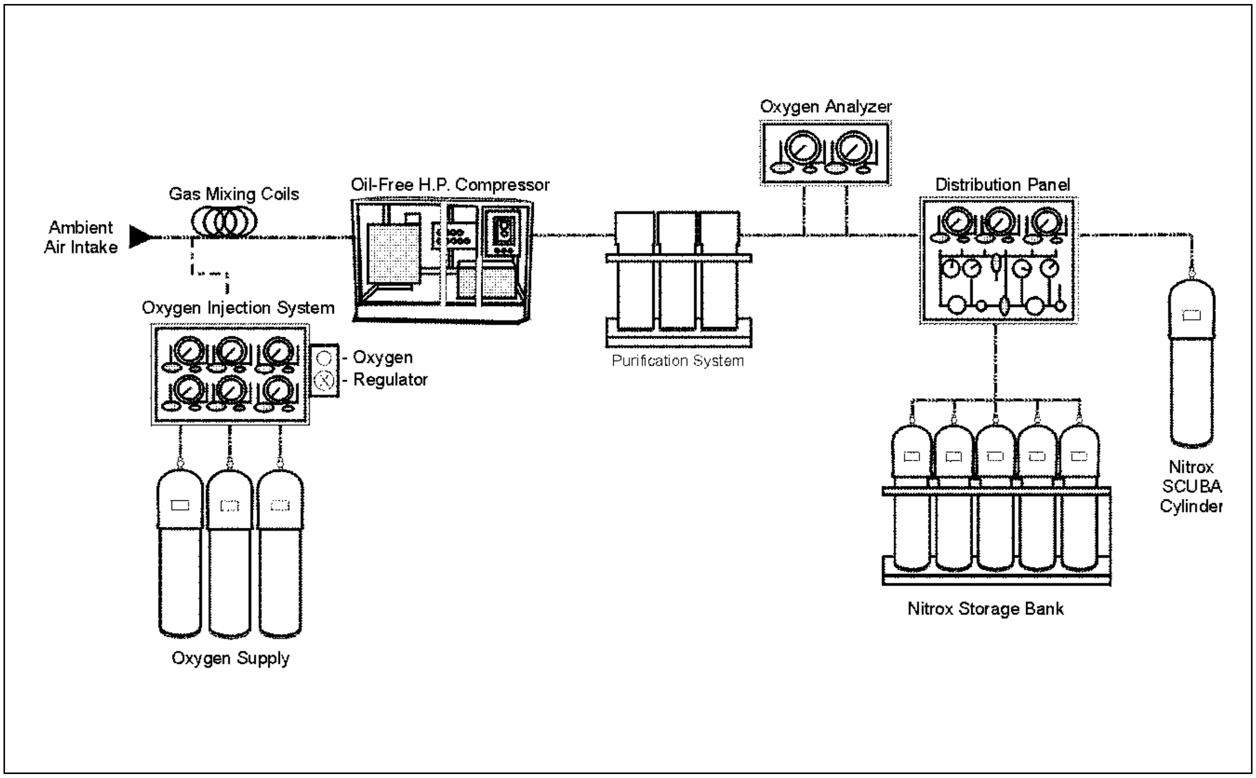


Figure 10-3. Nitrox O_2 Injection System.

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 MILSTD 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.

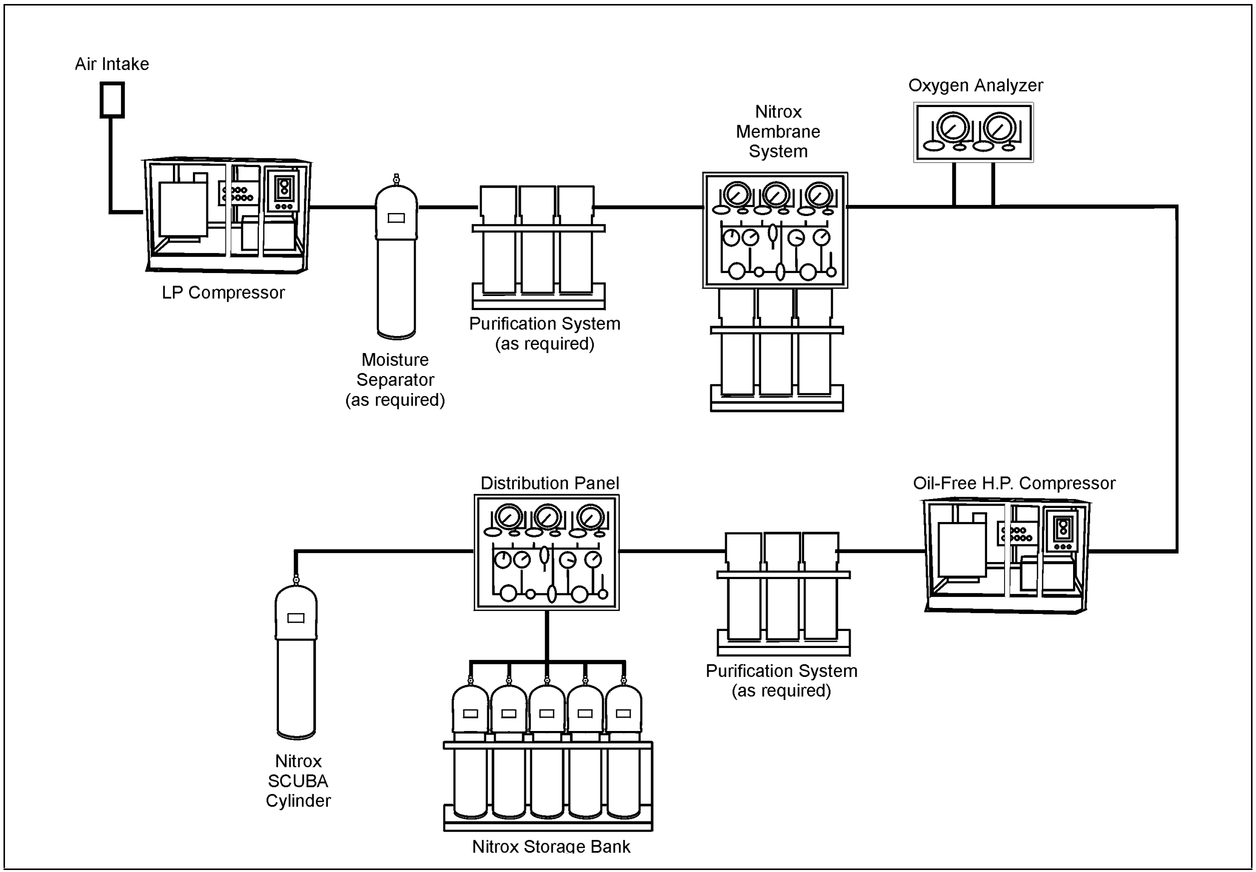


Figure 10-4. LP Air Supply NITROX Membrane Configuration.

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	1.4 acfm (demand) 6.0 acfm (free flow)	2.5 acfm (demand) 6.0 acfm (free flow)
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.

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 U.S. Navy surface-supplied procedures.

14-1.2 Scope. Surface-supplied 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 deep diving system. Surface-supplied mixed-gas diving is also useful in the deep 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 the limitations on the duration of carbon dioxide absorption canisters in cold water.

14-2.1 Depth and Exposure Time. The normal operational limit for surface-supplied mixed-gas diving is 300 fsw. Within each decompression table (Table 14-7), exceptional-exposure dives are enclosed in red 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 in emergency circumstances. Planned exceptional-exposure dives require prior CNO approval. Repetitive diving is not allowed in surface-supplied helium-oxygen diving.

14-2.2 Water Temperature. Loss of body temperature (hypothermia) can be a major problem during long, deep dives. Because the high thermal conductivity of helium in a dry suit accelerates the loss of body heat, a hot water suit is preferred for surface-supplied dives when using the MK 21 MOD 1 in very cold water.

Refer to Chapter 3 for more information on thermal problems and the signs and symptoms of hypothermia. Refer to Chapter 11 for information on ice and cold water diving operations.

14-2.3 Gas Mixtures. Air, 100 percent oxygen, and several helium-oxygen mixtures will be required to dive the surface-supplied mixed-gas tables over their full range. The logistics of supplying these gases must be carefully planned. Analysis of the oxygen content of helium-oxygen mixtures shall be accurate to within ±0.5 percent.

14-2.3.1 **Maximum/Minimum Mixtures.** For each depth in the decompression tables, the allowable maximum and minimum oxygen percentage in the helium-oxygen mixture used on the bottom is specified. For operations planning, the range of possible depths should be established and a mixture selected that will meet the maximum/minimum specification across the depth range. 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 16 percent for depths to 200 fsw, 12 percent for depths from 200 fsw to 300 fsw, and 10 percent for depths in excess of 300 fsw. Diving with a mixture near maximum oxygen percentage is encouraged as it offers a decompression advantage to the diver.

14-2.3.1.1 ***On the Surface.*** On the surface, the diver's gas mixture must contain a minimum of 16 percent oxygen. When a bottom mix with less than 16 percent oxygen is to be used, a shift to the bottom mix is made at 20 fsw during descent (see paragraph 14-3.2).

14-2.3.1.2 ***Deeper than 200 fsw.*** For dives deeper than 200 fsw in which the bottom mixture contains less than 16 percent oxygen, a gas shift from the bottom mix to a 60 percent helium/40 percent oxygen mixture is required at the 100-fsw decompression stop or the next shallower stop if there is no 100-fsw stop (see paragraph 14-3.3).

14-2.3.1.3 ***Up to 200 fsw.*** For dives to 200 fsw and shallower or for deeper dives in which the bottom mixture contains more than 16 percent oxygen, a shift to 60 percent helium/40 percent oxygen is not required but can be executed to increase decompression safety if desired.

14-2.3.1.4 ***Exceptional Exposure Dives.*** For exceptional-exposure dives, a shift to a 60 percent helium/40 percent oxygen mixture is required at the 100-fsw stop or the next shallower stop if there is no 100-fsw stop.

On all dives, a shift to 100 percent oxygen is made at the 50-fsw or 40-fsw water stop if there is no 50-fsw stop.

14-2.3.2 **Emergency Gas Supply.** All divers are equipped with an emergency gas supply (EGS). The EGS gas mixture will be the same as the bottom mixture unless the bottom mixture contains less than 16 percent oxygen, in which case the EGS gas mixture will be 16 + 0.5 percent oxygen and the balance will be helium. The EGS bottle shall be a minimum of steel 72 charged to 1,800 psig or aluminum 80 charged to 1,900 psig.

14-3 SURFACE-SUPPLIED HELIUM-OXYGEN DESCENT AND ASCENT PROCEDURES

The Surface-Supplied Helium-Oxygen Decompression Table (Table 14-7) 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

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

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.

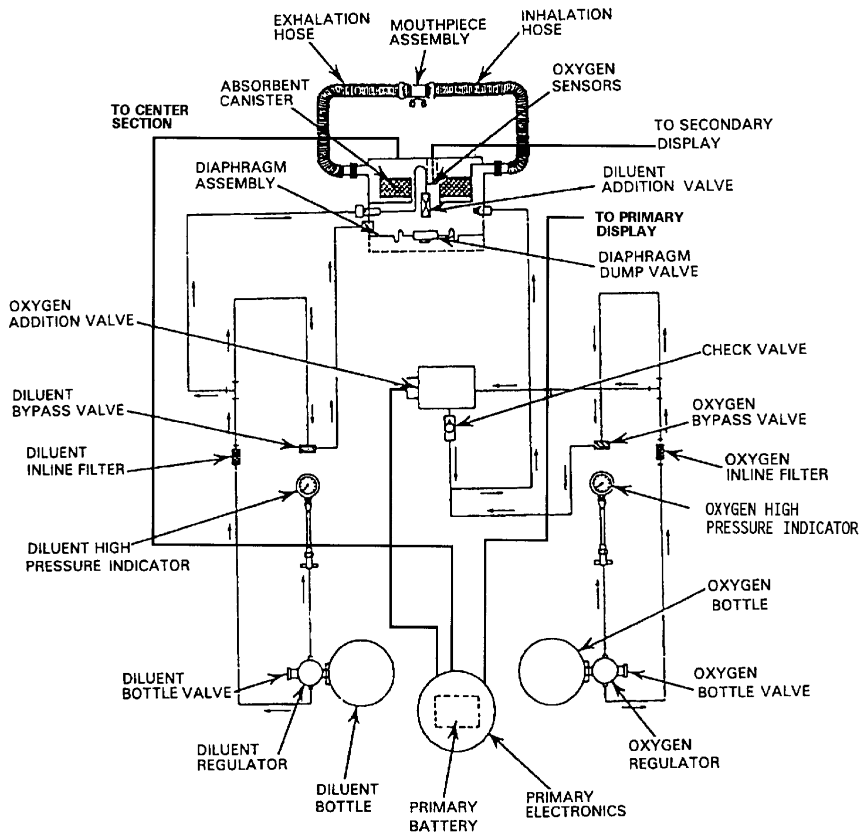


Figure 17-2. MK 16 MOD 0 UBA Functional Block Diagram.

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 diaphram 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.

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 if a maximum depth of 70 fsw (NEDU Report 13-83) is not exceeded at any time during the dive. 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.

17-4.1.1 **Oxygen Flask Endurance.** In 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

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 render safe procedure; for SPECWAR, 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 normal 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 normal working limit.
3. Dives deeper than the normal working limits require a recompression chamber on station. ***On station*** **is defined as at the dive location.**

- Initial predive pressure
- Required reserve pressure

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 maximim 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.

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-demompression 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 17-1 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. The decompression tables were calculated and tested using functioning or prototype MK 16 UBAs. When addition of oxygen to the UBA is manually controlled,

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

- *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.

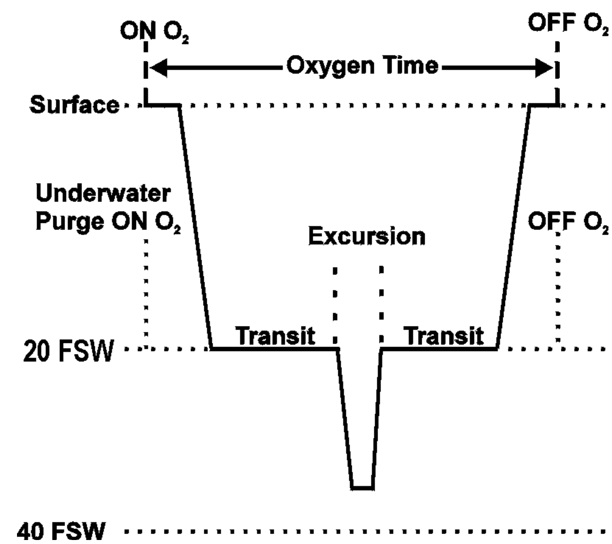


Figure 18-3. Example of Transit with Excursion.

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 25 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 25 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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- Carbon monoxide poisoning

- Gas gangrene

21-5.4.1.1 ***Performance of Neurological Exam at 60 fsw.*** After arrival at 60 fsw a neurological exam shall be performed (see Appendix 5A) to ensure that no overt neurological symptoms (e.g., weakness, numbness, incoordination) are present. If any abnormalities are found, the stricken diver should be treated using Treatment Table 6.

21-5.4.1.2 ***Extending Oxygen Breathing Periods on Treatment Table 5.*** Treatment Table 5 may be extended by two oxygen breathing periods at 30 fsw. Air breaks are not required prior to an extension, between extensions, or prior to surfacing. In other words, the Diving Supervisor may have the patient breathe oxygen continuously for 60 minutes at 30 fsw and travel to the surface while breathing oxygen. If the Diving Supervisor elects to extend this treatment table, the tender does not require additional oxygen breathing than currently prescribed.

21-5.4.1.3 ***When Use of Treatment Table 6 is Mandatory.*** Treatment Table 6 is mandatory if:

- Type I pain is severe and immediate recompression must be instituted before a neurological examination can be performed, or

- A complete neurological examination cannot be performed, or

- Any neurological symptom is present.

These rules apply no matter how rapidly or completely the symptoms resolve once recompression begins.

21-5.4.1.4 ***Complete Relief after 10 Minutes.*** If complete relief of Type I symptoms is not obtained within 10 minutes at 60 feet, Table 6 is required.

21-5.4.1.5 ***Musculoskeletal Pain Due to Orthopedic Injury.*** Symptoms of musculoskeletal pain that have shown absolutely no change after the second oxygen breathing period at 60 feet may be due to orthopedic injury rather than decompression sickness. If, after reviewing the patient's history, the Diving Medical Officer feels that the pain can be related to specific orthopedic trauma or injury, Treatment Table 5 may be completed. If no Diving Medical Officer is on site, Treatment Table 6 shall be used.

NOTE **Once recompression to 60 feet is done, Treatment Table 5 shall be used even if it was decided symptoms were probably not decompression sickness. Direct ascent to the surface is done only in emergencies.**

21-5.4.2 **Treatment Table 6.** Treatment Table 6 is used for the following:

- Type I symptoms where relief is not complete within 10 minutes at 60 feet or where a neurological exam is not complete

- Type II symptoms
- Cutis marmorata
- Severe carbon monoxide poisoning, cyanide poisoning, or smoke inhalation
- Arterial gas embolism
- Symptomatic uncontrolled ascent
- Asymptomatic divers with omitted decompression greater than 30 minutes
- Treatment of unresolved symptoms following in-water treatment
- Recurrence of symptoms shallower than 60 fsw

21-5.4.2.1 ***Treating Arterial Gas Embolism.*** Arterial gas embolism is treated by initial compression to 60 fsw. If symptoms are improved within the first oxygen breathing period, then treatment is continued using Treatment Table 6. Treatment Table 6 may be extended 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 (15 minutes on air, then 60 minutes on oxygen, then 15 minutes on air, then 60 minutes on oxygen). If there has been more than one extenstion, the tenders' breathing period is extended 60 minutes at 30 feet.

21-5.4.3 **Treatment Table 6A.** Arterial gas embolism or severe decompression symptoms are treated by initial compression to 60 fsw. If symptoms improve, complete Treatment Table 6. If symptoms are unchanged or worsen, assess the patient upon descent and compress to depth of relief (significant improvement), not to exceed 165 fsw. Once at the depth of relief, begin treatment gas (N_2O_2, HeO_2) IAW Table 21-5 if available. Stay there for 30 minutes. A breathing period of 25 minutes on treatment gas, interrupted by 5 minutes of air, is recommended at depth to simplify time keeping. The patient may remain on treatment gas during ascent from treatment depth to 60 fsw since the PO_2 will continually decrease during ascent. Decompress to 60 fsw at a travel rate not to exceed 3 ft./min. Upon arrival at 60 fsw, complete Treatment Table 6. Consult with a Diving Medical Officer at the earliest opportunity. The Diving Medical Officer may recommend a Treatment Table 4. Treatment Table 6A may be extended for two oxygen breathing periods at 60 fsw and two oxygen breathing periods at 30 fsw. If deterioration is noted during ascent to 60 feet, treat as a recurrence of symptoms (Figure 21-6).

21-5.4.4 **Treatment Table 4.** If a shift from Treatment Table 6A to Treatment Table 4 is contemplated, a Diving Medical Officer shall be consulted before the shift is made. Treatment Table 4 is used when it is determined that the patient would receive additional benefit at depth of significant relief, not to exceed 165 fsw. The time at depth shall be between 30 to 120 minutes, based on the patient's response.

21-5.4.4.1 ***Recurrence of Symptoms.*** If deterioration is noted during ascent to 60 feet, treat as a recurrence of symptoms (Figure 21-6).

patient's clinical condition and response to oxygen toxicity (paragraph 21-5.5.6.2).

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.

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, respirator 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.

graph 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 tradeoff 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

Table 21-8b. *Secondary Emergency Kit (sheet 2 of 2).*

Miscellaneous • Nasogastric tube • Urinary catheterization set with collection bag (Foley type) • Catheter and needle unit, intravenous (16- and 18-gauge - 4 ea) • Intravenous infusion sets (4) • Intravenous infusion extension sets with injection ports (2) • Straight and curved hemostats (2 ea) • Blunt straight surgical scissors • Thermometer (non-mercury type, high and low reading preferably) • Syringes (2, 5, 10 and 30 cc) • Sterile needles (18-, 20-, and 22- gauge) • 3-way stopcocks • 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: 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.

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.
4. No oxygen available.

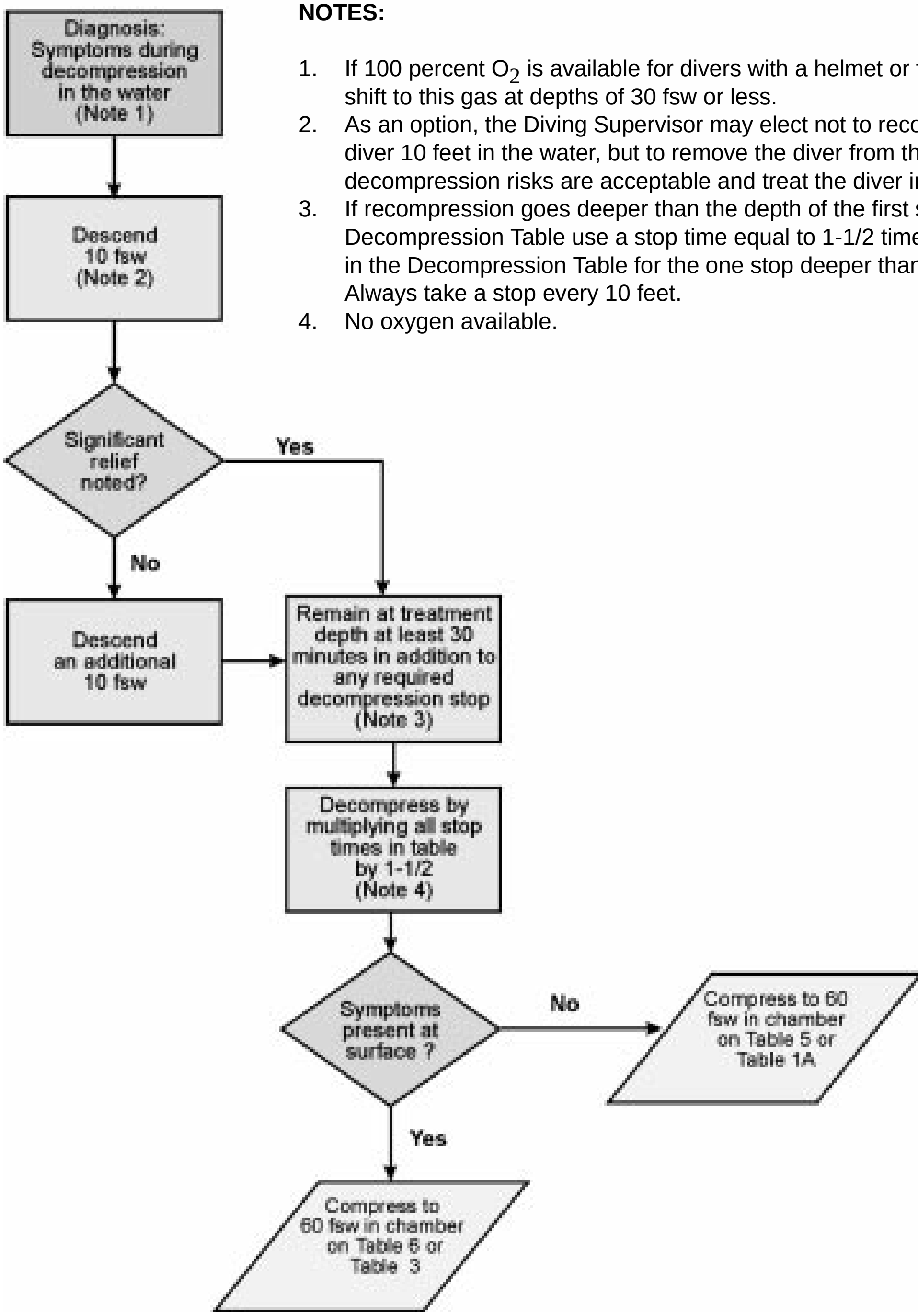
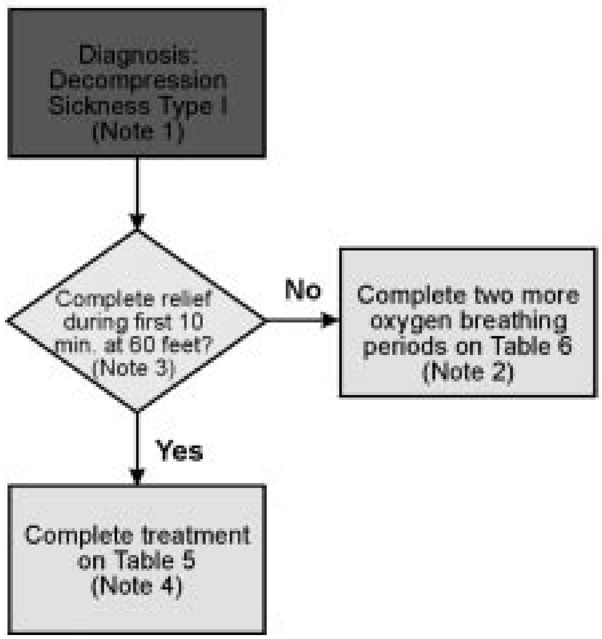


Figure 21-3. Treatment of Decompression Sickness Occurring while at Decompression Stop in the Water.

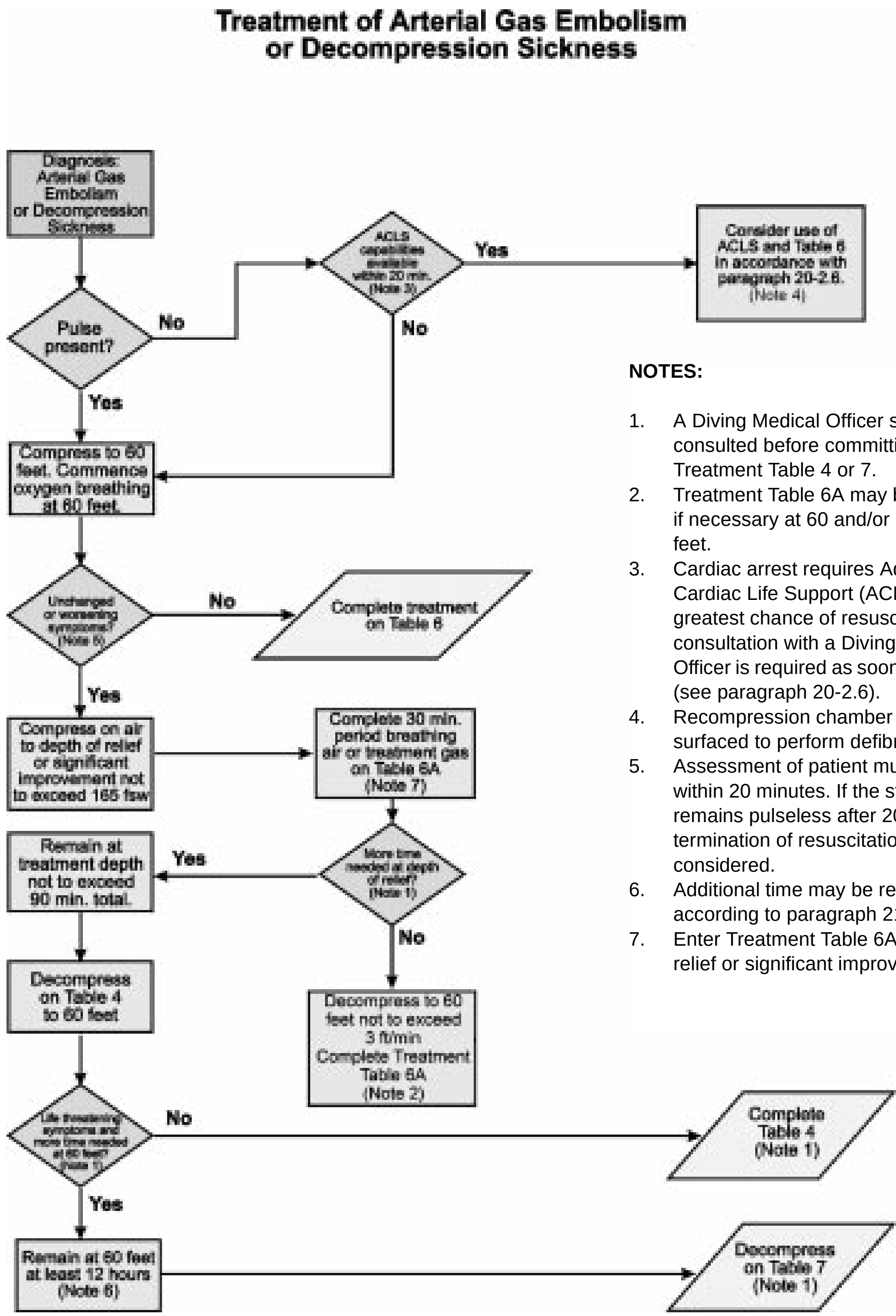
Treatment of Type I Decompression Sickness



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 or significant improvement.

Figure 21-5. Treatment of Arterial Gas Embolism or Decompression Sickness.

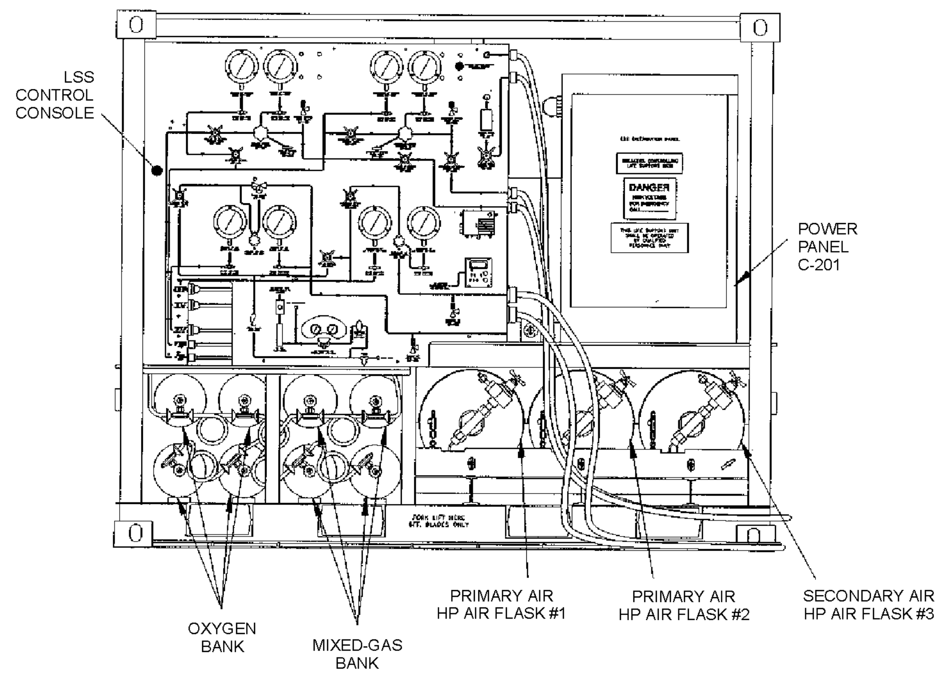


Figure 22-10. Fly Away Recompression Chamber Life Support Skid.

- **Primary.** Sufficient air to pressurize the inner lock once to 165 feet and the outer lock twice to 165 feet and ventilate during one Treatment Table 4 (Chapter 21).

- **Secondary.** Sufficient air to pressurize the inner and outer locks once to 165 feet and ventilate for one hour at 70.4 scfm.

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. The required total capacity is calculated as follows.

- Primary System Capacity:

$$C_p = (5 \times V_{il}) + (5 \times V_{ol}) + 45{,}390$$

Where:

C_P	=	minimum capacity of primary system in scf
V_{il}	=	volume of inner lock in scf
V_{ol}	=	volume of outer lock in scf
5	=	atmospheres equivalent to 165 fsw
10	=	twice 5 atmospheres
45,390	=	total air in scf required to ventilate during a Table 4 Treatment

- Secondary System Capacity:

  $C_s = (5 \times V_{il}) + (5 \times V_{ol}) + 4,224$

  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
4224	=	air in scf required for maximum ventilation rate of 70.4 scfm for one hour (60 min)

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.
- 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.

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		
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).

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.

- 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 Extinguishers.*** Only fire extinguishers listed on the NAVSEA Authorized for Navy Use (ANU) Lists 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 1220-100, 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, 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*