CHAPTER 8

Surface-Supplied Air Diving Operations

8-1 INTRODUCTION

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

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

8-2 MK 21 MOD 1

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

Figure 8-1. MK 21 MOD 1 SSDS.

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

8-2.2 **Air Supply.** Air for the MK 21 MOD 1 system is supplied from the surface by either an air compressor or a bank of high-pressure air flasks as described in paragraph 8-6.2.3.

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 (64.7 cubic-foot [minimum]) scuba bottle 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.

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). The optimum overbottom pressure for all dives shallower than 130 fsw is 135 psi. For those systems which cannot maintain 135 psig when diving shallower than 60 fsw, 90 psi is permissible. The manifold supply pressure requirement for dives 130-190 fsw is 165 psi. For those systems not capable of sustaining 165 psi overbottom due to design limitations, 135 psi overbottom is acceptable.

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).

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

   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 = 220 psig
   MMP = 223 psig
   V = Capacity of flasks = 8 cffv
   N = Number of flasks = 4

$$\text{scf available} = \frac{3000 - (220 + 223)}{14.7} \times 8 \times 4$$

$$= 5566.26 \text{ scf (round down to 5566)}$$

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 (minimum 64.7 cubic feet) with either a K- or J-valve, charged to a minimum of 1,800 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 **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.

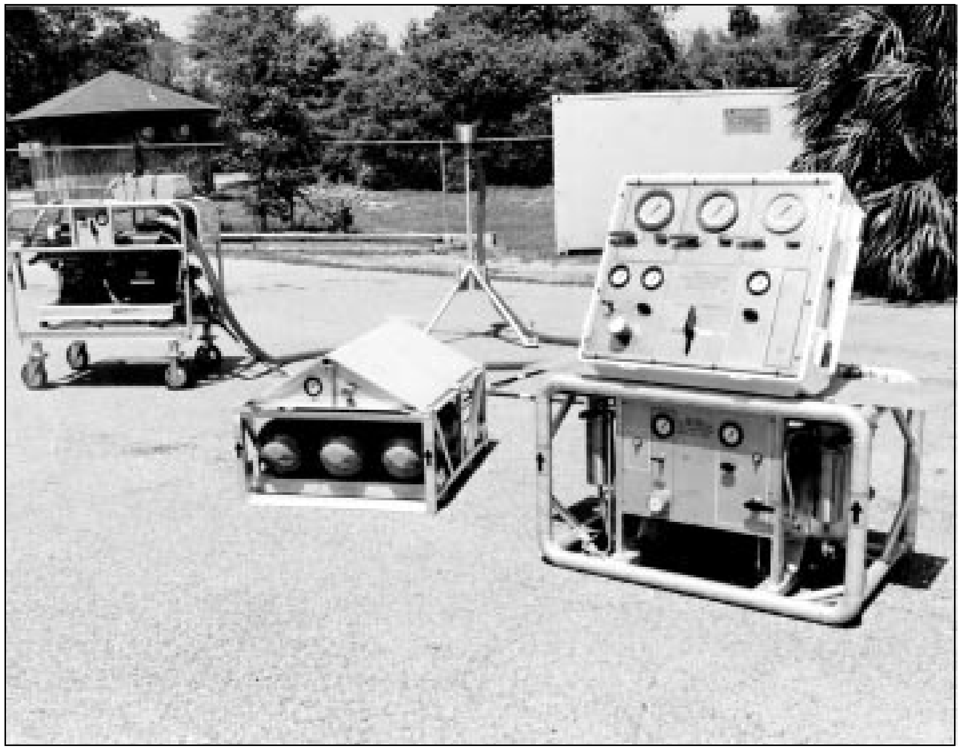


Figure 8-3. MK 3 MOD 0 Configuration 1.

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.

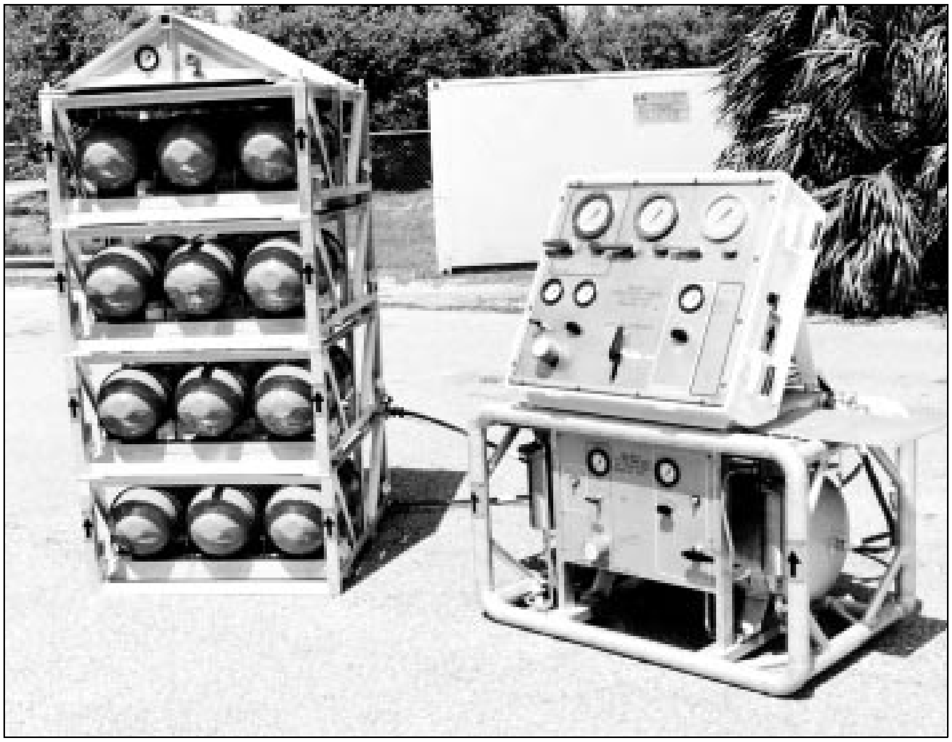


Figure 8-4. MK 3 MOD 0 Configuration 2.

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

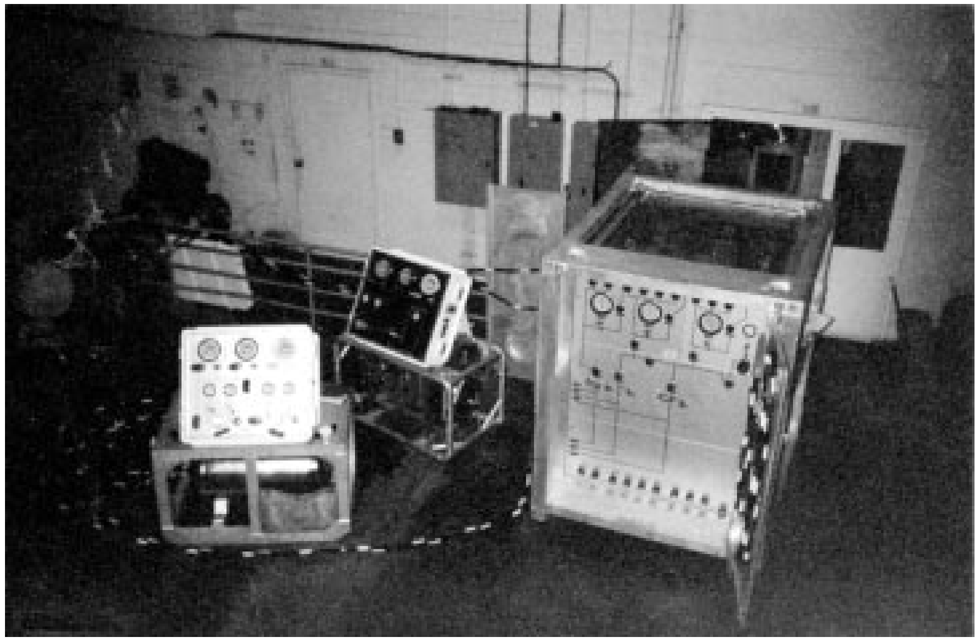


Figure 8-6. MK 3 MOD 1 Lightweight Dive System.

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.

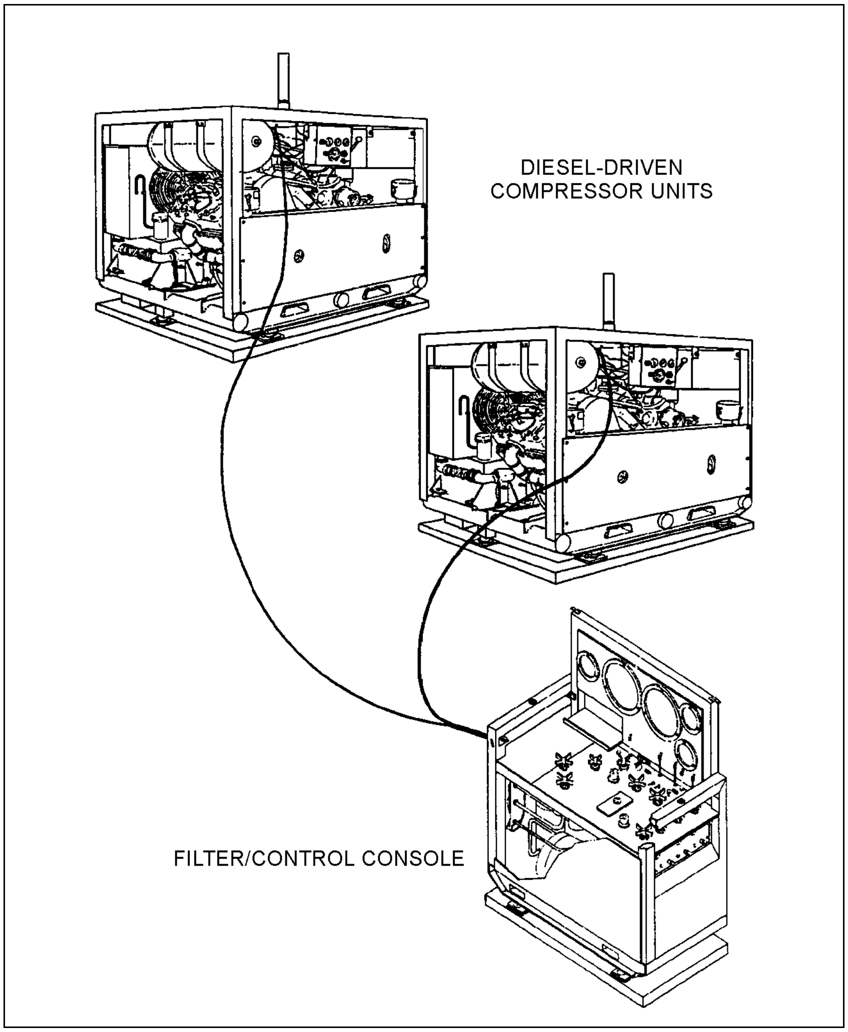


Figure 8-8. Flyaway Air Diving System (FADS) I.

- **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.

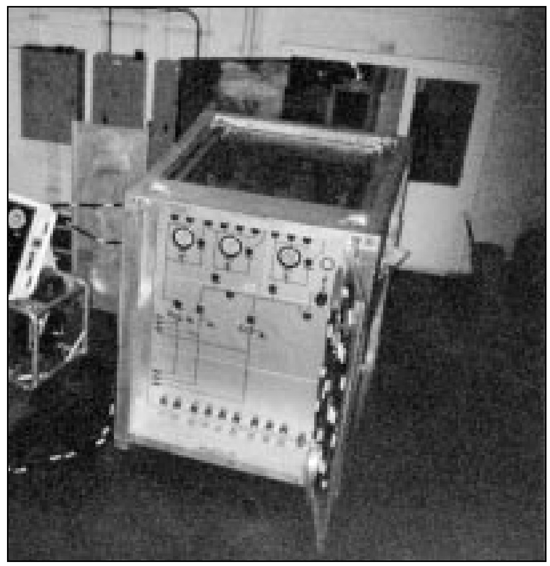


Figure 8-9. Control Console Assembly of FADS III.

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 use, the end of the line may be fastened to a fixed underwater object, or it may be anchored with a weight heavy enough to withstand the current.

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

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

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

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

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

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

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

8-6 SURFACE AIR SUPPLY SYSTEMS

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

8-6.1 Requirements for Air Supply.

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

8-6.1.1 **Air Purity Standards.** Air taken directly from the atmosphere and pumped to the diver may not meet established purity standards. It may be contaminated by engine exhaust or chemical smog. Initially pure air may become contaminated while passing through a faulty air compressor system. For this reason, all divers' air must be periodically sampled and analyzed to ensure the air meets purity standards. Refer to Table 4-1 for compressed air purity requirements.

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

8-6.1.2 **Air Supply Flow Requirements.** The required flow from an air supply depends upon the type of diving apparatus being used. The open-circuit air supply system must have a flow capacity (in acfm) that provides sufficient ventilation at depth to maintain acceptable carbon dioxide levels in the mask or helmet. Carbon dioxide levels must be kept within safe limits during normal work, heavy work, and emergencies.

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

8-6.1.3 **Supply Pressure Requirements.** In order to supply the diver with an adequate flow of air, the air source must deliver air at sufficient pressure to overcome the bottom seawater pressure and the pressure drop that is introduced as the air flows through the hoses and valves of the system. Table 8-1 shows the values for air consumption and minimum over-bottom pressures required for each of the surface-supplied air diving systems.

8-6.1.4 **Water Vapor Control.** A properly operated air supply system should never permit the air supplied to the diver to reach its dewpoint. Controlling the amount of water vapor (humidity) in the supplied air is normally accomplished by one or both of the following methods:

- **Compression/Expansion**. As high-pressure air expands across a pressure reducing valve, the partial pressure of the water vapor in the air is decreased. Since the expansion takes place at essentially a constant temperature (isothermal), the partial pressure of water vapor required to saturate the air remains unchanged. Therefore, the relative humidity of the air is reduced.

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 $\times$ 0.445) + 90 to 165 psi, depending on the depth of the dive	1.4 (Note 1)
MK 20 MOD 0	(Depth in fsw $\times$ 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 60-129 fsw. For dives from 130-190 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. 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

- Seals close clearances
- Protects against corrosion
- Transfers heat away from heat-producing surfaces
- Transfers minute particles generated from normal system wear to the oil sump or oil filter if so equipped

8-6.2.2.4 ***Lubricant Specifications.*** Unfortunately, the lubricant vaporizes into the air supply and, if not condensed or filtered out, will reach the diver. Lubricants used in air diving compressors must conform to military specifications MIL-L-17331 (2190 TEP) for normal operations, or MIL-H-17672 (2135 TH) for cold weather operations. Where the compressor manufacturer specifically recommends using a synthetic base oil, the recommended oil may be used in lieu of MIL-L-17331 or MIL-H-17672 oil.

8-6.2.2.5 ***Maintaining an Oil-Lubricated Compressor.*** Using an oil-lubricated compressor for diving is contingent upon proper maintenance to limit the amount of oil introduced into the diver's air (see *Topside Tech Notes*, March 1997). When using any lubricated compressor for diving, the air must be checked for oil contamination. Diving operations shall be aborted at the first indication that oil is in the air being delivered to the diver. An immediate air analysis must be conducted to determine whether the amount of oil present exceeds the maximum permissible level in accordance with table Table 4-1.

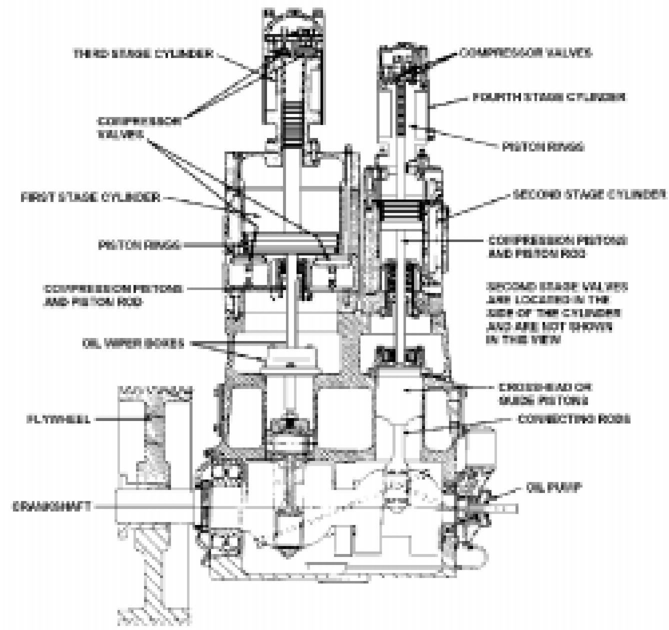
It should be noted that air in the higher stages of a compressor has a greater amount of lubricant injected into it than in the lower stages. It is recommended that the compressor selected for a diving operation provide as close to the required pressure for that operation as possible. A system that provides excessive pressure contributes to the buildup of lubricant in the air supply..

8-6.2.2.6 ***Intercoolers.*** Intercoolers are heat exchangers that are placed between the stages of a compressor to control the air temperature. Water, flowing through the heat exchanger counter to the air flow, serves both to remove heat from the air and to cool the cylinder walls. Intercoolers are frequently air cooled. During the cooling process, water vapor is condensed out of the air into condensate collectors. The condensate must be drained periodically during operation of the compressor, either manually or automatically.

8-6.2.2.7 ***Filters.*** As the air is discharged from the compressor, it passes through a moisture separator and an approved filter to remove lubricant, aerosols, and particulate contamination before it enters the system. Approved filters are listed in the NAVSEA/00C ANU list.

8-6.2.2.8 ***Pressure Regulators.*** A back-pressure regulator will be installed downstream of the compressor discharge. A compressor only compresses air to meet the supply pressure demand. If no demand exists, air is simply pumped through the compressor at atmospheric pressure. Systems within the compressor, such as the

HP Compressor Assembly



MP Compressor Assembly

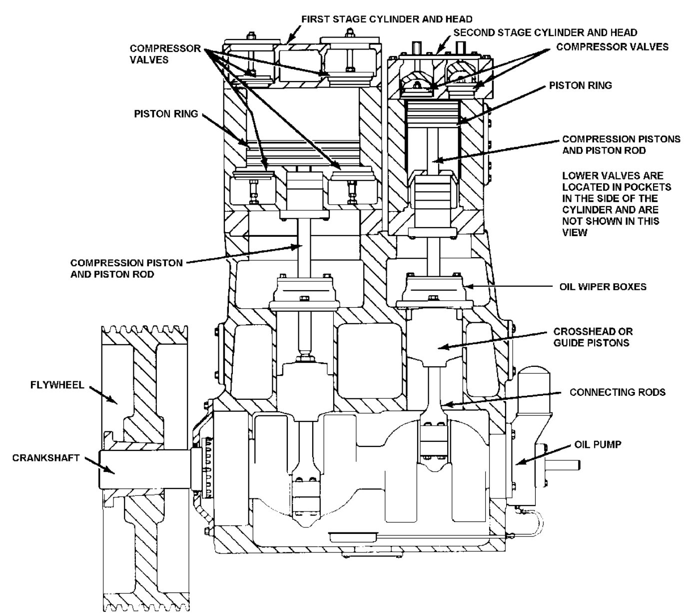


Figure 8-10. HP Compressor Assembly (top); MP Compressor Assembly (bottom).

intercoolers, are designed to perform with maximum efficiency at the rated pressure of the compressor. Operating at any pressure below this rating reduces the efficiency of the unit. Additionally, compression reduces water vapor from the air. Reducing the amount of compression increases the amount of water vapor in the air supplied to the diver.

The air supplied from the compressor expands across the pressure regulator and enters the air banks or volume tank. As the pressure builds up in the air banks or volume tank, it eventually reaches the relief pressure of the compressor, at which time the excess air is simply discharged to the atmosphere. Some electrically-driven compressors are controlled by pressure switches installed in the volume tank or HP flask. When the pressure reaches the upper limit, the electric motor is shut off. When sufficient air has been drawn from the volume tank or HP flask to lower its pressure to some lower limit, the electric motor is restarted.

All piping in the system must be designed to minimize pressure drops. Intake ducting, especially, must be of sufficient diameter so that the rated capacity of the compressor can be fully utilized. All joints and fittings must be checked for leaks using soapy water. Leaks must be repaired. All filters, strainers, and separators must be kept clean. Lubricant, fuel, and coolant levels must be periodically checked.

Any diving air compressor, if not permanently installed, must be firmly secured in place. Most portable compressors are provided with lashing rings for this purpose.

8-6.2.3 **High-Pressure Air Cylinders and Flasks.** HP air cylinders and flasks are vessels designed to hold air at pressures over 600 psi. Convenient and satisfactory diving air supply systems can be provided by using a number of these HP air cylinders or flasks. Any HP vessel to be used as a diving air supply unit must bear appropriate Department of Transportation (DOT) or military symbols certifying that the cylinders or flasks meet high-pressure requirements.

A complete air supply system includes the necessary piping and manifolds, HP filter, pressure reducing valve, and a volume tank. An HP gauge must be located ahead of the reducing valve and an LP gauge must be connected to the volume tank.

In using this type of system, one section must be kept in reserve. The divers take air from the volume tank in which the pressure is regulated to conform to the air supply requirements of the dive. The duration of the dive is limited to the length of time the banks can provide air before being depleted to 200 psi over minimum manifold pressure. This minimum pressure of 200 psi must remain in each flask or cylinder.

As in scuba operations, the quantity of air that can be supplied by a system using cylinders or flasks is determined by the initial capacity of the cylinders or flasks and the depth of the dive. The duration of the air supply must be calculated in advance and must include a provision for decompression.

Sample calculations for dive duration, based on bank air supply, are presented in Sample Problem 1 in paragraph 8-2.2.3 for the MK 21 MOD 1. The sample problems in this chapter do not take the secondary air system requirements into account. The secondary air system must be able to provide air in the event of failure of the primary system per *U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual*, SS521-AA-MAN-010. In the MK 21 sample problem (Sample Problem 2), this would mean decompressing three divers with a 30-minute bottom time using 1.4 acfm per diver. An additional requirement must be considered if the same air system is to support a recompression chamber. Refer to Chapter 22 for information on the additional capacity required to support a recompression chamber.

8-6.2.4 **Shipboard Air Systems.** Many Navy ships have permanently installed shipboard air supply systems that provide either LP or HP air. These systems are used in support of diving operations provided they meet the fundamental requirements of purity, capacity, and pressure.

In operation, a volume source (such as a diesel or electrically driven compressor) pumps air into a volume tank. The compressor automatically keeps the tank full as long as the amount of air being used by the diver does not exceed the capacity of the compressor. The ability of a given unit to support a diving operation may be determined from the capacity of the system.

8-7 DIVER COMMUNICATIONS

The surface-supplied diver has two means of communicating with the surface, depending on the type of equipment used. If the diver is using the MK 21 MOD 1, or the MK 20 MOD 0, both voice communications and line-pull signals are available. Voice communications are used as the primary means of communication. Line-pull signals are used only as a backup. Diver-to-diver communications are available through topside intercom, diver-to-diver hand signals or slate boards.

8-7.1 Diver Intercommunication Systems. The major components of the intercommunication system include the diver's earphones and microphone, the communication cable to each diver, the surface control unit, and the tender's speaker and microphone. The system is equipped with an external power cord and can accept 115 VAC or 12 VDC. The internal battery is used for backup power requirements. It should not be used as the primary power source unless an external power source is not available.

The intercom system is operated by a designated phone talker at the diving station. The phone talker monitors voice communications and keeps an accurate log of significant messages. All persons using the intercom system should lower the pitch of their voices and speak slowly and distinctly. The conversation should be kept brief and simple, using standard diving terminology. Divers must repeat verbatim all directions and orders received from topside.

The approved Navy diver communication system is compatible with the MK 21 MOD 1 and the MK 20 MOD 0. This is a surface/underwater system that allows conference communications between the tender and up to three divers. It incorporates voice correction circuitry that compensates for the distortion caused by divers speaking in a helium-oxygen atmosphere.

The divers' voices are continuously monitored on the surface. All communications controls are located at the surface. The topside supervisor speaks with any or all of the divers by exercising the controls on the front panel. It is necessary for a phone talker to monitor and control the underwater communications system at all times.

8-7.2 **Line-Pull Signals.** A line-pull signal consists of one pull or a series of sharp, distinct pulls on the umbilical that are strong enough to be felt by the diver (Figure 8-11). All slack must be taken out of the umbilical before the signal is given.

The line-pull signal code (Table 8-2) has been established through many years of experience. Standard signals are applicable to all diving operations; special signals may be arranged between the divers and Diving Supervisor to meet particular mission requirements. Most signals are acknowledged as soon as they are received. This acknowledgment consists of replying with the same signal. If a signal is not properly returned by the diver, the surface signal is sent again. A continued absence of confirmation is assumed to mean one of three things: the line has become fouled, there is too much slack in the line, or the diver is in trouble.

If communications are lost, the Diving Supervisor must be notified immediately and steps taken to identify the problem. The situation is treated as an emergency (see paragraph 6-12.5.3.2).

There are three line-pull signals that are not answered immediately. Two of these, from diver to tender, are "Haul me up" and "Haul me up immediately." Acknowledgment consists of initiation of the action. The other signal, from the tender to diver, is "Come up." This signal is not acknowledged until the diver is ready to leave the bottom. If for some reason the diver cannot respond to the order, the diver must communicate the reason via the voice intercom system or through the line-pull signal meaning "I understand," followed (if necessary) by an appropriate emergency signal.

Figure 8-11. Communicating with Line-Pull Signals.

Table 8-2. *Line-Pull Signals.*

From Tender to Diver		**Searching Signals (Without Circling Line)**	
1 Pull	“Are you all right?” When diver is descending, one pull means “Stop.”	7 Pulls	“Go on (or off) searching signals.”
2 Pulls	“Going Down.” During ascent, two pulls mean “You have come up too far; go back down until we stop you.”	1 Pull	“Stop and search where you are.”
3 Pulls	“Stand by to come up.”	2 Pulls	“Move directly away from the tender if given slack; move toward the tender if strain is taken on the life line.”
4 Pulls	“Come up.”	3 Pulls	“Face your umbilical, take a strain, move right.”
2-1 Pulls	“I understand” or “Talk to me.”	4 Pulls	“Face your umbilical, take a strain, move left.”
3-2 Pulls	“Ventilate.”		
4-3 Pulls	“Circulate.”		
From Diver to Tender		**Searching Signals (With Circling Line)**	
1 Pull	“I am all right.” When descending, one pull means “Stop” or “I am on the bottom.”	7 Pulls	Same
2 Pulls	“Lower” or “Give me slack.”	1 Pull	Same
3 Pulls	“Take up my slack.”	2 Pulls	“Move away from the weight.”
4 Pulls	“Haul me up.”	3 Pulls	“Face the weight and go right.”
2-1 Pulls	“I understand” or “Talk to me.”	4 Pulls	“Face the weight and go left.”
3-2 Pulls	“More air.”		
4-3 Pulls	“Less air.”		
Special Signals From the Diver		**Emergency Signals From the Diver**	
1-2-3 Pulls	“Send me a square mark.”	2-2-2 Pulls	“I am fouled and need the assistance of another diver.”
5 Pulls	“Send me a line.”	3-3-3 Pulls	“I am fouled but can clear myself.”
2-1-2 Pulls	“Send me a slate.”	4-4-4 Pulls	“Haul me up immediately.”
ALL EMERGENCY SIGNALS SHALL BE ANSWERED AS GIVEN EXCEPT 4-4-4			

A special group of searching signals is used by the tender to direct a diver in moving along the bottom. These signals are duplicates of standard line-pull signals, but their use is indicated by an initial seven-pull signal to the diver that instructs the diver to interpret succeeding signals as searching signals. When the tender wants to revert to standard signals, another seven-pull signal is sent to the diver which means searching signals are no longer in use. Only the tender uses searching signals; all signals initiated by the diver are standard signals. To be properly oriented for using searching signals, the diver must face the line (either the lifeline or the descent line, if a circling line is being employed).

8-8 PREDIVE PROCEDURES

The predive activities for a surface-supplied diving operation involve many people and include inspecting and assembling the equipment, activating the air supply systems, and dressing the divers.

8-8.1 **Predive Checklist.** A comprehensive predive checklist is developed to suit the requirements of the diving unit and of the particular operation. This is in addition to the general Diver Safety and Planning Checklist (Figure 6-19a) and suggested Predive Checklist (Figure 6-21a).

8-8.2 **Diving Station Preparation.** The diving station is neatly organized with all diving and support equipment placed in an assigned location. Deck space must not be cluttered with gear; items that could be damaged are placed out of the way (preferably off the deck). A standard layout pattern should be established and followed.

8-8.3 **Air Supply Preparation.** The primary and secondary air supply systems are checked to ensure that adequate air is available. Air compressors of the divers' air system are started and checked for proper operation. The pressure in the accumulator tanks is checked. If HP air cylinders are being used, the manifold pressure is checked. If a compressor is being used as a secondary air supply, it is started and kept running throughout the dive. The air supply must meet purity standards (see paragraph 8-6.1.1).

8-8.4 **Line Preparation.** Depth soundings are taken and descent line, stage, stage lines, and connections are checked, with decompression stops properly marked.

8-8.5 **Recompression Chamber Inspection and Preparation.** If available, the recompression chamber is inspected and all necessary equipment and a copy of appropriate recompression treatment tables are placed on hand at the chamber. Two stop watches and the decompression tables are also required. Adequate air supply for immediate pressurization of the chamber is verified and the oxygen supply system is charged and made ready for operation in accordance with Chapter 22.

8-8.6 **Predive Inspection.** When the Diving Supervisor is satisfied that all equipment is on station and in good operating condition, the next step is to dress the divers.

8-8.7 **Donning Gear.** Dressing the divers is the responsibility of the tender.

8-8.8 **Diving Supervisor Predive Checklist.** The Diving Supervisor must always use a predive checklist prior to putting divers in the water. This checklist must be tailored by the unit to the specific equipment and systems being used. Chapter 6 contains typical predive checklists for surface-supplied equipment. Refer to the appropriate operations and maintenance manual for detailed checklists for specific equipment.

8-9 WATER ENTRY AND DESCENT

Once the predive procedures have been completed, the divers are ready to enter the water. There are several ways to enter the water, with the choice usually determined by the nature of the diving platform. Regardless of the method of entry, the divers should look before entering the water. Three methods for entering the water are the:

- Ladder method
- Stage method
- Step-in method

8-9.1 **Predescent Surface Check.** In the water and prior to descending to operating depth, the diver makes a final equipment check.

- The diver immediately checks for leaks in the suit or air connections.
- If two divers are being employed, both divers perform as many checks as possible on their own rigs and then check their dive partner's rig. The tender or another diver can be of assistance by looking for any telltale bubbles.
- A communications check is made and malfunctions or deficiencies not previously noted are reported at this time.

When satisfied that the divers are ready in all respects to begin the dive, they notify the Diving Supervisor and the tenders move the divers to the descent line. When in position for descent, the diver adjusts for negative buoyancy and signals readiness to the Diving Supervisor.

8-9.2 **Descent.** Descent may be accomplished with the aid of a descent line or stage. Topside personnel must ensure that air is being supplied to the diver in sufficient quantity and at a pressure sufficient to offset the effect of the steadily increasing water pressure. The air pressure must also include an overbottom pressure allowance to protect the diver against a serious squeeze if he or she falls.

While descending, the diver adjusts the air supply so that breathing is easy and comfortable. The diver continues to equalize the pressure in the ears as necessary during descent and must be on guard for any pain in the ears or sinuses, or any other warning signals of possible danger. If any such indications are noted, the descent is halted. The difficulty may be resolved by ascending a few feet to regain a pressure balance; if this is not effective, the diver is returned to the surface.

Some specific guidelines for descent are as follows:

- With a descent line, the diver locks the legs around the line and holds on to the line with one hand.
- In a current or tideway, the diver descends with back to the flow in order to be held against the line and not be pulled away. If the current measures more than

1.5 knots, the diver wears additional weights or descends on a weighted stage, so that descent is as nearly vertical as possible.

- When the stage is used for descent, it is lowered with the aid of a winch and guided to the site by a shackle around the descent line. The diver stands in the center of the stage, maintaining balance by holding on to the side bails. Upon reaching the bottom, the diver exits the stage as directed by the Diving Supervisor.

- The maximum allowable rate of descent, by any method, shall not exceed 75 feet per minute (fpm), although such factors as the diver's ability to clear the ears, currents and visibility and the need to approach an unknown bottom with caution may render the actual rate of descent considerably less.

- The diver signals arrival on the bottom and quickly checks bottom conditions. Conditions that are radically different than expected are reported to the Diving Supervisor. If there is any doubt about the safety of the diver or the diver's readiness to operate under the changed conditions, the dive is aborted.

- A diver should thoroughly ventilate when reaching the bottom, at subsequent intervals as the diver feels necessary and as directed from the surface. On dives deeper than 100 fsw, the diver may not notice the CO_2 warning symptoms because of nitrogen narcosis. It is imperative that the Diving Supervisor monitors his or her divers' ventilation.

8-10 UNDERWATER PROCEDURES

8-10.1 Adapting to Underwater Conditions. Through careful and thorough planning, the divers can be properly prepared for the underwater conditions at the diving site. The diver will employ the following techniques to adapt to underwater conditions:

- Upon reaching the bottom and before leaving the area of the stage or descent line, the diver adjusts buoyancy and makes certain that the air supply is adequate.

- The diver becomes oriented to the bottom and the work site using such clues as the lead of the umbilical, natural features on the bottom, the direction of current. However, bottom current may differ from the surface current. The direction of current flow may change significantly during the period of the dive. If the diver has any trouble in orientation, the tender can guide the diver by using the line-pull searching signals.

The diver is now ready to move to the work site and begin the assignment.

8-10.2 Movement on the Bottom. Divers should follow these guidelines for movement on the bottom areas:

- Before leaving the descent line or stage, ensure that the umbilical is not fouled.
- Loop one turn of the lifeline and air hose over an arm; this acts as a buffer against a sudden surge or pull on the lines.
- Proceed slowly and cautiously to increase safety and to conserve energy.
- If obstructions are encountered, adjust buoyancy to pass over the obstruction (not under or around). If you pass around an obstruction, you must return by the same side to avoid fouling lines.
- When using buoyancy adjustments to aid in movement, avoid bouncing along the bottom; all diver movements are controlled.
- If the current is strong, stoop or crawl to reduce body area exposed to the current. Adjust the inflation of the dress to compensate for any change in depth, even if the change is only a few feet.
- When moving on a rocky or coral bottom, make sure lines do not become fouled on outcroppings, guarding against tripping and getting feet caught in crevices. Watch for sharp projections that can cut hoses, diving dress or unprotected hands. The tender is particularly careful to take up any slack in the diver's umbilical to avoid fouling.
- Guard against slipping and falling on gravel bottoms, especially on slopes.
- Avoid unnecessary movements that stir up the bottom and impair visibility.

CAUTION **Avoid overinflation and be aware of the possibility of blowup when breaking loose from mud. It is better to call for aid from the standby diver than to risk blowup.**

- Mud and silt may not be solid enough to support your weight. Many hours may be spent working under mud without unreasonable risk. The primary hazard with mud bottoms comes from the concealment of obstacles and dangerous debris.

8-10.3 **Searching on the Bottom.** If appropriate electronic searching equipment is not available, it may be necessary to use unaided divers to conduct the search. Procedures for searching on the bottom with unaided divers are:

1. A diver search of the bottom can be accomplished with a circling line, using the descent line as the base point of the search. The first sweep is made with the circling line held taut at a point determined by the range of visibility. If possible, the descent line should be in sight or, if visibility is limited, within reach. The starting point is established by a marker, a line orientation with the current or the light, signals from topside, or a wrist compass. After a full 360-degree sweep has been made, the diver moves out along the circling line

another increment (roughly double the first) and makes a second sweep in the opposite direction to avoid twisting or fouling the lifeline and air hose.

2. If the object is not found when the end of the circling line has been reached, the base point (the descent line) is shifted. Each base point in succession should be marked by a buoy to avoid unnecessary duplication in the search. If the search becomes widespread, many of the marker buoys can be removed, leaving only those marking the outer limits of the area.

3. If the diver is unable to make a full circle around the descent line because of excessive current or obstructions, the search patterns are adjusted accordingly.

4. A linear search pattern (Jack-Stay) can be established by laying two large buoys and setting a line between them. A diving launch, with a diver on the bottom, can follow along the line from buoy to buoy, coordinating progress with the diver who is searching to each side of the established base line. These buoys may be readjusted to enlarge search areas.

5. Once the object of a search is located, it is marked. The diver can secure the circling line to the object as an interim measure, while waiting for a float line to be sent down.

8-10.4 Enclosed Space Diving. Divers are often required to work in enclosed or confined spaces. Enclosed space diving shall be supported by a surface-supplied air system (MK 20 MOD 0 and MK 21 MOD 1).

8-10.4.1 **Enclosed Space Hazards.** The interior of sunken ships, barges, submarine ballast tanks, mud tanks, sonar domes, and cofferdams is hazardous due to limited access, poor visibility, and slippery surfaces. Enclosed spaces may be dry or flooded, and dry spaces may contain a contaminated atmosphere.

NOTE When a diver is working in an enclosed or confined space, the Diving Supervisor shall have the diver tended by another diver at the access opening. Ultimately, the number of tending divers deployed depends on the situation and the good judgement of the Diving Officer, Master Diver, or Diving Supervisor on the site.

8-10.4.2 **Enclosed Space Safety Precautions.** Because of the hazards involved in enclosed space operations, divers must rigorously adhere to the following warnings.

WARNING During enclosed space diving, all divers shall be outfitted with 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.

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.

WARNING **If the diving equipment should fail, the diver shall immediately switch to the EGS and abort the dive.**

8-10.5 **Working Around Corners.** When working around corners where the umbilical is likely to become fouled or line-pull signals may be dissipated, a second diver (tending diver) may be sent down to tend the lines of the first diver at the obstruction and to pass along any line-pull signals. Line-pull signals are used when audio communications are lost, and are passed on the first diver's lines; the tending diver uses his own lines only for signals directly pertaining to his own situation.

8-10.6 **Working Inside a Wreck.** When working inside a wreck, the same procedure of deploying tending divers is followed. This technique applies to the tending divers as well: every diver who penetrates a deck level has another tending diver at that level, or levels, above. Ultimately, the number of tending divers deployed depends on the situation and the good judgment of the Diving Officer, Master Diver, or Diving Supervisor on the site. Obviously, an operation requiring penetration through multiple deck levels requires detailed advanced planning in order to provide for the proper support of the number of divers required. MK 21 MOD 1 and MK 20 MOD 0 are the only equipment approved for working inside a wreck. The diver enters a wreck feet first and never uses force to gain entry through an opening.

8-10.7 **Working With or Near Lines or Moorings.** When working with or near lines or moorings, observe the following rules:

- Stay away from lines under strain.
- Avoid passing under lines or moorings if at all possible; avoid brushing against lines or moorings that have become encrusted with barnacles.
- If a line or mooring is to be shifted, the diver is brought to the surface and, if not removed from the water, moved to a position well clear of any hazard.
- If a diver must work with several lines (messengers, float lines, lifting lines, etc.) each should be distinct in character (size or material) or marking (color codes, tags, wrapping).
- Never cut a line unless the line is positively identified.
- When preparing to lift heavy weights from the bottom, the lines selected must be strong enough and the surface platform must be positioned directly over the object to be raised. Prior to the lift, make sure the diver is clear of the lift area or leaves the water.

8-10.8 **Bottom Checks.** Bottom checks are conducted after returning to the stage or descent line and prior to ascent. The checks are basically the same for each rig.

1. Ensure all tools are ready for ascent.

2. Check that all umbilicals and lines are clear for ascent.

3. Assess and report your condition (level of fatigue, remaining strength, physical aches or pains, etc.) and mental acuity.

8-10.9 **Job Site Procedures.** The range of diving jobs is wide and varied. Many jobs follow detailed work procedures and require specific predive training to ensure familiarity with the work. The *U.S. Navy Underwater Work Techniques Manual*, Volumes 1 and 2, NAVSEA 0994-LP-007-8010 and NAVSEA 0994-LP-007-8020, presents guidance for most commonly encountered jobs, such as clearing fouled propellers, patching collision damage, replacing underwater valves or fittings, preparing for salvage of sunken vessels, and recovering heavy objects from the bottom.

8-10.9.1 **Underwater Ship Husbandry Procedures.** With the advent of more highly technical underwater work procedures, the *Underwater Ship Husbandry Manual*, S0600-AA-PRO-010, was published. Like the *Naval Ships Technical Manual* (NSTM), the manual is published in separately bound chapters, each dealing with a separate area of underwater work. Chapter 1 of the manual (S0600-AA-PRO-010) is the Index and User Guide, which provides information on the subsequent chapters of the manual.

8-10.9.2 **Working with Tools.** Underwater work requires appropriate tools and materials, such as cement, foam plastic, and patching compounds. Many of these are standard hand tools (preferably corrosion-resistant) and materials; others are specially designed for underwater work. A qualified diver will become familiar with the particular considerations involved in working with these various tools and materials in an underwater environment. Hands-on training experience is the only way to get the necessary skills. Consult the appropriate operations and maintenance manuals for the use techniques of specific underwater tools. In working with tools the following basic rules always apply:

- Never use a tool that is not in good repair. If a cutting tool becomes dulled, return it to the surface for sharpening.

- Do not overburden the worksite with unnecessary tools, but have all tools that may be needed readily available.

- Tools are secured to the diving stage by lanyard, carried in a tool bag looped over the diver's arm, or lowered on the descent line using a riding shackle and a light line for lowering. Prior to ascent or descent, secure power to all tools. Attach lanyards to all tools, connectors, shackles and shackle pins.

- Using the diving stage as a worksite permits organization of tools while providing for security against loss. The stage also gives the diver leverage and stability when applying force (as to a wrench), or when working with a power tool that transmits a force back through the diver.

- Tying a hogging line to the work also gives the diver leverage while keeping him close to his task without continually having to fight a current.

8-10.10 Safety Procedures. The best safety factors are a positive, confident attitude about diving and careful advance planning for emergencies. A diver in trouble underwater should relax, avoid panic, communicate the problem to the surface and carefully think through the possible solutions to the situation. Topside support personnel should implement emergency job-site procedures as indicated in Chapter 6. In all situations, the Diving Supervisor should ensure that common sense and good seamanship prevail to safely resolve each emergency.

Emergency procedures are covered specifically for each equipment in its appropriate operations and maintenance manual and in general in Chapter 6. However, there are a number of situations a diver is likely to encounter in the normal range of activity which, if not promptly solved, can lead to full-scale emergencies. These situations and the appropriate action to be taken follow.

8-10.10.1 **Fouled Umbilical Lines.** As soon as a diver discovers that the umbilical has become fouled, the diver must stop and examine the situation. Pulling or tugging without a plan may only serve to complicate the problem and could lead to a severed hose. The Diving Supervisor is notified if possible (the fouling may prevent transmission of line-pull signals). If the lines are fouled on an obstruction, retracing steps should free them. If the lines cannot be cleared quickly and easily, the standby diver is sent down to assist. The standby diver is sent down as normal procedure, should communications be interrupted and the tender be unable to haul the diver up. The standby diver, using the first diver's umbilical (as a descent line), should be able to trace and release the lines. If it is impossible to free the first diver, the standby diver should signal for a replacement umbilical.

8-10.10.2 **Fouled Descent Lines.** If the diver becomes fouled with the descent line and cannot be easily cleared, it is necessary to haul the diver and the line to the surface, or to cut the weight free of the line and attempt to pull it free from topside. If the descent line is secured to an object or if the weight is too heavy, the diver may have to cut the line before being hauled up. For this reason, a diver should not descend on a line that cannot be cut.

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

8-10.10.3 **Falling.** When working at mid-depth in the water column, the diver should keep a hand on the stage or rigging to avoid falling. The diver avoids putting an arm overhead in a dry suit; air leakage around the edges of the cuffs may change the suit buoyancy and increase the possibility of a fall in the water column.

8-10.10.4 **Damage to Helmet and Diving Dress.** If a leak occurs in the helmet, the diver's head is lowered and the air pressure slightly increased to prevent water leakage. A leak in the diving suit only requires remaining in an upright position; water in the suit does not directly endanger breathing.

8-10.11 Tending the Diver. Procedures for tending the diver follow.

1. Before the dive, the tender carefully checks the diving dress with particular attention to the nonreturn valve, air control valve, helmet locking device, intercom system, helmet seal and harness.

2. When the diver is ready, the tenders dress and assist the diver to the stage or ladder or waters edge, always keeping a hand on the umbilical.

3. The primary tender and a backup tender as required are always on station to assist the diver. As the diver enters the water, the tenders handle the umbilical, using care to avoid sharp edges. The umbilical must never be allowed to run free or be belayed around a cleat or set of bitts. Pay out of the umbilical is at a steady rate to permit the diver to descend smoothly. If a stage is being used, the descent rate is coordinated with the winch operator or line handlers.

4. Throughout the dive the tender keeps slack out of the line while not holding it too tautly. Two or three feet of slack permits the diver freedom of movement and prevents the diver from being pulled off the bottom by surging of the support craft or the force of current acting on the line. The tender occasionally checks the umbilical to ensure that movement by the diver has not resulted in excessive slack. Excessive slack makes signaling difficult, hinders the tender from catching the diver if falling and increases the possibility of fouling the umbilical.

5. The tender monitors the umbilical by feel and the descent line by sight for any line-pull signals from the diver. If an intercom is not being used, or if the diver is silent, the tender periodically verifies the diver's condition by line-pull signal. If the diver does not answer, the signal is repeated; if still not answered, the Diving Supervisor is notified. If communications are lost, the situation is treated as an emergency (see paragraph 6-12.5.3.2 for loss-of-communication procedures).

8-10.12 Monitoring the Diver's Movements. The Diving Supervisor and designated members of the dive team constantly monitor the diver's progress and keep track of his relative position.

- **Supervisor Actions**.

  1. Follow the bubble trail, while considering current(s). If the diver is searching the bottom, bubbles move in a regular pattern. If the diver is working in place, bubbles do not shift position. If the diver has fallen, the bubbles may move rapidly off in a straight line.

2. Monitor the pneumofathometer pressure gauge to keep track of operating depth. If the diver remains at a constant depth or rises, the gauge provides a direct reading, without the need to add air. If the diver descends, the hose must be cleared and a new reading made.

- **Tender Actions**. Feel the pull of the umbilical.

- **Additional Personnel Actions**. Monitor the gauges on the supply systems for any powered equipment. For example, the ammeter on an electric welding unit indicates a power drain when the arc is in use; the gas pressure gauges for a gas torch registers the flow of fuel. Additionally, the pop made by a gas torch being lighted will probably be audible over the intercom and bubbles from the torch will break on the surface, giving off small quantities of smoke.

8-11 ASCENT PROCEDURES

Follow these ascent procedures when it is time for the divers to return to the surface:

1. To prepare for a normal ascent, the diver clears the job site of tools and equipment. These can be returned to the surface by special messenger lines sent down the descent line. If the diver cannot find the descent line and needs a special line, this can be bent onto his umbilical and pulled down by the diver. The diver must be careful not to foul the line as it is laid down. The tender then pulls up the slack. This technique is useful in shallow water, but not practical in deep dives.

2. If possible, the diving stage is positioned on the bottom. If some malfunction such as fouling of the descent line prevents lowering the stage to the bottom, the stage should be positioned below the first decompression stop if possible. Readings from the pneumofathometer are the primary depth measurements.

3. If ascent is being made using the descent line or the stage has been positioned below the first decompression stop, the tender signals the diver “Standby to come up” when all tools and extra lines have been cleared away. The diver acknowledges the signal. The diver, however, does not pull up. The tender lifts the diver off the bottom when the diver signals “Ready to come up,” and the tender signals “Coming up. Report when you leave the bottom.” The diver so reports.

4. If, during the ascent, while using a descent line, the diver becomes too buoyant and rises too quickly, the diver checks the ascent by clamping his legs on the descent line.

5. The rate of ascent is a critical factor in decompressing the diver. Ascent must be carefully controlled at 30 feet per minute by the tender. The ascent is monitored with the pneumofathometer. As the diver reaches the stage and climbs aboard, topside is notified of arrival. The stage is then brought up to the

first decompression stop. Refer to Chapter 9 for decompression procedures, including an explanation of the tables.

6. While ascending and during the decompression stops, the diver must be satisfied that no symptoms of physical problems have developed. If the diver feels any pain, dizziness, or numbness, the diver immediately notifies topside. During this often lengthy period of ascent, the diver also checks to ensure that his umbilical is not becoming fouled on the stage line, the descent line, or by any steadying weights hanging from the stage platform.

7. Upon arrival at the surface, topside personnel, timing the movement as dictated by any surface wave action, coordinate bringing the stage and umbilical up and over the side.

8. If the diver exits the water via the ladder, the tenders provide assistance. The diver will be tired, and a fall back into the water could result in serious injury. Under no conditions is any of the diver's gear to be removed before the diver is firmly on deck.

8-12 SURFACE DECOMPRESSION

8-12.1 Disadvantages of In-Water Decompression. Decompression in the water column is time consuming, uncomfortable, and inhibits the ability of the support vessel to get underway. Delay could also present other problems for the support vessel: weather, threatened enemy action or operating schedule constraints. In-water decompression delays medical treatment, when needed, and increases the possibility of severe chilling and accident. For these reasons, decompression is often accomplished in a recompression chamber on the support ship (Figure 8-12). Refer to Chapter 9 for surface decompression procedures.

8-12.2 Transferring a Diver to the Chamber. When transferring a diver from the water to the chamber, the tenders are allowed no more than 3½ minutes to undress the diver. A tender or diving medical personnel, as required by the nature of the dive or the condition of the diver, must be in the chamber with any necessary supplies prior to arrival of the diver. The time factor is critical and delays cannot be tolerated. Undressing a diver for surface decompression should be practiced until a smooth, coordinated procedure is developed.

8-13 POSTDIVE PROCEDURES

Postdive procedures are planned in advance to ensure personnel are carefully examined for any possible injury or adverse effects and equipment is inspected, maintained and stowed in good order.

8-13.1 Personnel and Reporting. Immediate postdive activities include any required medical treatment for the diver and the recording of mandatory reports.

- Medical treatment is administered for cuts or abrasions. The general condition of the diver is monitored until problems are unlikely to develop. The Diving

Figure 8-12. Surface Decompression.

Supervisor resets the stopwatch after the diver reaches the surface and remains alert for irregularities in the diver's actions or mental state. The diver must remain within 30 minutes' travel time of the diving unit for at least 2 hours after surfacing.

- Mandatory records and reports are covered in Chapter 5. Certain information is logged as soon as the diving operations are completed, while other record keeping is scheduled when convenient. The Diving Supervisor is responsible for the diving log, which is kept as a running account of the dive. The diver is responsible for making appropriate entries in the personal diving record. Other personnel, as assigned, are responsible for maintaining equipment usage logs.

8-13.2 **Equipment.** A postdive checklist, tailored to the equipment used, is followed to ensure equipment receives proper maintenance prior to storage. Postdive maintenance procedures are contained in the equipment operation and maintenance manual and the planned maintenance system package.