

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	Overbottom Pressure (Minimum)	Gas Consumption (Normal)	Gas Consumption (Heavy Work)
MK 21 MOD 0 UBA	165 psi	1.4 acfm (demand)	2.5 acfm (demand)
MK 21 MOD 1 UBA		6.0 acfm (free flow)	6.0 acfm (free flow)
MK 22 MOD 0 UBA	165 psi	1.4 acfm (demand) 6.0 acfm (free flow)	2.5 acfm (demand) 6.0 acfm (free flow)

13-3 SELECT DIVING METHOD AND EQUIPMENT

Selecting the appropriate diving method is essential to any diving operations planning. The method will dictate many aspects of an operation including personnel and equipment.

13-3.1 Mixed-Gas Diving Methods. Mixed-gas diving methods are defined by the type of mixed-gas diving equipment that will be used. The three types of mixed-gas diving equipment are:

- Surface-supplied gear (MK 21 MOD 1)
- Semiclosed-circuit and closed-circuit UBAs
- Saturation deep dive systems

For deep dives (190-300 fsw) of short duration, or for shallower dives where nitrogen narcosis reduces mental acuity and physical dexterity, helium-oxygen diving methods should be employed.

Because of the unusual hazards incurred by long exposures to extreme environmental conditions, extended excursions away from topside support, and great decompression obligations, semiclosed-circuit and closed-circuit diving should only be undertaken by specially trained divers. Semiclosed-circuit and closed-circuit diving operations are covered in depth in Volume 4.

Saturation diving is the preferred method for dives deeper than 300 fsw or for shallow dives where extensive in-water times are required. Disadvantages of saturation diving include the requirement for extensive logistic support and the inability of the support ship to easily shift position once the mooring is set. For this reason, it is very important that the ship be moored as closely over the work site as possible. Using side-scan sonar, remotely operated vehicles (ROVs) or precision navigation systems will greatly aid in the successful completion of the operation. Saturation diving is discussed in Chapter 15.

13-3.2 Method Considerations. In mixed-gas diving, the principle factors influencing the choice of a particular method are:

- Depth and planned duration of the dive
- Equipment availability
- Quantities of gas mixtures available
- Qualifications and number of personnel available
- Type of work and degree of mobility required
- Environmental considerations such as temperature, visibility, type of bottom, current, and pollution levels
- Communication requirements
- Need for special operations procedures

13-3.3 Depth. Equipment depth limitations are contained in Table 13-2. The limitations are based on a number of interrelated factors such as decompression obligations,

duration of gas supply and carbon dioxide absorbent material, oxygen tolerance, and the possibility of nitrogen narcosis when using emergency gas (air). Divers must be prepared to work at low temperatures and for long periods of time.

Table 13-2. Equipment Operational Characteristics.

Diving Equipment	Normal Working Limit (fsw)	Maximum Working Limit (fsw)	Chamber Requirement	Minimum Personnel
MK 21 MOD 1 UBA	300 (HeO ₂) (Note 1)	380 (HeO ₂) (Note 1)	On station (Note 2)	12
MK 21 MOD 0 UBA MK 22 MOD 0 UBA	950	950	Part of system	21 (7 per watch)

Notes:

1. Depth limits are based on considerations of working time, decompression obligation, oxygen tolerance and nitrogen narcosis. 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. An on-station chamber is defined as a certified and ready chamber at the dive site.

Operations deeper than 300 fsw usually require Deep Diving Systems (DDSs). The decompression obligation upon the diver is of such length that in-water decompression is impractical. Using a personnel transfer capsule (PTC) to transport divers to a deck decompression chamber (DDC) increases the margin of diver safety and support-ship flexibility.

13-3.4 Bottom Time Requirements. The nature of the operation may influence the bottom time requirements of the diver. An underwater search may be best undertaken by using multiple divers with short bottom times or by conducting a single bounce dive simply to identify a submerged object. Other tasks, such as underwater construction work, may require numerous dives with long bottom times requiring surface-supplied or saturation diving techniques. Although primarily intended to support deep diving operations, saturation diving systems may be ideal to support missions as shallow as 150 fsw where the nature of the work is best accomplished using several dives with extended bottom times. Under these conditions, time is saved by eliminating in-water decompression obligations for each diver and by reducing the number of dive team changes, thus compensating for the increased logistical complexity such operations entail.

13-3.5 Environment. Environmental conditions play an important role in planning mixed-gas diving operations. Environmental factors, such as those addressed in Chapter 6, should be considered when planning such operations. Mixed-gas diving operations often involve prolonged dives requiring lengthy decompression and travels that carry divers great distances from a safe haven. Special attention should therefore be given to preventing diver hypothermia. Mixed-gas diving apparatus are designed to minimize thermal stress, but the deepest, longest helium-oxygen dives place the greatest stress on the diver. Exposure to extreme surface conditions prior to the dive may leave the diver in a thermally compromised state. A diver

who has been exposed to adverse environmental conditions should not be considered for mixed-gas diving until complete rewarming of the diver has taken place, as shown by sweating, normal pulse, and return of normal core temperature. Subjective thermal comfort does not accurately indicate adequate rewarming.

- 13-3.6** **Mobility.** Some diving operations may dictate the use of a diving method that is selected as a result of special mobility requirements in addition to depth, bottom time and logistical requirements. The MK 21 MOD 1 is the preferred method when operations require mobility in the water column (see Figure 13-1).



Figure 13-1. Searching Through Aircraft Debris on the Ocean Floor.

For missions where mobility is an essential operating element and depth and bottom time requirements are great, closed-circuit diving may be the only available option. Such diving is frequently required by special warfare and/or explosive ordnance disposal (EOD) personnel.

- 13-3.7** **Equipment Selection.** Equipment and supplies available for mixed-gas diving operations by U.S. Navy personnel have been tested under stringent conditions to ensure that they will perform according to design specifications under the most difficult conditions that may be encountered. Several types of equipment are available for mixed-gas operations. Equipment selection is based upon the chosen diving method, depth of the dive and the operation to be performed. Table 13-3 outlines the differences between equipment configurations.

Table 13-3. Mixed-Gas Diving Equipment.

Type	Principal Applications	Minimum Personnel	Advantages	Disadvantages	Restrictions and Depth Limits
MK 21 MOD 1 (Notes 1 & 3)	Deep search, inspection and repair.	12 (Note 3)	Horizontal mobility. Voice communications.	Support craft required. High rate of gas consumption.	Normal 300 fsw. Maximum: 380 fsw with CNO authorization.
MK 21 MOD 0 (Note 2)	Saturation diving search, salvage, and repair. Extensive bottom time.	21 (7 per watch) (Note 4)	Maximum diver safety. Bottom time efficiency. Maximum comfort. Continuous personnel monitoring.	Slow deployment. Large support craft and crew. Limited mobility. High rate of gas consumption.	Varies with DDS certification
MK 22 MOD 0 (Note 2)	Standby diver for PTC.	21 (7 per watch) (Note 4)	Collapsible for storage in PTC.	Slow deployment. Large support craft and crew. Limited mobility. High rate of gas consumption.	Varies with DDS certification

Notes:

1. Surface-supplied deep-sea
2. Saturation UBA
3. Minimum personnel consists of topside support and one diver in the water
4. Varies according to manning requirements of deep dive system

The UBA MK 21 MOD 0 is an open circuit, demand-regulated diving helmet designed for saturation, mixed-gas diving at depths in excess of 300 fsw and as deep as 950 fsw. With the exception of the demand regulator, it is functionally identical to the UBA MK 21 MOD 1, which is used for air and mixed-gas diving. The regulator for the MK 21 MOD 0 helmet is the Ultraflow 500, which provides improved breathing resistance and gas flow over the MK 21 MOD 1.

The UBA MK 22 MOD 0 is an open circuit, demand-regulated, band-mask version of the UBA MK 21 MOD 0. It is used for the standby diver for saturation, mixed-gas diving at depths in excess of 300 fsw and as deep as 950 fsw. It is provided with a hood and head harness instead of the helmet shell to present a smaller profile for storage.

13-3.8 Operational Characteristics. Equipment operational characteristics are reviewed in Table 13-2 and specific equipment information can be found in paragraph 13-8.

All diving equipment must be certified or authorized for Navy use. Authorized equipment is listed in the NAVSEA/00C Authorized for Navy Use (ANU) list. For proper operation and maintenance of U.S. Navy approved diving equipment, refer to the appropriate equipment operation and maintenance manual.

13-3.9 Support Equipment and ROVs. In addition to the UBA, support equipment must not be overlooked. Items commonly used include tools, underwater lighting, power sources, and communications systems. The Coordinated Shipboard Allow-

ance List (COSAL) for the diving platform is a reliable source of support equipment. Commercial resources may also be available.

Occasionally, a mission is best undertaken with the aid of a remotely operated vehicle (ROV). ROVs offer greater depth capabilities with less risk to personnel but at the expense of the mobility, maneuverability, and versatility that only manned operations can incorporate.

13-3.9.1 **Types of ROV.** There are two types of ROVs, tethered and untethered. Tethered ROVs receive power, control signals, and data through an umbilical. Untethered ROVs can travel three to five times faster than tethered ROVs, but because their energy source must be contained in the vehicle their endurance is limited. ROVs used in support of diving operations must have ground fault interrupter (GFI) systems installed to protect the divers.

13-3.9.2 **ROV Capabilities.** Currently, much of the Fleet's requirements for observation diving are being met by using ROVs. They have been used for search and salvage since 1966. State-of-the-art ROVs combine short-range search, inspection, and recovery capabilities in a single system. A typical ROV system includes a control and display console, a power source, a launch and retrieval system, and the vehicle itself. Tethered systems are connected to surface support by an umbilical that supplies power, control signals and data. Untethered search systems that will greatly increase current search rates with extended endurance rates of 24 hours or more are currently under development. Figure 13-2 shows a typical NAVSEA ROV.

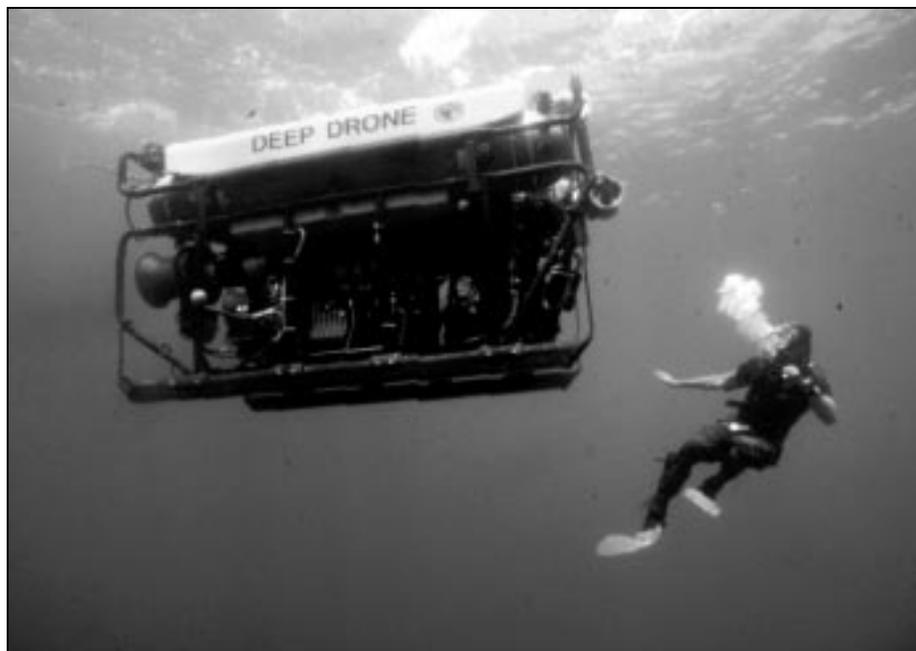


Figure 13-2. Remotely Operated Vehicle (ROV) Deep Drone.

- 13-3.10 Diver's Breathing Gas Requirements.** In air diving, the breathing mixture is readily available, although pump and compressor capacities and the availability of back-up systems may impose operational limitations. The primary requirement for mixed-gas diving is that there be adequate quantities of the appropriate gases on hand, as well as a substantial reserve, for all phases of the operation. The initial determinations become critical if the nearest point of resupply is far removed from the operation site.
- 13-3.10.1 **Gas Consumption Rates.** The gas consumption rates and carbon dioxide absorbent durations for various types of underwater breathing apparatus are shown in Table 13-1. Refer to Chapter 4 for required purity standards.
- 13-3.10.2 **Surface-Supplied Diving Requirements.** For surface-supplied diving, the diver gas supply system is designed so that helium-oxygen, oxygen, or air can be supplied to the divers as required. All surface-supplied mixed-gas diving systems require a primary and secondary source of breathing medium consisting of helium-oxygen and oxygen in cylinder banks and an emergency supply of air from compressors or high-pressure flasks. Each system must be able to support the gas flow and pressure requirements of the specified equipment. The gas capacity of the primary system must meet the consumption rate of the designated number of divers for the duration of the dive. The secondary system must be able to support recovery operations of all divers and equipment if the primary system fails. This may occur immediately prior to completing the planned bottom time at maximum depth when decompression obligations are the greatest. Emergency air supply is provided in the event all mixed-gas supplies are lost.
- 13-3.10.3 **Deep Diving System Requirements.** A deep diving system must be able to store and supply enough gas to support saturation diving to the maximum certified depth. Deep diving systems can handle and store pure gases, and mix the required percentages of helium-oxygen as needed. When DDS-type equipment is employed, additional quantities of gas must be included for DDC and PTC charging and for replacing losses due to leakage, transfer trunk and service lock usage and scrubber cycling. A DDS must also have an air system capable of supporting surface-supplied air diving operations and initial pressurization of the DDS for saturation operations.

13-4 SELECTING AND ASSEMBLING THE DIVE TEAM

Selecting a properly trained team for a particular diving mission is critical. Refer to Chapter 6 for an expanded discussion on dive team selection, as well as the criteria for selecting qualified personnel for various tasks. It is critical to ensure that only formally qualified personnel are assigned. The Diving Officer, Master Diver, and Diving Supervisor must verify the qualification level of each team member. The size and complexity of deep dive systems reinforces the need for a detailed and comprehensive watch station qualification program.

- 13-4.1 **Diver Training.** Training must be given the highest command priority. The command that dives infrequently, or with insufficient training and few work-up dives between operations, will be ill-prepared in the event of an emergency. The

dive team must be exercised on a regular diving schedule using both routine and nonroutine drills to remain proficient not only in the water but on topside support tasks as well. Cross-training ensures that divers are qualified to substitute for one another when circumstances warrant.

13-4.2 Personnel Requirements. To ensure a sufficient number of properly trained and qualified individuals are assigned to the most critical positions on a surface-supplied mixed-gas dive station, the following minimum stations shall be manned by formally trained (NDSTC) mixed-gas divers:

- Diving Officer
- Diving Medical Officer (required on-site for all dives exceeding the normal working limit)
- Master Diver
- Diving Supervisor
- Diving Medical Technician
- Timekeeper/Recorder

All other assignments to a surface-supplied mixed-gas dive station shall be filled in accordance with Table 13-4.

13-4.3 Diver Fatigue. Fatigue will predispose a diver to decompression sickness. A tired diver is not mentally alert. Mixed-gas dives shall not be conducted using a fatigued diver. The command must ensure that all divers making a mixed-gas dive are well rested prior to the dive. All divers making mixed-gas dives must have at least 8 hours of sleep within the last 24 hours before diving.

13-5 BRIEFING THE DIVE TEAM

Large personnel requirements and the increased complexities of mixed-gas diving operations make comprehensive briefings of all personnel extremely important. For mixed-gas surface-supplied operations, briefings of each day's schedule are appropriate. In addition, during saturation diving operations, a dive protocol is required to be read and signed in accordance with the unit's instructions. The briefing should cover all aspects of the operation including communications, equipment, gas supply, and emergencies such as fouling and entrapment. Each diving member should understand his own role as well as that of his diving companions and the support crew (Figure 13-3).

While the operation is in progress, divers returning to the surface or to the PTC should be promptly debriefed. This ensures that topside personnel are kept advised of the progress of the dive and have the information necessary to modify the dive plan or protocol as appropriate.

Table 13-4. Surface-Supplied Mixed-Gas Dive Team

Designation	Deep-Sea (MK 21)	
	One Diver	Two Divers
Diving Officer	1 (Note 1)	1 (Note 1)
Diving Medical Officer	1 (Notes 1 and 4)	1 (Notes 1 and 4)
Diving Supervisor/Master Diver	1 (Notes 1 and 5)	1 (Notes 1 and 5)
Diving Medical Technician	1 (Notes 1 and 6)	1 (Notes 1 and 6)
Diver	1 (Note 2)	2 (Note 2)
Standby Diver	1 (Note 2)	1 (Note 2)
Tender	3 (Note 2)	5 (Note 2)
Timekeeper/Recorder	1 (Note 1)	1 (Note 1)
Rack Operator	1 (Note 2)	1 (Note 2)
Winch Operator	1 (Note 3)	1 (Note 3)
Console Operator	1 (Note 2)	1 (Note 2)
Total Personnel Required	12	15

Notes:

1. To ensure sufficient properly trained and qualified individuals are assigned to the most critical positions on a surface-supplied mixed-gas dive station, the following minimum stations shall be manned by formally trained (NDSTC) mixed-gas divers:

- Diving Officer
- Diving Medical Officer
- Master Diver
- Diving Supervisor
- Diving Medical Technician
- Time Keeper - Recorder

2. The following stations shall be manned by formally trained (NDSTC) surface-supplied divers:

- Diver
- Standby Diver
- Rack Operator
- Console Operator

3. The following stations should be a qualified diver. When circumstances require the use of a non-diver, the Diving Officer, Master Diver, and Diving Supervisor must ensure that the required personnel has been thoroughly instructed in the required duties. These stations include:

- Tender
- Standby Tender
- Winch Operator

4. A Diving Medical Officer is required on site for all dives exceeding the normal working limit.
5. Master Diver may serve as the Diving Officer if so designated in writing by the Commanding Officer.
6. Diving Medical Technician required when no Diving Medical Officer is available.

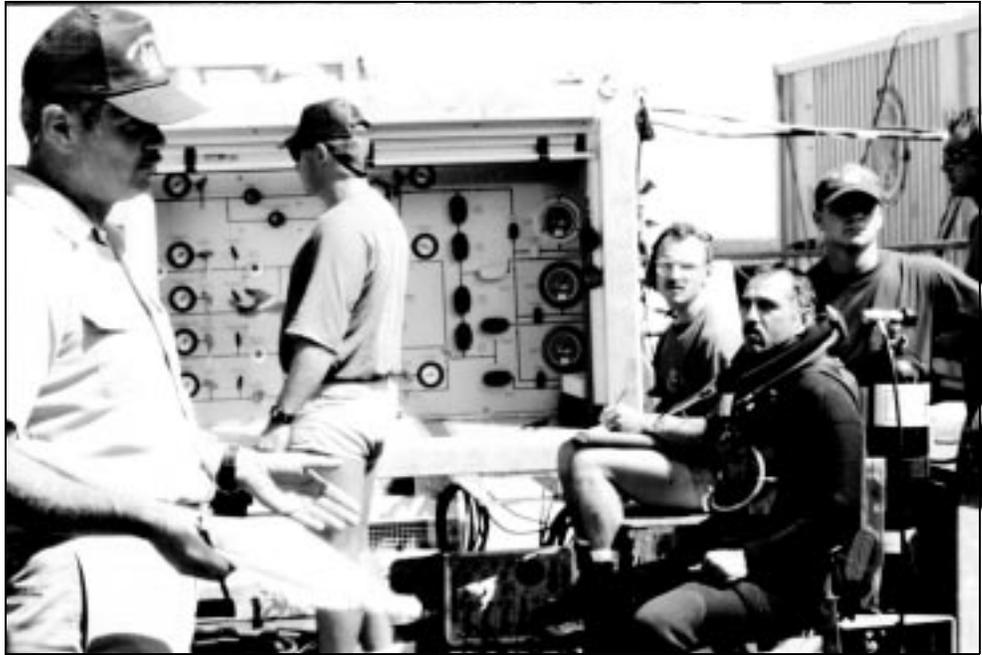


Figure 13-3. Dive Team Brief for Divers.

13-6 FINAL PREPARATIONS AND SAFETY PRECAUTIONS

Prior to the start of a mixed-gas diving operation, it is important to check that all necessary preparations have been made and that all safety precautions have been checked. This ensures that the diving team is properly supported in its mission and that all possible contingencies have been evaluated in case an unexpected circumstance should arise.

13-7 RECORD KEEPING

Chapter 5 describes the objectives and importance of maintaining accurate records. The Diving Officer, Master Diver, and Diving Supervisor should identify the records required for their respective systems and tailor them to suit their needs. The purpose of any record is to provide an accurate and detailed account of every facet of the diving operation and a tabulation of supplies expended to support the operation (e.g., gases, carbon dioxide absorbent, etc.). Any unusual circumstances regarding dive conduct (i.e., treatments, operational/emergency procedures, or deviation from procedures) established in the U.S. Navy Diving Manual shall be brought to the attention of the Commanding Officer and logged in the Command Smooth Diving Log.

13-8 MIXED-GAS DIVING EQUIPMENT

There are several modes of diving that are characterized by the diving equipment used. The following descriptions outline capabilities and logistical requirements for various mixed-gas diving systems.

13-8.1 Minimum Required Equipment. Minimum required equipment for the pool phase of dive training conducted at Navy diving schools may be modified as necessary. Any modifications to the minimum required equipment listed herein must be noted in approved lesson training guides.

Minimum Equipment:

1. MK 21 MOD 1 helmet with tethered umbilical
2. Thermal protection garment
3. Weight belt
4. Dive knife
5. Swim fins or shoes/booties
6. EGS bottle with submersible tank pressure gauge
7. Integrated diver's vest/harness

13-8.2 MK 21 MOD 1 Lightweight Surface-Supplied Helium-Oxygen Description.

Principle of Operation:

Surface-supplied open-circuit mixed-gas (HeO₂) system

Operational Considerations:

1. Adequate mixed-gas supply
2. Master Diver required on station for mixed-gas operations
3. Diving Medical Officer required on-site for dives deeper than 300 fsw
4. Recompression chamber required on-site
5. Planned exceptional exposure dives or dives exceeding normal working limits require CNO approval
6. Breathing gas heater
7. Hot water suit



Figure 13-4. MK 21 MOD 1 UBA.

13-8.3 Flyaway Dive System III Mixed Gas System (FMGS). The FADS III Mixed Gas System (FMGS) is a portable, self-contained, surface-supplied diver life-support system designed to support mixed gas dive missions to 300 fsw (Figure 13-5 and Figure 13-6). The FMGS consists of five gas rack assemblies, one air supply rack assembly (ASRA), one oxygen supply rack assembly (OSRA), and three helium-oxygen supply rack assemblies (HOSRA). Each rack consists of nine 3.15 cu ft floodable volume composite flasks vertically mounted in rack assembly. The ASRA will hold 9600 scf of compressed air at 5000 psi. Compressed air is provided by a 5000 psi air compressor assembly, which includes an air purification system. Oxygen is stored at 3000 psi. The FMGS also includes a mixed-gas control console assembly (MGCCA) and two gas booster assemblies for use in charging the OSRA and HOSRA. Three banks of two, three, and four flasks allow the ASRA to provide air to the divers as well as air to support chamber operations. Set-up and operating procedures for the FMGS are found in the Operating and Maintenance Technical Manual for Fly Away Dive System (FADS) III Mixed Gas System, S9592-B2-OMI-010.



Figure 13-5. FADS III Mixed Gas System (FMGS).

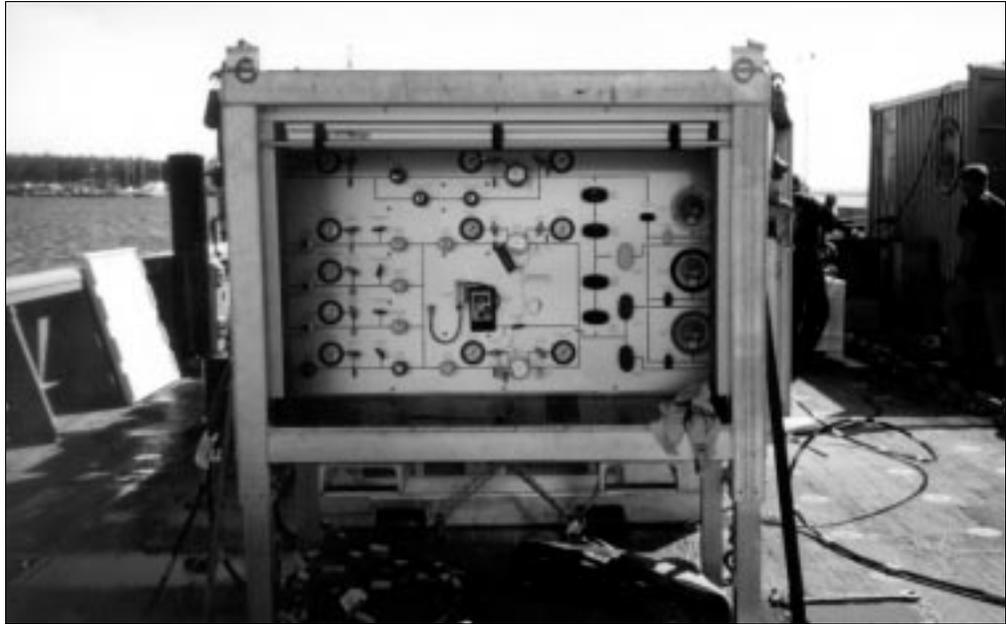


Figure 13-6. FMGS Control Console Assembly.