CHAPTER 18

Closed-Circuit Oxygen UBA Diving

18-1 INTRODUCTION

The term *closed-circuit oxygen rebreather* describes a specialized type of underwater breathing apparatus (UBA). In this type of UBA, all exhaled gas is kept within the rig. As it is exhaled, the gas is carried via the exhalation hose to an absorbent canister through a carbon dioxide-absorbent bed that removes the carbon dioxide by chemically reacting with the carbon dioxide produced as the diver breathes. After the unused oxygen passes through the canister, the gas travels to the breathing bag where it is available to be inhaled again by the diver. The gas supply used in such a rig is pure oxygen, which prevents inert gas buildup in the diver and allows all of the gas carried by the diver to be used for metabolic needs. Closed-circuit oxygen UBAs offer advantages valuable to special warfare, including stealth (no escaping bubbles), extended operating duration, and less weight than open-circuit air scuba. Weighed against these advantages are the disadvantages of increased hazards to the diver, greater training requirements, and greater expense. However, when compared to a closed-circuit mixed-gas UBA, an oxygen UBA offers the advantages of reduced training and maintenance requirements, lower cost, and reduction in weight and size.

Figure 18-1. Diver in Draeger LAR V UBA.

18-1.1 **Purpose.** This chapter provides general guidance for MK 25 diving operations and procedures. For detailed operation and maintenance instructions, see appropriate technical manual (see Appendix 1B for manual reference numbers).

18-1.2 **Scope.** This chapter covers MK 25 UBA principles of operations, operational planning, dive procedures, and medical aspects of closed-circuit oxygen diving.

18-2 MEDICAL ASPECTS OF CLOSED-CIRCUIT OXYGEN DIVING

Closed-circuit oxygen divers are subject to many of the same medical problems as other divers. Volume 5 provides in-depth coverage of all medical considerations. Only the diving disorders that merit special attention for closed-circuit oxygen divers are addressed in this chapter.

18-2.1 **Oxygen Toxicity.** Breathing oxygen at high partial pressures may have toxic effects in the body. Relatively brief exposure to elevated oxygen partial pressure, when it occurs at depth or in a pressurized chamber, can result in CNS oxygen toxicity causing CNS-related symptoms. High partial pressures of oxygen are associated with many biochemical changes in the brain, but which of the changes are responsible for the signs and symptoms of CNS oxygen toxicity is presently unknown.

18-2.1.1 **Off-Effect.** The off-effect, a hazard associated with CNS oxygen toxicity, may occur several minutes after the diver comes off gas or experiences a reduction of oxygen partial pressure. The off-effect is manifested by the onset or worsening of CNS oxygen toxicity symptoms. Whether this paradoxical effect is truly caused by the reduction in partial pressure or whether the association is coincidental is unknown.

18-2.1.2 **Pulmonary Oxygen Toxicity.** Pulmonary oxygen toxicity, causing lung irritation with coughing and painful breathing, can result from prolonged exposure to elevated oxygen partial pressure. This form of oxygen toxicity produces symptoms of chest pain, cough, and pain on inspiration that develop slowly and become increasingly worse as long as the elevated level of oxygen is breathed. Although hyperbaric oxygen may cause serious lung damage, if the oxygen exposure is discontinued before the symptoms become too severe, the symptoms will slowly abate. This form of oxygen toxicity is generally seen during oxygen recompression treatment and saturation diving, and on long, shallow, in-water oxygen exposures.

18-2.1.3 **Symptoms of CNS Oxygen Toxicity.** In diving, the most serious effects of oxygen toxicity are CNS symptoms. The most hazardous is a sudden convulsion which can result in drowning or arterial gas embolism. The symptoms of CNS oxygen toxicity may occur suddenly and dramatically, or they may have a gradual, almost imperceptible onset. The mnemonic device VENTIDC is a helpful reminder of these common symptoms.

V: Visual symptoms. Tunnel vision, a decrease in the diver’s peripheral vision, and other symptoms, such as blurred vision, may occur.

E: Ear symptoms. Tinnitus is any sound perceived by the ears but not resulting from an external stimulus. The sound may resemble bells ringing, roaring, or a machinery-like pulsing sound.

N: Nausea or spasmodic vomiting. These symptoms may be intermittent.

T: Twitching and tingling symptoms. Any of the small facial muscles, lips, or muscles of the extremities may be affected. These are the most frequent and clearest symptoms.

I: Irritability. Any change in the diver’s mental status; including confusion, agitation, and anxiety.

D: Dizziness. Symptoms include clumsiness, incoordination, and unusual fatigue.

C: Convulsions. The first sign of CNS oxygen toxicity may be a convulsion that occurs with little or no warning.

The most serious symptom of CNS oxygen toxicity is convulsion. Refer to Chapter 3 for a complete description of a convulsive episode. The following factors should be noted regarding an oxygen convulsion:

- The diver is unable to carry on any effective breathing during the convulsion.
- After the diver is brought to the surface, there will be a period of unconsciousness or neurologic impairment following the convulsion; these symptoms are indistinguishable from those of arterial gas embolism.
- No attempt should be made to insert any object between the clenched teeth of a convulsing diver. Although a convulsive diver may suffer a lacerated tongue, this trauma is preferable to the trauma that may be caused during the insertion of a foreign object. In addition, the person providing first aid may incur significant hand injury if bitten by the convulsing diver.
- There may be no warning of an impending convulsion to provide the diver the opportunity to return to the surface. Therefore, buddy lines are essential to safe closed-circuit oxygen diving.

18-2.1.4 **Causes of CNS Oxygen Toxicity.** Factors that increase the likelihood of CNS oxygen toxicity are:

- Increased partial pressure of oxygen. At depths less than 25 fsw, a change in depth of five fsw increases the risk of oxygen toxicity only slightly, but a similar depth increase in the 30-fsw to 50-fsw range may significantly increase the likelihood of a toxicity episode.
- Increased time of exposure
- Prolonged immersion
- Stress from strenuous physical exercise
- Carbon dioxide buildup. The increased tendency toward CNS oxygen toxicity may occur before the diver is aware of any symptoms of carbon dioxide buildup.
- Cold stress resulting from shivering or an increased exercise rate as the diver attempts to keep warm.
- Systemic diseases that increase oxygen consumption. Conditions associated with increased metabolic rates (such as certain thyroid or adrenal disorders) tend to cause an increase in oxygen sensitivity. Divers with these diseases should be excluded from oxygen diving.

18-2.1.5 **Treatment of Nonconvulsive Symptoms.** The stricken diver should alert his dive buddy and make a controlled ascent to the surface. The victim's life preserver should be inflated (if necessary) with the dive buddy watching him closely for progression of symptoms.

18-2.1.6 **Treatment of Underwater Convulsion.** The following steps should be taken when treating a convulsing diver:

1. Assume a position behind the convulsing diver. Release the victim's weight belt unless he is wearing a dry suit, in which case the weight belt should be left in place to prevent the diver from assuming a face-down position on the surface.

2. Leave the victim's mouthpiece in his mouth. If it is not in his mouth, do not attempt to replace it; however, if time permits, ensure that the mouthpiece is switched to the SURFACE position.

3. Grasp the victim around his chest above the UBA or between the UBA and his body. If difficulty is encountered in gaining control of the victim in this manner, the rescuer should use the best method possible to obtain control. The UBA waist or neck strap may be grasped if necessary.

4. Make a controlled ascent to the surface, maintaining a slight pressure on the diver's chest to assist exhalation.

5. If additional buoyancy is required, activate the victim's life jacket. The rescuer should not release his own weight belt or inflate his own life jacket.

6. Upon reaching the surface, inflate the victim's life jacket if not previously done.

7. Remove the victim's mouthpiece and switch the valve to SURFACE to prevent the possibility of the rig flooding and weighing down the victim.

8. Signal for emergency pickup.

9. Once the convulsion has subsided, open the victim's airway by tilting his head back slightly.

10. Ensure the victim is breathing. Mouth-to-mouth breathing may be initiated if necessary.

11. If an upward excursion occurred during the actual convulsion, transport to the nearest chamber and have the victim evaluated by an individual trained to recognize and treat diving-related illness.

18-2.2 **Oxygen Deficiency (Hypoxia).** Oxygen deficiency, or *hypoxia*, is the condition in which the partial pressure of oxygen is too low to meet the metabolic needs of the body. Chapter 3 contains an in-depth description of this disorder. In the context of closed-circuit oxygen diving, the cause of hypoxia may be considered to be the result of too much inert gas (nitrogen) in the breathing loop. Although all cells in the body need oxygen, the initial symptoms of hypoxia are a manifestation of central nervous system dysfunction.

18-2.2.1 **Causes of Hypoxia with the MK 25 UBA.** If a diver begins breathing from a MK 25 UBA with too low an oxygen fraction in the breathing loop, hypoxia may develop. A diver can become hypoxic in a rig that uses pure oxygen. Oxygen is added to the UBA only on a demand basis as the breathing bag is emptied on inhalation. If, as the diver consumes the oxygen in the UBA, there is sufficient nitrogen in the breathing loop to prevent the breathing bag from being emptied, no oxygen will be added and the diver may become hypoxic even though he has sufficient gas volume in the breathing bag for normal inhalation. If a diver waiting to begin a dive finishes his purge with a low level of oxygen (e.g., 25 percent) in the breathing loop and the oxygen fraction remains at 25 percent, there will be no problem. As the diver consumes oxygen, the oxygen fraction in the breathing loop will begin to decrease, as will the gas volume in the breathing bag. If the breathing bag is emptied and the UBA begins to add oxygen before a dangerously low fraction of oxygen is obtained, hypoxia may be avoided. If the diver begins with a very full breathing bag, however, the gas volume in the bag may decrease two or three liters without adding any oxygen. In this case, the oxygen fraction may drop to ten percent or lower and hypoxia may result. The risk of this happening is greatest when the diver is on the surface before the dive starts because as the diver descends to the transit depth of 15-25 fsw, two things happen: (1) pure oxygen is added to the rig to maintain volume as the diver descends and the oxygen fraction in the rig increases and (2) the pressure increase causes a rise in the partial pressure of the oxygen.

18-2.2.2 **Underwater Purge.** If the diver conducts an underwater purge or purge under pressure at depth, no descent may be required following the purge procedure and the pressure-related increase in oxygen fraction as described above would not occur. Therefore, in the under-pressure purge procedure strict adherence to prescribed procedures is extremely important to ensure an adequate oxygen fraction in the rig.

18-2.2.3 **MK 25 UBA Purge Procedure.** The possibility of hypoxia developing in the situation described above led to the development of a detailed purge procedure for the MK 25 UBA to ensure that the oxygen fraction in the breathing loop is sufficiently high to prevent such an occurrence. This is accomplished by using the purging procedures described in the appropriate MK 25 Operation and Maintenance Manual.

18-2.2.4 **Symptoms of Hypoxia.** Hypoxia due to a low oxygen content in the breathing gas may have no warning symptoms prior to loss of consciousness. Other symptoms that may appear include confusion, incoordination, dizziness, and convulsion. It is important to note that if symptoms of unconsciousness or convulsion occur at the beginning of a closed-circuit oxygen dive, hypoxia, not oxygen toxicity, is the most likely cause.

18-2.2.5 **Treatment of Hypoxia.** Treatment for a suspected case of hypoxia consists of the following:

- If the diver becomes unconscious or incoherent at depth, the dive buddy should add oxygen to the stricken diver's UBA.

- The diver must be brought to the surface. Remove the mouthpiece and allow the diver to breathe fresh air. If unconscious, check breathing and circulation, maintain an open airway and administer 100-percent oxygen.

- If the diver surfaces in an unconscious state, transport to the nearest chamber and have the victim evaluated by an individual trained to recognize and treat diving-related illness. If the diver recovers fully with normal neurological function, he does not require immediate treatment for arterial gas embolism.

18-2.3 Carbon Dioxide Toxicity (Hypercapnia). Carbon dioxide toxicity, or *hypercapnia*, is an abnormally high level of carbon dioxide in the body tissues. Hypercapnia is generally the result of a buildup of carbon dioxide in the breathing supply or in the body. Inadequate ventilation (breathing volume) by the diver or failure of the carbon dioxide-absorbent canister to remove carbon dioxide from the exhaled gas will cause a buildup to occur.

18-2.3.1 **Symptoms of Hypercapnia.** Symptoms of hypercapnia are:

- Increased rate and depth of breathing
- Labored breathing (similar to that seen with heavy exercise)
- Headache
- Confusion
- Unconsciousness

NOTE Symptoms are dependent on the partial pressure of carbon dioxide, which is a factor of both the fraction of carbon dioxide and the absolute pressure. Thus, symptoms would be expected to increase as depth increases.

It is important to note that the presence of a high partial pressure of oxygen may reduce the early symptoms of hypercapnia. As previously mentioned, elevated levels of carbon dioxide may result in an episode of CNS oxygen toxicity on a normally safe dive profile.

18-2.3.2 **Treating Hypercapnia.** To treat hypercapnia:

- Increase ventilation if skip-breathing is a possible cause.

- Decrease exertion level.

- Abort the dive. Return to the surface and breathe air.

- During ascent, while maintaining a vertical position, the diver should activate his bypass valve, adding fresh gas to his UBA. If the symptoms are a result of canister floodout, an upright position decreases the likelihood that the diver will sustain chemical injury (paragraph 18-2.4).

- If unconsciousness occurs at depth, the same principles of management for underwater convulsion as described in paragraph 18-2.1.6 apply.

NOTE **If carbon dioxide toxicity is suspected, the dive should be aborted even if symptoms dissipate upon surfacing. The decrease in symptoms may be a result of the reduction in partial pressure, in which case the symptoms will reappear if the diver returns to depth.**

18-2.3.3 **Avoiding Hypercapnia.** To minimize the risk of hypercapnia:

- Use only an approved carbon dioxide absorbent in the UBA canister.

- Follow the prescribed canister-filling procedure to ensure that the canister is correctly packed with carbon dioxide absorbent.

- Dip test the UBA carefully before the dive. Watch for leaks that may result in canister floodout.

- Do not exceed canister duration limits for the water temperature.

- Ensure that the one-way valves in the supply and exhaust hoses are installed and working properly.

- Swim at a relaxed, comfortable pace.

- Avoid skip-breathing. There is no advantage to this type of breathing in a closed-circuit rig and it may cause elevated blood carbon dioxide levels even with a properly functioning canister.

18-2.4 **Chemical Injury.** The term “chemical injury” refers to the introduction of a caustic solution from the carbon dioxide scrubber of the UBA into the upper airway of a diver.

18-2.4.1 **Causes of Chemical Injury.** The caustic alkaline solution results from water leaking into the canister and coming in contact with the carbon dioxide absorbent. When the diver is in a horizontal or head-down position, this solution may travel through the inhalation hose and irritate or injure his upper airway.

18-2.4.2 **Symptoms of Chemical Injury.** The diver may experience rapid breathing or headache, which are symptoms of carbon dioxide buildup in the breathing gas. This occurs because an accumulation of the caustic solution in the canister may be impairing carbon dioxide absorption. If the problem is not corrected promptly, the alkaline solution may travel into the breathing hoses and consequently be inhaled or swallowed. Choking, gagging, foul taste, and burning of the mouth and throat may begin immediately. This condition is sometimes referred to as a "caustic cocktail." The extent of the injury depends on the amount and distribution of the solution.

18-2.4.3 **Management of a Chemical Incident.** If the caustic solution enters the mouth, nose, or face mask, the diver must take the following steps:

1. Immediately assume an upright position in the water.

2. Depress the manual bypass valve continuously and make a controlled ascent to the surface, exhaling through the nose to prevent overpressurization.

3. Should signs of system flooding occur during underwater purging, abort the dive and return to open-circuit or mixed-gas UBA if possible.

Using fresh water, rinse the mouth several times. Several mouthfuls should then be swallowed. If only sea water is available, rinse the mouth, but do not swallow. Other fluids may be substituted if available, but the use of weak acid solutions (vinegar or lemon juice) is not recommended. Do not attempt to induce vomiting.

As a result of the chemical injury, the diver may have difficulty breathing properly on ascent. He should be observed for signs of an arterial gas embolism and treated if necessary. A victim of a chemical injury should be evaluated by a Diving Medical Officer or a Diving Medical Technician/Special Operations Technician as soon as possible. Respiratory distress which may result from the chemical trauma to the air passages requires immediate hospitalization.

NOTE Performance of a careful dip test during predive set up is essential to detect system leaks. Additionally, dive buddies should check each other carefully before leaving the surface at the start of a dive.

18-2.5 Middle Ear Oxygen Absorption Syndrome. Middle ear oxygen absorption syndrome refers to the negative pressure that may develop in the middle ear following a long oxygen dive. Gas with a very high percentage of oxygen enters the middle ear cavity during the course of an oxygen dive. Following the dive, the oxygen is slowly absorbed by the tissues of the middle ear. If the Eustachian tube does not open spontaneously, a negative pressure relative to ambient may result in the middle ear cavity. Symptoms are often noted the morning after a long oxygen dive. Middle ear oxygen absorption syndrome is difficult to avoid but usually does not pose a significant problem because symptoms are generally minor and easily eliminated. There may also be fluid (serous otitis media) present in the middle ear as a result of the differential pressure.

18-2.5.1 **Symptoms of Middle Ear Oxygen Absorption Syndrome.** Symptoms of middle ear oxygen absorption syndrome are:

- The diver may notice mild discomfort and hearing loss in one or both ears.

- There may also be a sense of pressure and a moist, cracking sensation as a result of fluid in the middle ear.

18-2.5.2 **Treating Middle Ear Oxygen Absorption Syndrome.** Equalizing the pressure in the middle ear using a normal Valsalva maneuver (paragraph 3-8.3.1) or the diver's procedure of choice (e.g., swallowing, yawning) will usually relieve the symptoms. Discomfort and hearing loss resolve quickly, but the middle ear fluid is absorbed more slowly. If symptoms persist, a Diving Medical Technician or Diving Medical Officer shall be consulted.

18-3 MK 25 (DRAEGER LAR V UBA)

The closed-circuit oxygen UBAs currently used by U.S. Navy combat swimmers are the MK 25 MOD 0, MOD 1, and MOD 2 (Draeger LAR V UBA). Refer to Table 18-1 for the operational characteristics of the MK 25.

Table 18-1. *MK 25 Equipment Information.*

Type	Principal Applications	Minimum Personnel	Advantages	Disadvantages	Restrictions and Depth Limits
MK 25 MOD 0	Special Warfare only. Shallow search and inspection	5	No surface bubbles. Minimum support. Long duration. Portability. Mobility.	Limited to shallow depths. CNS O_2 toxicity hazards. No voice communications. Limited physical and thermal protection.	Normal: 25 fsw for 240 m. Maximum: 50 fsw for 10 m. No excursion allowed when using Single Depth Diving Limits.
MK 25 MOD 1	Same as MOD 0.	5	Same as MOD 0, plus low magnetic signature, increased cold water duration capability.	Same as MOD 0.	Same as MOD 0.
MK 25 MOD 2	Same as MOD 0.	5	Same as MOD 0, plus increased cold water duration capability.	Same as MOD 0.	Same as MOD 0.

18-3.1 **Gas Flow Path.** The gas flow path of the MK 25 UBA is shown in Figure 18-2. The gas is exhaled by the diver and directed by the mouthpiece one-way valves into the exhalation hose. The gas then enters the carbon dioxide-absorbent canister, which is packed with a NAVSEA-approved carbon dioxide-absorbent material. The carbon dioxide is removed by passing through the CO_2-absorbent bed and chemically combining with the CO_2-absorbent material in the canister. Upon leaving the canister the used oxygen enters the breathing bag. When the diver inhales, the gas is drawn from the breathing bag through the inhalation hose and back into the diver's lungs. The gas flow described is entirely breath activated. As the diver exhales, the gas in the UBA is pushed forward by the exhaled gas, and upon inhalation the one-way valves in the hoses allow fresh gas to be pulled into the diver's lungs from the breathing bag.

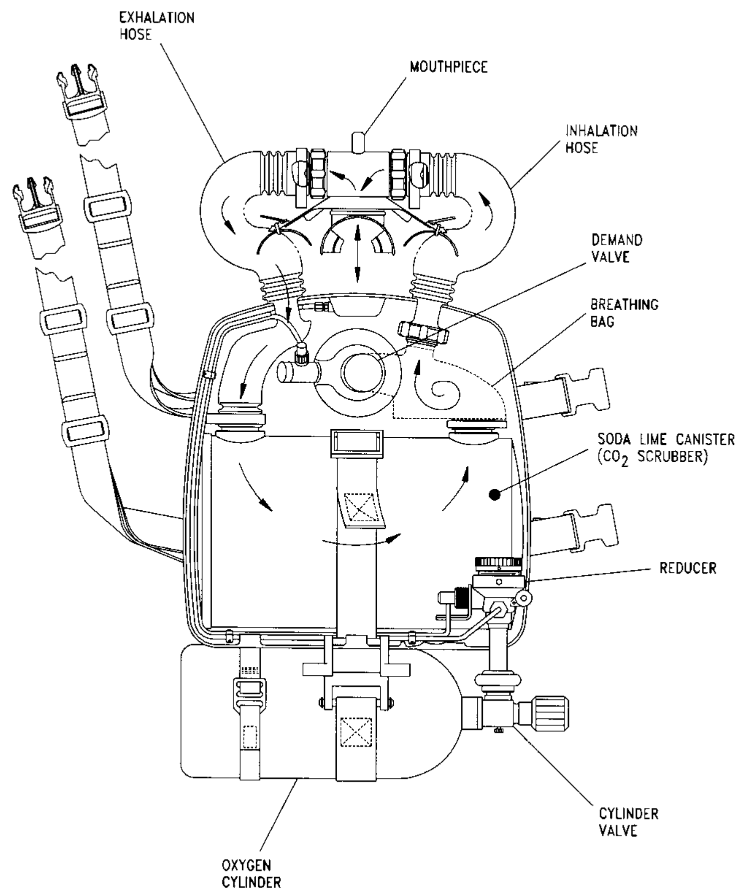

Figure 18-2. Gas Flow Path of the MK 25.

18-3.1.1 **Breathing Loop.** The demand valve adds oxygen to the breathing bag of the UBA from the oxygen cylinder only when the diver empties the bag on inhalation. The demand valve also contains a manual bypass knob to allow for manual filling of the breathing bag during rig setup and as required. There is no constant flow of fresh oxygen to the diver. This feature of the MK 25 UBA makes it essential that nitrogen be purged from the apparatus prior to the dive. If too much nitrogen is present in the breathing loop, the breathing bag may not be emptied and the demand valve may not add oxygen even when metabolic consumption by the diver has reduced the oxygen in the UBA to dangerously low levels (see paragraph 18-2.2).

18-3.2 **Operational Duration of the MK 25 UBA.** The operational duration of the MK 25 UBA may be limited by either the oxygen supply or the canister duration. Refer to Table 18-2 for the breathing gas consumption rates for the MK 25 UBA.

Table 18-2. *Average Breathing Gas Consumption.*

Diving Equipment	Overbottom Pressure (Minimum)	Gas Consumption (Normal)	Gas Consumption (Heavy Work)
MK 25 UBA (100% O_2)	72.5 psi (4.9 BAR)	15-17 psi/min (1-1.2 BAR)	(See Note)

Note:

Heavy work is not recommended for the MK 25.

18-3.2.1 **Oxygen Supply.** The MK 25 oxygen bottle is charged to 3,000 psig (200 BAR). The oxygen supply may be depleted in two ways: by the diver's metabolic consumption or by the loss of gas from the UBA. A key factor in maximizing the duration of the oxygen supply is for the diver to swim at a relaxed, comfortable pace. A diver swimming at a high exercise rate may have an oxygen consumption of two liters per minute (oxygen supply duration = 150 minutes) while one swimming at a relaxed pace may have an oxygen consumption of one liter per minute (oxygen supply duration = 300 minutes).

18-3.2.2 **Canister Duration.** The canister duration is dependent on water temperature, exercise rate, and the mesh size of the NAVSEA-approved carbon dioxide absorbent. (Table 18-3 lists NAVSEA-approved absorbents.) The canister will function adequately as long as the UBA has been set up properly. Factors that may cause the canister to fail early are discussed under carbon dioxide buildup in paragraph 18-2.3.

Table 18-3. *NAVSEA-Approved Sodalime CO_2 Absorbents*

Name	Vendor	NSN
High Performance Sodasorb, Regular	W.R. Grace	6810-01-113-0110
Sofnolime 4-8 Mesh NI, L Grade	O.C. Lugo	6810-01-113-0110
Sofnolime 8-12 Mesh NI, D Grade	O.C. Lugo	6810-01-412-0637

Note:

Sofnolime 8-12 is only approved for use in the MK 16 UBA.

Dives should be planned so as not to exceed the canister duration limits. Oxygen pressure is monitored during the dive by the UBA oxygen pressure gauge, displayed in bars. The duration of the oxygen supply will be dependent on the factors discussed in paragraph 18-5.2 and must be estimated using the anticipated swim speed and the expertise of the divers in avoiding gas loss.

18-3.3 Packing Precautions. Caution should be used when packing the carbon dioxide canister to ensure the canister is completely filled with carbon dioxide-absorbent material to minimize the possibility of channeling. Channeling allows the diver's exhaled carbon dioxide to pass through channels in the absorbent material without being absorbed, resulting in an ever-increasing concentration of carbon dioxide in the breathing bag, leading to hypercapnia. Channeling can be avoided by following the canister-packing instructions provided by the specific MK 25 Operation and Maintenance Manual. Basic precautions include orienting the canister vertically and filling the canister to approximately 1/3 full with the approved absorbent material and tapping the sides of the canister with the hand or a rubber mallet. This process should be repeated by thirds until the canister is filled to the fill line scribed on the inside of the absorbent canister. Mashing the material with a balled fist is not recommended as it may cause the approved absorbent material to fracture, thereby producing dust which would then be transported through the breathing loop to the diver's lungs while breathing the UBA.

18-3.4 Preventing Caustic Solutions in the Canister. Additional concerns include ensuring water is not inadvertently introduced into the canister by leaving the mouthpiece in the "dive" position when on the surface or through system leaks. The importance of performing the tightness and dip test while performing predive setup procedures cannot be overemphasized. When water combines with the absorbent material, it creates strong caustic solution commonly referred to as "caustic cocktail," which is capable of producing chemical burns in the diver's mouth and airway. In the event of a "caustic cocktail," the diver should immediately maintain a heads-up attitude in the water column, depress the manual bypass knob on the demand valve, and terminate the dive.

18-3.5 References. References for Additional Information.

- *MK 25 MOD 0 (UBA LAR V) Operation and Maintenance Manual*, NAVSEA Publication SS-600-AJ-MMO-010, Change 1, August 1, 1985
- *MK 25 MOD 1 Operation and Maintenance Manual*, NAVSEA Publication SS-600-A2-MMO-010, 31 August, 1996
- *MK 25 MOD 2 Operation and Maintenance Manual*, NAVSEA Publication SS-600-A3-MMO-010/53833
- Marine Corps TM 09603B-14 & P/1
- *Evaluation of the Draeger LAR V Pure Oxygen Scuba*; NEDU Report 11-75

- *Evaluation of the Modified Draeger LAR V Closed-Circuit Oxygen Rebreather*; NEDU Report 5-79

- *Unmanned Evaluation of Six Closed-Circuit Oxygen Rebreathers*; NEDU Report 3-82

18-4 CLOSED-CIRCUIT OXYGEN EXPOSURE LIMITS

The U.S. Navy closed-circuit oxygen exposure limits have been extended and revised to allow greater flexibility in closed-circuit oxygen diving operations. The revised limits are divided into two categories: Transit with Excursion Limits and Single Depth Limits.

18-4.1 **Transit with Excursion Limits Table.** The Transit with Excursion Limits (Table 18-4) call for a maximum dive depth of 25 fsw or shallower for the majority of the dive, but allow the diver to make a brief excursion to depths as great as 50 fsw. The Transit with Excursion Limits is normally the preferred mode of operation because maintaining a depth of 25 fsw or shallower minimizes the possibility of CNS oxygen toxicity during the majority of the dive, yet allows a brief downward excursion if needed (see Figure 18-3). Only a single excursion is allowed.

Table 18-4. *Excursion Limits.*

Depth	Maximum Time
26-40 fsw	15 minutes
41-50 fsw	5 minutes

18-4.2 **Single-Depth Oxygen Exposure Limits Table.** The Single-Depth Limits (Table 18-5) allow maximum exposure at the greatest depth, but have a shorter overall exposure time. Single-depth limits may, however, be useful when maximum bottom time is needed deeper than 25 fsw.

18-4.3 **Oxygen Exposure Limit Testing.** The Transit with Excursion Limits and Single-Depth Limits have been tested extensively over the entire depth range and are acceptable for routine diving operations. They are not considered exceptional exposure. It must be noted that the limits shown in this section apply only to closed-circuit 100-percent oxygen diving and are not applicable to deep mixed-gas diving. Separate oxygen exposure limits have been established for deep, helium-oxygen mixed-gas diving.

18-4.4 **Individual Oxygen Susceptibility Precautions.** Although the limits described in this section have been thoroughly tested and are safe for the vast majority of individuals, occasional episodes of CNS oxygen toxicity may occur. This is the basis for requiring buddy lines on closed-circuit oxygen diving operations.

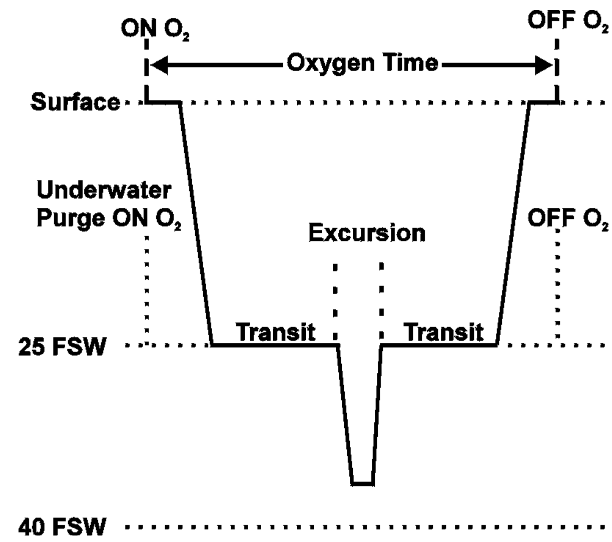

Figure 18-3. Example of Transit with Excursion.

Table 18-5. *Single-Depth Oxygen Exposure Limits.*

Depth	Maximum Oxygen Time
25 fsw	240 minutes
30 fsw	80 minutes
35 fsw	25 minutes
40 fsw	15 minutes
50 fsw	10 minutes

18-4.5 **Transit with Excursion Limits.** A transit with one excursion, if necessary, will be the preferred option in most combat swimmer operations. When operational considerations necessitate a descent to deeper than 25 fsw for longer than allowed by the excursion limits, the appropriate single-depth limit should be used (paragraph 18-4.6).

18-4.5.1 **Transit with Excursion Limits Definitions.** The following definitions are illustrated in Figure 18-3:

- *Transit* is the portion of the dive spent at 25 fsw or shallower.
- *Excursion* is the portion of the dive deeper than 25 fsw.
- *Excursion time* is the time between the diver's initial descent below 25 fsw and his return to 25 fsw or shallower at the end of the excursion.

- *Oxygen time* is calculated as the time interval between when the diver begins breathing from the closed-circuit oxygen UBA (on-oxygen time) and the time when he discontinues breathing from the closed-circuit oxygen UBA (off-oxygen time).

18-4.5.2 **Transit with Excursion Rules.** A diver who has maintained a transit depth of 25 fsw or shallower may make one brief downward excursion as long as he observes these rules:

- Maximum total time of dive (oxygen time) may not exceed 240 minutes.
- A single excursion may be taken at any time during the dive.
- The diver must have returned to 25 fsw or shallower by the end of the prescribed excursion limit.
- The time limit for the excursion is determined by the maximum depth attained during the excursion (Table 18-4). Note that the Excursion Limits are different from the Single-Depth Limits.

Example: Dive Profile Using Transit with Excursion Limits. A dive mission calls for a swim pair to transit at 25 fsw for 45 minutes, descend to 36 fsw, and complete their objective. As long as the divers do not exceed a maximum depth of 40 fsw, they may use the 40-fsw excursion limit of 15 minutes. The time at which they initially descend below 25 fsw to the time at which they finish the excursion must be 15 minutes or less.

18-4.5.3 **Inadvertent Excursions.** If an inadvertent excursion should occur, one of the following situations will apply:

- If the depth and/or time of the excursion exceeds the limits in paragraph 18-4.5.2 or if an excursion has been taken previously, the dive must be aborted and the diver must return to the surface.
- If the excursion was within the allowed excursion limits, the dive may be continued to the maximum allowed oxygen dive time, but no additional excursions deeper than 25 fsw may be taken.
- The dive may be treated as a single-depth dive applying the maximum depth and the total oxygen time to the Single-Depth Limits shown in Table 18-5.

Example 1. A dive pair is having difficulty with a malfunctioning compass. They have been on oxygen (oxygen time) for 35 minutes when they notice that their depth gauge reads 55 fsw. Because this exceeds the maximum allowed oxygen exposure depth, the dive must be aborted and the divers must return to the surface.

Example 2. A diver on a compass swim notes that his depth gauge reads 32 fsw. He recalls checking his watch 5 minutes earlier and at that time his depth gauge read 18 fsw. As his excursion time is less than 15 minutes, he has not exceeded the excursion limit for 40 fsw. He may continue the dive, but he must maintain his depth at 25 fsw or less and make no additional excursions.

NOTE **If the diver is unsure how long he was below 25 fsw, the dive must be aborted.**

18-4.6 **Single-Depth Limits.** The term Single-Depth Limits does not mean that the entire dive must be spent at one depth, but refers to the time limit applied to the dive based on the maximum depth attained during the dive.

18-4.6.1 **Single-Depth Limits Definitions.** The following definitions apply when using the Single-Depth Limits:

- *Oxygen time* is calculated as the time interval between when the diver begins breathing from the closed-circuit oxygen UBA (on-oxygen time) and the time when he discontinues breathing from the closed-circuit oxygen UBA (off-oxygen time).

- The *depth* for the dive used to determine the allowable exposure time is determined by the maximum depth attained during the dive. For intermediate depth, the next deeper depth limit will be used.

18-4.6.2 **Depth/Time Limits.** The Single-Depth Limits are provided in Table 18-5. No excursions are allowed when using these limits.

Example. Twenty-two minutes (oxygen time) into a compass swim, a dive pair descends to 28 fsw to avoid the propeller of a passing boat. They remain at this depth for 8 minutes. They now have two choices for calculating their allowed oxygen time: (1) they may return to 25 fsw or shallower and use the time below 25 fsw as an excursion, allowing them to continue their dive on the Transit with Excursion Limits to a maximum time of 240 minutes; or (2) they may elect to remain at 28 fsw and use the 30-fsw Single-Depth Limits to a maximum dive time of 80 minutes.

18-4.7 **Exposure Limits for Successive Oxygen Dives.** If an oxygen dive is conducted after a previous closed-circuit oxygen exposure, the effect of the previous dive on the exposure limit for the subsequent dive is dependent on the Off-Oxygen Interval.

18-4.7.1 **Definitions for Successive Oxygen Dives.** The following definitions apply when using oxygen exposure limits for successive oxygen dives.

- *Off-Oxygen Interval*. The interval between off-oxygen time and on-oxygen time is defined as the time from when the diver discontinues breathing from his closed-circuit oxygen UBA on one dive until he begins breathing from the UBA on the next dive.

- *Successive Oxygen Dive*. A successive oxygen dive is one that follows a previous oxygen dive after an Off-Oxygen Interval of more than 10 minutes but less than 2 hours.

18-4.7.2 **Off-Oxygen Exposure Limit Adjustments.** If an oxygen dive is a successive oxygen dive, the oxygen exposure limit for the dive must be adjusted as shown in Table 18-6. If the Off-Oxygen Interval is 2 hours or greater, no adjustment is required for the subsequent dive. An oxygen dive undertaken after an Off-Oxygen Interval of more than 2 hours is considered to be the same as an initial oxygen exposure. If a negative number is obtained when adjusting the single-depth exposure limits as shown in Table 18-6, a 2-hour Off-Oxygen Interval must be taken before the next oxygen dive.

Table 18-6. *Adjusted Oxygen Exposure Limits for Successive Oxygen Dives.*

	Adjusted Maximum Oxygen Time	**Excursion**
Transit with Excursion Limits	Subtract oxygen time on previous dives from 240 minutes	Allowed if none taken on previous dives
Single-Depth Limits	1. Determine maximum oxygen time for deepest exposure. 2. Subtract oxygen time on previous dives from maximum oxygen time in Step 1 (above)	No excursion allowed when using Single-Depth Limits to compute remaining oxygen time

NOTE **A maximum of 4 hours oxygen time is permitted within a 24-hour period.**

Example. Ninety minutes after completing a previous oxygen dive with an oxygen time of 75 minutes (maximum dive depth 19 fsw), a dive pair will be making a second dive using the Transit with Excursion Limits. Calculate the amount of oxygen time for the second dive, and determine whether an excursion is allowed.

Solution. The second dive is considered a successive oxygen dive because the Off-Oxygen Interval was less than 2 hours. The allowed exposure time must be adjusted as shown in Table 18-6. The adjusted maximum oxygen time is 165 minutes (240 minutes minus 75 minutes previous oxygen time). A single excursion may be taken because the maximum depth of the previous dive was 19 fsw.

Example. Seventy minutes after completing a previous oxygen dive (maximum depth 28 fsw) with an oxygen time of 60 minutes, a dive pair will be making a second oxygen dive. The maximum depth of the second dive is expected to be 25 fsw. Calculate the amount of oxygen time for the second dive, and determine whether an excursion is allowed.

Solution. First compute the adjusted maximum oxygen time. This is determined by the Single-Depth Limits for the deeper of the two exposures (30 fsw for 80 minutes), minus the oxygen time from the previous dive. The adjusted maximum oxygen time for the second dive is 20 minutes (80 minutes minus 60 minutes previous oxygen time). No excursion is permitted using the Single-Depth Limits.

18-4.8 Exposure Limits for Oxygen Dives Following Mixed-Gas or Air Dives. When a subsequent dive must be conducted and if the previous exposure was an air or MK 16 dive, the exposure limits for the subsequent oxygen dive require no adjustment.

18-4.8.1 **Mixed-Gas to Oxygen Rule.** If the previous dive used a mixed-gas breathing mix having an oxygen partial pressure of 1.0 ata or greater, the previous exposure must be treated as a closed-circuit oxygen dive as described in paragraph 18-4.7. In this case, the Off-Oxygen Interval is calculated from the time the diver discontinued breathing the previous breathing mix until he begins breathing from the closed-circuit oxygen rig.

18-4.8.2 **Oxygen to Mixed-Gas Rule.** If a diver employs the MK 25 UBA for a portion of the dive and another UBA that uses a breathing gas other than oxygen for another portion of the dive, only the portion of the dive during which the diver was breathing oxygen is counted as oxygen time. The use of multiple UBAs is generally restricted to special operations. Decompression procedures for multiple-UBA diving must be in accordance with approved procedures.

Example. A dive scenario calls for three swim pairs to be inserted near a harbor using a SEAL Delivery Vehicle (SDV). The divers will be breathing compressed air for a total of 3 hours prior to leaving the SDV. No decompression is required as determined by the Combat Swimmer Multilevel Dive (CSMD) procedures. The SDV will surface and the divers will purge their oxygen rigs on the surface, take a compass bearing and begin the oxygen dive. The Transit with Excursion Limits rules will be used. There would be no adjustment necessary for the oxygen time as a result of the 3 hour compressed air dive.

18-4.9 Oxygen Diving at High Elevations. The oxygen exposure limits and procedures as set forth in the preceding paragraphs may be used without adjustment for closed-circuit oxygen diving at altitudes above sea level.

18-4.10 Flying After Oxygen Diving. Flying is permitted immediately after oxygen diving unless the oxygen dive has been part of a multiple-UBA dive profile in which the diver was also breathing another breathing mixture (air, N_2O_2, or HeO_2). In this case, the rules found in the paragraph 9-13 apply.

18-4.11 Combat Operations. The oxygen exposure limits in this section are the only limits approved for use by the U.S. Navy and should not be exceeded in a training or exercise scenario. Should combat operations require a more severe oxygen exposure, an estimate of the increased risk of CNS oxygen toxicity may be obtained from a Diving Medical Officer or the Naval Experimental Diving Unit. The advice of a Diving Medical Officer is essential in such situations and should be obtained whenever possible.

18-4.12 References for Additional Information.

- *CNS Oxygen Toxicity in Closed-Circuit Scuba Divers*; NEDU Report 11-84
- *CNS Oxygen Toxicity in Closed-Circuit Scuba Divers II*; NEDU Report 3-85
- *CNS Oxygen Toxicity in Closed-Circuit Scuba Divers III*; NEDU Report 5-86
- *Diving with Self-Contained Underwater Operating Apparatus*; NEDU Report 11-54
- *Symptoms of Oxygen Poisoning and Limits of Tolerance at Rest and at Work*; NEDU Report 1-47
- "Oxygen Poisoning in Man"; K. W. Donald; *British Medical Journal*, 1947; 1:667-672, 712-717

18-5 OPERATIONS PLANNING

Certain factors must be taken into consideration in the planning of the oxygen dive operation. The following gives detailed information on specific areas of planning.

18-5.1 Operating Limitations. Diving Officers and Diving Supervisors must consider the following potential limiting factors when planning closed-circuit oxygen combat swimmer operations:

- UBA oxygen supply (paragraph 18-3.2)
- UBA canister duration (NAVSEA 10560 ltr ser 00C35/3215, 22 Apr 96)
- Oxygen exposure limits (paragraphs 18-4.7 and 18-4.8)
- Thermal factors (Chapter 11 and Chapter 19)

18-5.2 Maximizing Operational Range. The operational range of the UBA may be maximized by adhering to these guidelines:

- Whenever possible, plan the operation using the turtleback technique, in which the diver swims on the surface part of the time, breathing air where feasible.
- Use tides and currents to maximum advantage. Avoid swimming against a current when possible.
- Ensure that oxygen bottles are charged to a full 3,000 psig (200 bar) before the dive.
- Minimize gas loss from the UBA by avoiding leaks and unnecessary depth changes.
- Maintain a comfortable, relaxed swim pace during the operation. For most divers, this is a swim speed of approximately 0.8 knot. At high exercise rates,

the faster swim speed is offset by a disproportionately higher oxygen consumption, resulting in a net decrease in operating range. High exercise rates may reduce the oxygen supply duration below the canister carbon dioxide scrubbing duration and become the limiting factor for the operation (paragraph 18-3.2)

- Ensure divers wear adequate thermal protection. A cold diver will begin shivering or increase his exercise rate, either of which will increase oxygen consumption and decrease the operating duration of the oxygen supply.

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

18-5.3 **Training.** Training and requalification dives shall be performed with the following considerations in mind:

- Training dives shall be conducted with equipment that reflects what the diver will be required to use on operations. This should include limpets, demolitions, and weapons as deemed appropriate.

- Periodic classroom refresher training shall be conducted in oxygen diving procedures, CNS oxygen toxicity and management of diving accidents.

- Develop a simple set of hand signals, including the following signals:

— Surface	— Okay
— Emergency Surface	— Feel Strange
— Descend	— Ear Squeeze
— Ascend	— Stop
— Speed Up	— Caution
— Slow Down	— Excursion

- Match swim pairs according to swim speed.

- If long duration oxygen swims are to be performed, work-up dives of gradually increasing length are recommended.

18-5.4 **Personnel Requirements.** The following topside personnel must be present on all training and exercise closed-circuit oxygen dives:

- Diving Supervisor/Boat Coxswain

- Standby diver/surface swimmer with air (not oxygen) scuba

- Diving Medical Technician/Special Operations Technician (standby diver tender)

18-5.5 **Equipment Requirements.** The operational characteristics of the MK 25 UBA are shown in Table 18-7. Equipment requirements for training and exercise closed-circuit oxygen dives are shown in Table 18-8. Several equipment items merit special consideration as noted below:

Table 18-7. *Equipment Operational Characteristics.*

Diving Equipment	Normal Working Limit (fsw) (Notes 1 and 2)	Maximum Working Limit (fsw) (Note 1)	Chamber Requirement	Minimum Personnel
MK 25 UBA	25 (Note 3)	50	None	5

Notes:

1. Depth limits are based on considerations of working time, decompression obligation, oxygen tolerance and nitrogen narcosis. The expected duration of the gas supply, the expected duration of the carbon dioxide absorbent, the adequacy of thermal protection or other factors may also limit both the depth and the duration of the dive.
2. A Diving Medical officer is required on site for all dives exceeding the normal working limit.
3. The normal depth limit for closed-circuit oxygen diving operations should be 25 fsw. The option of making an excursion to a greater depth (down to 50 fsw), if required during a dive, is acceptable and not considered “exceptional exposure.” A Diving Medical officer is not required on site for an excursion or a single-depth dive.

- **Motorized Chase Boat**. A minimum of one motorized chase boat must be present for the dive. Safe diving practice in many situations, however, would require the presence of more than one chase boat (e.g., night operations). The Diving Supervisor must determine the number of boats required based on the diving area, medical evacuation plan and number of personnel participating in the dive. When more than one safety craft is used, communications between support craft should be available.

- **Buddy Lines**. Because the risk is greater that a diver will become unconscious or disabled during a closed-circuit oxygen dive than during other types of dives, buddy lines are required equipment for oxygen dives. In a few special diving scenarios, when their use may hinder or endanger the divers, buddy lines may not be feasible. The Diving Supervisor must carefully consider each situation and allow buddy lines to be disconnected only when their use will impede the performance of the mission.

- **Depth Gauge**. The importance of maintaining accurate depth control on oxygen swims mandates that a depth gauge be worn by each diver.

18-5.6 **Transport and Storage of Prepared UBA.** Once the UBA has been set up, the mouthpiece valve must be placed in the SURFACE position and the oxygen-supply valve turned off. In this configuration, the rig is airtight and the carbon dioxide absorbent in the canister is protected from moisture which can impair carbon dioxide absorption. Two weeks is the maximum allowable time a rig may be stored from preparation to the time the rig is used.

Table 18-8. Closed-Circuit Oxygen Diving Equipment.

A. General

1. Motorized chase boat*
2. Radio (radio communications with parent unit, chamber, medevac units, and support craft when feasible)
3. High-intensity, wide-beam light (night operations)
4. Dive flags and/or dive lights as required

B. Diving Supervisor

1. Dive watch
2. Dive pair list
3. Recall devices
4. Copy of Oxygen Exposure Limits
5. Copy of Air Tables

C. Standby Diver

1. Compressed-air scuba
2. Weight belt (if needed)
3. Approved life jacket
4. Face mask
5. Fins
6. Appropriate thermal protection
7. Dive knife
8. Flare
9. Tending line
10. Depth gauge
11. Dive watch

D. Diving Medical Technician

1. Self-inflating bag-mask ventilator with medium adult mask
2. Oro-pharyngeal airway, adaptable to mask used
3. First aid kit/portable O_2
4. Two canteens of fresh water for treating chemical injury

E. Divers

Required:

1. Approved life jacket
2. Weight belt
3. Face mask
4. Fins
5. Dive knife
6. Flare
7. Dive watch
8. Appropriate thermal protection
9. Whistle
10. Buddy line (one per pair)*
11. Depth gauge (large face; accurate at shallow depths; one per diver)*
12. Compass (one per pair if on compass course)

Optional:

1. Gloves
2. Buoy (one per pair)
3. Slate with writing device

* See paragraph 18-5.5

High temperatures during transport and storage will not adversely affect approved CO_2 absorbent; however, storage temperatures below freezing may decrease performance and should be avoided. Should additional carbon dioxide absorbents other than those provided in Table 18-3 be approved for use in closed-circuit UBAs, the manufacturer's recommendations regarding storage temperatures shall be followed.

In the event an operation calls for an oxygen dive followed by a surface interval and a second oxygen dive, the UBA shall be sealed during the surface interval as described above. It is not necessary to change carbon dioxide absorbent in the UBA before the second dive as long as the combined oxygen time of both dives does not exceed the canister duration limits.

18-5.7 Predive Precautions. The following items shall be determined prior to the diving operation:

- Means of communicating with the nearest available Diving Medical Officer.

- Location of the nearest functional recompression chamber. Positive confirmation of the chamber's availability must be obtained prior to diving.

- Nearest medical facility for treatment of injuries or medical problems not requiring recompression therapy.

- Optimal method of transportation to recompression chamber or medical facility. If coordination with other units for aircraft/boat/vehicle support is necessary, the Diving Supervisor must know the frequencies, call signs and contact personnel needed to make transportation available in case of emergency. A medical evacuation plan must be included in the Diving Supervisor brief.

- The preparation of a checklist similar to that found in Chapter 6 is recommended.

- When operations are to be conducted in the vicinity of ships, the guidelines provided in the Ship Repair Safety Checklist (Chapter 6) and appropriate Naval Special Warfare Group instructions shall be followed.

- Notification of intent to conduct diving operations must be sent to the appropriate authority in accordance with local directives.

18-6 PREDIVE PROCEDURES

This section provides the predive procedures for closed-circuit oxygen dives.

18-6.1 Equipment Preparation. The predive set up of the MK 25 (Draeger LAR V) is performed using the appropriate checklist from the appropriate MK 25 (UBA LAR V) Operation and Maintenance Manual. Transport and storage guidelines found in paragraph 18-5.6 shall be followed.

18-6.2 Diving Supervisor Brief. The Diving Supervisor brief shall be given separately from the overall mission brief and shall focus on the diving portion of the operation with special attention to the items shown in Table 18-9.

18-6.3 Diving Supervisor Check.

18-6.3.1 **First Phase.** The Diving Supervisor check is accomplished in two stages. As the divers set up their rigs prior to the dive, the Diving Supervisor must ensure that the steps in the set up procedure are accomplished properly. The Diving Supervisor checklist [see MK 25 (UBA LAR V) Operation and Maintenance Manual] is completed during this phase.

18-6.3.2 **Second Phase.** The second phase of the Diving Supervisor check is done after the divers are dressed. At this point, the Diving Supervisor must check for the following items:

- Adequate oxygen pressure

Table 18-9. Diving Supervisor Brief.

A. **Dive Plan**
   1. Operating depth
   2. Distance, bearings, transit lines
   3. Dive time
   4. Known obstacles or hazards

B. **Environmental**
   1. Weather conditions
   2. Water/air temperatures
   3. Water/air visibility
   4. Diving medical technician

C. **Special Equipment for:**
   1. Divers (include thermal garment)
   2. Diving supervisor
   3. Standby Diver
   4. Diving medical technician

D. **Review of Hand Signals**

E. **Communications**
   1. Frequencies
   2. Call signs

F. **Emergency Procedures**
   1. Symptoms of O_2 Toxicity - review in detail
   2. Symptoms of CO_2 buildup - review in detail
   3. Review management of underwater convulsion, nonconvulsive O_2 hit, CO_2 buildup, hypoxia, chemical injury, unconscious diver
   4. UBA malfunction
   5. Lost swim-pair procedures
   6. Medical evacuation plan
      - nearest available chamber
      - nearest Diving Medical Officer (DMO)
      - transportation plan
      - recovery of other swim pairs

G. **Review of Purge Procedure**

H. **Times for Operations**

- Proper functioning of hose one-way valves
- Loose-fitting waist strap
- Proper donning of UBA, life jacket and weight belt. The weight belt is worn so it may be easily released
- Presence of required items such as compasses, depth gauges, dive watches, buddy lines, and tactical equipment

18-7 WATER ENTRY AND DESCENT

The diver is required to perform a purge procedure prior to or during any dive in which closed-circuit oxygen UBA is to be used. The purge procedure is designed to eliminate the nitrogen from the UBA and the diver's lungs as soon as he begins breathing from the rig. This procedure prevents the possibility of hypoxia as a result of excessive nitrogen in the breathing loop. The gas volume from which this excess nitrogen must be eliminated is comprised of more than just the UBA breathing bag. The carbon dioxide-absorbent canister, inhalation/exhalation hoses, and diver's lungs must also be purged of nitrogen.

18-7.1 **Purge Procedure.** Immediately prior to entering the water, the divers shall carry out the appropriate purge procedure. It is both difficult and unnecessary to eliminate nitrogen completely from the breathing loop. The purge procedure need only raise the fraction of oxygen in the breathing loop to a level high enough to prevent the diver from becoming hypoxic, as discussed in paragraph 18-2.2. For the MK

25 UBA, this value has been determined to be 45 percent. For further information on purge procedures, see paragraph 18-7.4.

If the dive is part of a tactical scenario that requires a turtleback phase, the purge must be done in the water after the surface swim, prior to submerging. If the tactical scenario requires an underwater purge procedure, this will be completed while submerged after an initial subsurface transit on open-circuit scuba or other UBA. When the purge is done in either manner, the diver must be thoroughly familiar with the purge procedure and execute it carefully with attention to detail so that it may be accomplished correctly in this less favorable environment.

18-7.2 **Turtleback Emergency Descent Procedure.** This procedure is approved for turtleback emergency descents:

1. Open the oxygen supply.
2. Exhale completely, clearing the mouthpiece with the dive/surface valve in the surface position.
3. Put the dive/surface valve in the DIVE position and make the emergency descent.
4. Immediately upon reaching depth, perform purging under pressure (pressurized phase) (IAW the appropriate MK 25 Technical Manual).

18-7.3 **Avoiding Purge Procedure Errors.** The following errors may result in a dangerously low percentage of oxygen in the UBA and should be avoided:

- Exhaling back into the bag with the last breath rather than to the atmosphere while emptying the breathing bag.
- Underinflating the bag during the fill segment of the fill/empty cycle.
- Adjusting the waist strap of the UBA or adjustment straps of the life jacket too tightly. Lack of room for bag expansion may result in underinflation of the bag and inadequate purging.
- Breathing gas volume deficiency caused by failure to turn on the oxygen-supply valve prior to underwater purge procedures.

18-7.4 **References for Additional Information.** The following references provide information on the LAR V purge procedures:

- *Purging Procedures for the Draeger LAR V Underwater Breathing Apparatus*; NEDU Report 5-84
- *Underwater Purging Procedures for the Draeger LAR V UBA*; NEDU Report 6-86

- *MK 25 UBA (LAR V) Operation and Maintenance Manual*; NAVSEA SS600-AJ-MMO-010, Change 1, January 1, 1985

18-8 UNDERWATER PROCEDURES

18-8.1 General Guidelines. During the dive, the divers shall adhere to the following guidelines:

- Know and observe the oxygen exposure limits.
- Observe the UBA canister limit for the expected water temperature [see NAVSEA 10560 ltr ser 00C35/3215, 22 Apr 96].
- Wear the appropriate thermal protection.
- Use the proper weights for the thermal protection worn and for equipment carried.
- Wear a depth gauge to allow precise depth control. The depth for the pair of divers is the greatest depth attained by either diver.
- Dive partners check each other carefully for leaks at the onset of the dive. This should be done in the water after purging, but before descending to transit depth.
- Swim at a relaxed, comfortable pace as established by the slower swimmer of the pair.
- Maintain frequent visual or touch checks with buddy.
- Be alert for any symptoms suggestive of a medical disorder (CNS oxygen toxicity, carbon dioxide buildup, etc.).
- Use tides and currents to maximum advantage.
- Swim at 25 fsw or shallower unless operational requirements dictate otherwise.
- Use the minimum surface checks consistent with operational necessity.
- Minimize gas loss from the UBA.
- Do not use the UBA breathing bag as a buoyancy compensation device.
- Do not perform additional purges during the dive unless the mouthpiece is removed and air is breathed.
- If an excursion is taken, the diver not using the compass will note carefully the starting and ending time of the excursion.

18-8.2 UBA Malfunction Procedures. The diver shall be thoroughly familiar with the malfunction procedures unique to his UBA. These procedures are described in the appropriate UBA MK 25 Operational and Maintenance Manual.

18-9 ASCENT PROCEDURES

The ascent rate shall never exceed 30 feet per minute.

18-10 POSTDIVE PROCEDURES AND DIVE DOCUMENTATION

UBA postdive procedures should be accomplished using the appropriate checklist from the appropriate UBA MK 25 Operation and Maintenance Manual.

Document all dives performed by submitting a Combined Diving Log and Mishap/Injury Report.

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