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WARNING Hypoxia and hypercapnia may give the diver little or no warning prior to onset of unconsciousness. (Page 15-28)

WARNING Most CC-UBAs do not have a carbon dioxide-monitoring capability. Failure to adhere to canister duration operations planning could lead to unconsciousness and/or death. (Page 16-14)

CAUTION Defibrillation is not currently authorized at depth. (Page 17-8)

CAUTION If the tender is outside of no-decompression limits, take appropriate steps to manage the tender's decompression obligation. (Page 17-8)

CAUTION If tenders are outside of no-decompression limits, take appropriate steps to manage the tender's decompression obligation. If the pulseless diver does not regain a pulse with application of an AED, continue resuscitation efforts until the diver recovers, the rescuers are unable to continue CPR, or a physician pronounces the patient dead. Avoid recompressing a pulseless diver who has failed to regain vital signs after use of an AED. (Page 17-8)

NOTE If deterioration or recurrence of symptoms is noted during ascent to 60 feet, treat as a recurrence of symptoms. (Page 17-18)

CAUTION Inserting an airway device or bite block is not recommended while the patient is convulsing; it is not only difficult, but may cause harm if attempted. (Page 17-26)

WARNING Drug therapy shall be administered only after consultation with a Undersea Medical Officer and only by qualified inside tenders adequately trained and capable of administering prescribed medications. (Page 17-32)

CAUTION AED's are not currently approved for use under pressure (hyperbaric environment) due to electrical safety concerns. (Page 17-36)

NOTE Some vendors supply pre-packed ACLS kits with automated replenishment programs (examples of which can be found on the Naval Expeditionary Combat Command (NECC) AMAL). (Page 17-41)

NOTE Stoppered multi-dose vials with large air volumes may need to be vented with a needle during pressurization and depressurization and then discarded. (Page 17-41)

WARNING The gag valve must remain open at all times. Close only if relief valve fails. (Page 18-20)

WARNING This procedure is to be performed with an unmanned chamber to avoid exposing occupants to unnecessary risks. (Page 18-21)

WARNING Fire/Explosion Hazard. No matches, lighters, electrical appliances, or flammable materials permitted in chamber. (Page 18-30)

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tion system. As the diver consumed oxygen, an oxygen sensor detected the fall in oxygen partial pressure and signaled an oxygen valve to open, allowing a small amount of pure oxygen to be admitted to the breathing circuit from a cylinder. Oxygen addition was thus exactly matched to metabolic consumption. Exhaled carbon dioxide was absorbed in an absorption canister. The system had the endurance and completely closed-circuit characteristics of an oxygen rebreather without the concerns and limitations associated with oxygen toxicity.

Beginning in 1979, the MK 6 semiclosed-circuit underwater breathing apparatus (UBA) was phased out by the MK 15 closed-circuit, constant oxygen partial pressure UBA. The Navy Experimental Diving Unit developed decompression procedures for the MK 15 with nitrogen and helium in the early 1980s. In 1985, an improved low magnetic signature version of the MK 15, the MK 16, was approved for Explosive Ordnance Disposal (EOD) team use.

1-3.5 **SCUBA Use During World War II.** Although closed-circuit equipment was restricted to shallow-water use and carried with it the potential danger of oxygen toxicity, its design had reached a suitably high level of efficiency by World War II. During the war, combat diver breathing units were widely used by navies on both sides of the conflict. The swimmers used various modes of underwater attack. Many notable successes were achieved including the sinking of several battleships, cruisers, and merchant ships.

1-3.5.1 **Diver-Guided Torpedoes.** Italian divers, using closed-circuit gear, rode chariot torpedoes fitted with seats and manual controls in repeated attacks against British ships. In 1936, the Italian Navy tested a chariot torpedo system in which the divers used a descendant of the Fleuss SCUBA. This was the Davis Lung (Figure 1-10). It was originally designed as a submarine escape device and was later manufactured in Italy under a license from the English patent holders.

Figure 1-10. Original Davis Submerged Escape Apparatus.

British divers, carried to the scene of action in midget submarines, aided in placing explosive charges under the keel of the German battleship *Tirpitz*. The British began their chariot program in 1942 using the Davis Lung and exposure suits. Swimmers using the MK 1 chariot dress quickly discovered that the steel oxygen bottles adversely affected the compass of the chariot torpedo. Aluminum oxygen cylinders were not readily available in England, but German aircraft used aluminum oxygen cylinders that were almost the same size as the steel cylinders aboard the chariot torpedo. Enough aluminum cylinders were salvaged from downed enemy bombers to supply the British forces.

Changes introduced in the MK 2 and MK 3 diving dress involved improvements in valving, faceplate design, and arrangement of components. After the war, the MK 3 became the standard Royal Navy shallow water diving dress. The MK 4 dress was used near the end of the war. Unlike the MK 3, the MK 4 could be supplied with oxygen from a self-contained bottle or from a larger cylinder carried in the chariot. This gave the swimmer greater endurance, yet preserved freedom of movement independent of the chariot torpedo.

In the final stages of the war, the Japanese employed an underwater equivalent of their kamikaze aerial attack—the kaiten diver-guided torpedo.

1-3.5.2 **U.S. Combat Swimming.** There were two groups of U.S. combat divers during World War II: Naval beach reconnaissance swimmers and U.S. operational swimmers. Naval beach reconnaissance units did not normally use any breathing devices, although several models existed.

U.S. operational swimmers, however, under the Office of Strategic Services, developed and applied advanced methods for true self-contained diver-submersible operations. They employed the Lambertsen Amphibious Respiratory Unit (LARU), a rebreather invented by Dr. C.J. Lambertsen (see Figure 1-11). The LARU was a closed-circuit oxygen UBA used in special warfare operations where a complete absence of exhaust bubbles was required. Following World War II, the Emerson-Lambertsen Oxygen Rebreather replaced the LARU (Figure 1-12). The Emerson Unit was used extensively by Navy special warfare divers until 1982, when it was replaced by the Draeger Lung Automatic Regenerator (LAR) V. The LAR V is the standard unit now used by U.S. Navy combat divers (see Figure 1-13).

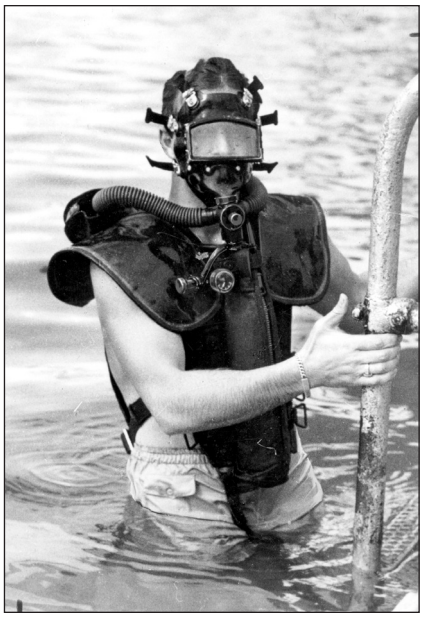

Figure 1-11. Lambertsen Amphibious Respiratory Unit (LARU).

Today Navy divers are organized into two separate groups, Special Operations Forces (SOF) and Non-SOF, each with specialized training and missions. The Explosive Ordnance Disposal (EOD) team handles, defuses, and disposes of munitions and other explosives. The Sea, Air and Land (SEAL) special warfare teams make up the second group of Navy combat divers. SEAL team members are trained to operate in all of these environments. They qualify as parachutists, learn to handle a range of weapons, receive intensive training in hand-to-hand combat, and are expert in SCUBA and other swimming and diving techniques. In Vietnam, SEALs were deployed in special counter-insurgency and guerrilla warfare operations. The SEALs also participated in the

T-ARS	Auxiliary Rescue/Salvage Ship
T-ATF	Fleet Ocean Tug
TBT	Total Bottom Time
TDCS	Tethered Diver Communication System
TDT	Total Decompression Time
TL	Transfer Lock
TLC	Total Lung Capacity
TLD	Thermal Luminescence Dosimeter
TLV	Threshold Limit Values
TM	Technical Manual
TMDER	Technical Manual Deficiency Evaluation Report
TRC	Transportable Recompression Chamber
TRCS	Transportable Recompression Chamber System
TTD	Total Time of Dive
UBA	Underwater Breathing Apparatus
UCT	Underwater Construction Team
UDM	Underwater Decompression Monitor
UMO	Undersea Medical Officer
UQC	Underwater Sound Communications
UWSH	Underwater Ship Husbandry
VENTIDC	Vision Ear Nausea Twitching Irritability Dizziness Convulsions
VTA	Volume Tank Assembly
VVDS	Variable Volume Dry Suit
WOB	Work of Breathing
YDT	Diving Tender

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17-8.1 **Oxygen Control.** All treatment schedules listed in this chapter are usually performed with a chamber atmosphere of air. To accomplish safe decompression, the oxygen percentage should not be allowed to fall below 19 percent. Oxygen may be added to the chamber by ventilating with air or by bleeding in oxygen from an oxygen breathing system. If a portable oxygen analyzer is available, it can be used to determine the adequacy of ventilation and/or addition of oxygen. If no oxygen analyzer is available, ventilation of the chamber in accordance with paragraph 17-8.4 will ensure adequate oxygenation. Chamber oxygen percentages as high as 25 percent are permitted. If the chamber is equipped with a life-support system so that ventilation is not required and an oxygen analyzer is available, the oxygen level should be maintained between 19 percent and 25 percent. If chamber oxygen goes above 25 percent, ventilation with air should be used to bring the oxygen percentage down.

17-8.2 **Carbon Dioxide Control.** Ventilation of the chamber in accordance with paragraph 17-8.4 will ensure that carbon dioxide produced metabolically does not cause the chamber carbon dioxide level to exceed 1.5 percent SEV (11.4 mmHg).

17-8.2.1 **Carbon Dioxide Monitoring.** Chamber carbon dioxide should be monitored with electronic carbon dioxide monitors. Monitors generally read CO_2 percentage once chamber air has been exhausted to the surface. The CO_2 percent reading at the surface 1 ata must be corrected for depth. To keep chamber CO_2 below 1.5 percent SEV (11.4 mmHg), the surface CO_2 monitor values should remain below 0.78 percent with chamber depth at 30 feet, 0.53 percent with chamber depth at 60 feet, and 0.25 percent with the chamber at 165 feet. If the CO_2 analyzer is within the chamber, no correction to the CO_2 readings is necessary.

17-8.2.2 **Carbon Dioxide Scrubbing.** If the chamber is equipped with a carbon dioxide scrubber, the absorbent should be changed when the partial pressure of carbon dioxide in the chamber reaches 1.5 percent SEV (11.4 mmHg). If absorbent cannot be changed, supplemental chamber ventilation will be required to maintain chamber CO_2 at acceptable levels. With multiple or working chamber occupants, supplemental ventilation may be necessary to maintain chamber CO_2 at acceptable levels.

17-8.2.3 **Carbon Dioxide Absorbent.** CO_2 absorbent may be used beyond the expiration date when used in a recompression chamber equipped with a CO_2 monitor. When used in a recompression chamber that has no CO_2 monitor, CO_2 absorbent in an opened but resealed bucket may be used until the expiration date on the bucket is reached. Pre-packed, double-bagged canisters shall be labeled with the expiration date from the absorbent bucket for recompression chambers with no CO_2 monitor.

17-8.3 **Temperature Control.** Internal chamber temperature should be maintained at a level comfortable to the occupants whenever possible. Cooling can usually be accomplished by chamber ventilation. If the chamber is equipped with a heater/chiller unit, temperature control can usually be maintained for chamber occupant comfort under any external environmental conditions. Usually, recompression chambers will become hot and must be cooled continuously. Chambers should always be shaded from direct sunlight. The maximum durations for chamber occupants will depend on the internal chamber temperature as listed in Table 17-5. Never commit to a treatment table that will expose the chamber occupants to

greater temperature/time combinations than listed in Table 17-5 unless qualified medical personnel who can evaluate the trade-off between the projected heat stress and the anticipated treatment benefit are consulted. A chamber temperature below 85°F (29°C) is always desirable, no matter which treatment table is used.

For patients with brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of AGE or severe neurological DCS, hot environments that elevate body temperature above normal should be avoided, whenever possible. Patient temperature should be a routinely monitored vital sign.

Table 17-5. *Maximum Permissible Recompression Chamber Exposure Times at Various Internal Chamber Temperatures.*

Internal Temperature	Maximum Tolerance Time	Permissible Treatment Tables
Over 104°F (40°C)	Intolerable	No treatments
95–104°F (34.4–40°C)	2 hours	Table 5, 9
85–94°F (29–34.4°C)	6 hours	Tables 5, 6, 6A, 1A, 9
Under 85°F (29°C)	Unlimited	All treatments

NOTE:
Internal chamber temperature can be kept considerably below ambient by venting or by using an installed chiller unit. Internal chamber temperature can be measured using electronic, bimetallic, alcohol, or liquid crystal thermometers. Never use a mercury thermometer in or around hyperbaric chambers. Since chamber ventilation will produce temperature swings during ventilation, the above limits should be used as averages when controlling temperature by ventilation. Always shade chamber from direct sunlight.

17-8.3.1 **Patient Hydration.** Always ensure patients are adequately hydrated. Fully conscious patients may be given fluid by mouth to maintain adequate hydration. One to two liters of water, juice, or non-carbonated drink, over the course of a Treatment Table 5 or 6, is usually sufficient. Patients with Type II symptoms, or symptoms of arterial gas embolism, should be considered for IV fluids. Stuporous or unconscious patients should always be given IV fluids, using large-gauge plastic catheters. If trained personnel are present, an IV should be started as soon as possible and kept dripping at a rate of 75 to 100 cc/hour, using isotonic fluids (Lactated Ringer's Solution, Normal Saline) until specific instructions regarding the rate and type of fluid administration are given by qualified medical personnel. Avoid solutions containing glucose (Dextrose) if brain or spinal cord injury is present. Intravenously administered glucose may worsen the outcome. In some cases, the bladder may be paralyzed. The victim's ability to void shall be assessed as soon as possible. If the patient cannot empty a full bladder, a urinary catheter shall be inserted as soon as possible by trained personnel. Always inflate catheter balloons with liquid, not air. Adequate fluid is being given when urine output is at least 0.5cc/kg/hr. Thirst is an unreliable indicator of the water intake to compensate

for heavy sweating. A useful indicator of proper hydration is a clear colorless urine.

17-8.4 **Chamber Ventilation.** Ventilation is the usual means of controlling oxygen level, carbon dioxide level, and temperature. Ventilation using air is required for chambers without carbon dioxide scrubbers and atmospheric analysis. A ventilation rate of two acfm for each resting occupant, and four acfm for each active occupant, should be used. These procedures are designed to assure that the effective concentration of carbon dioxide will not exceed 1.5 percent sev (11.4 mmHg) and that, when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent.

17-8.5 **Access to Chamber Occupants.** Recompression treatments usually require access to occupants for passing in items such as food, water, and drugs and passing out such items as urine, excrement, and trash. Never attempt a treatment longer than a Treatment Table 6 unless there is access to inside occupants. When doing a Treatment Table 4, 7, or 8, a double-lock chamber is mandatory because additional personnel may have to be locked in and out during treatment.

17-8.6 **Inside Tender Oxygen Breathing.** During treatments, all chamber occupants may breathe 100 percent oxygen at depths of 45 feet or shallower without locking in additional personnel. Tenders should not fasten the oxygen masks to their heads, but should hold them on their faces. When deeper than 45 feet, at least one chamber occupant must breathe air. Tender oxygen breathing requirements are specified in the figure for each Treatment Table.

17-8.7 **Tending Frequency.** Normally, tenders should allow a surface interval of at least 18 hours between consecutive treatments on Treatment Tables 1A, 2A, 3, 5, 6, and 6A, and at least 48 hours between consecutive treatments on Tables 4, 7, and 8. If necessary, however, tenders may repeat Treatment Tables 5, 6, or 6A within this 18-hour surface interval if oxygen is breathed at 30 feet and shallower as outlined in Table 17-7. Minimum surface intervals for Treatment Tables 1A, 2A, 3, 4, 7, and 8 shall be strictly observed.

17-8.8 **Equalizing During Descent.** Descent rates may have to be decreased as necessary to allow the patient to equalize; however, it is vital to attain treatment depth in a timely manner for a suspected arterial gas embolism patient.

17-8.9 **Use of High Oxygen Mixes.** High oxygen N_2O_2/HeO_2 mixtures may be used to treat patients when recompression deeper than 60 fsw is required. These mixtures offer significant therapeutic advantages over air. Select a treatment gas that will produce a ppO_2 between 1.5 and 3.0 ata at the treatment depth. The standardized gas mixtures shown in Table 17-6 are suitable over the depth range of 61-225 fsw.

Decompression sickness following helium dives can be treated with either nitrogen or helium mixtures. For recompression deeper than 165 fsw, helium mixtures are preferred to avoid narcosis. The situation is less clear for treatment of decompression sickness following air or nitrogen-oxygen dives. Experimental studies have shown both benefit and harm with helium treatment. Until more experience is obtained,

high oxygen mixtures with nitrogen as the diluent gas are preferred if available. High oxygen mixtures may also be substituted for 100% oxygen at 60 fsw and shallower on Treatment Tables 4, 7, and 8 if the patient is unable to tolerate 100% oxygen.

Table 17-6. *High Oxygen Treatment Gas Mixtures.*

Depth (fsw)	Mix (HeO_2 or N_2O_2)	ppO_2
0-60	100%	1.00-2.82
61-165	50/50	1.42-3.00
166-225	64/36 (HeO_2 only)	2.17-2.81

17-8.10 Oxygen Toxicity During Treatment. Acute CNS oxygen toxicity may develop on any oxygen treatment table.

During prolonged treatments on Treatment Tables 4, 7, or 8, and with repeated Treatment Table 6, pulmonary oxygen toxicity may also develop.

17-8.10.1 **Central Nervous System Oxygen Toxicity.** When employing the oxygen treatment tables, tenders must be particularly alert for the early symptoms of CNS oxygen toxicity. The symptoms can be remembered readily by using the mnemonic VENTID-C (Vision, Ears, Nausea, Twitching\Tingling, Irritability, Dizziness, Convulsions). Unfortunately, a convulsion may occur without early warning signs or before the patient can be taken off oxygen in response to the first sign of CNS oxygen toxicity. CNS oxygen toxicity is unlikely in resting individuals at chamber depths of 50 feet or shallower and very unlikely at 30 feet or shallower, regardless of the level of activity. However, patients with severe Type II decompression sickness or arterial gas embolism symptoms may be abnormally sensitive to CNS oxygen toxicity. Convulsions unrelated to oxygen toxicity may also occur and may be impossible to distinguish from oxygen seizures.

17-8.10.1.1 ***Procedures in the Event of CNS Oxygen Toxicity.*** At the first sign of CNS oxygen toxicity, the patient should be removed from oxygen and allowed to breathe chamber air. Fifteen minutes after all symptoms have subsided, resume oxygen breathing. For Treatment Tables 5, 6, 6A resume treatment at the point of interruption. For Treatment Tables 4, 7 and 8 no compensatory lengthening of the table is required. If symptoms of CNS oxygen toxicity develop again or if the first symptom is a convulsion, take the follow action:

CAUTION **Inserting an airway device or bite block is not recommended while the patient is convulsing; it is not only difficult, but may cause harm if attempted.**

For Treatment Tables 5, 6, and 6A:

- Remove the mask.

- After all symptoms have completely subsided, decompress 10 feet at a rate of 1 fsw/min. For a convulsion, begin travel when the patient is fully relaxed and breathing normally.
- Resume oxygen breathing at the shallower depth at the point of interruption.
- If another oxygen symptom occurs after ascending 10 fsw, contact a Undersea Medical Officer to recommend appropriate modifications to the treatment schedule.

For Treatment Tables 4, 7, and 8:

- Remove the mask.
- Consult with a Undersea Medical Officer before administering further oxygen breathing. No compensatory lengthening of the table is required for interruption in oxygen breathing.

17-8.10.2 **Pulmonary Oxygen Toxicity.** Pulmonary oxygen toxicity is unlikely to develop on single Treatment Tables 5, 6, or 6A. On Treatment Tables 4, 7, or 8 or with repeated Treatment Tables 5, 6, or 6A (especially with extensions) prolonged exposure to oxygen may result in end-inspiratory discomfort, progressing to substernal burning and severe pain on inspiration. If a patient who is responding well to treatment complains of substernal burning, discontinue use of oxygen and consult with a UMO. However, if a significant neurological deficit remains and improvement is continuing (or if deterioration occurs when oxygen breathing is interrupted), oxygen breathing should be continued as long as considered beneficial or until pain limits inspiration. If oxygen breathing must be continued beyond the period of substernal burning, or if the 2-hour air breaks on Treatment Tables 4, 7, or 8 cannot be used because of deterioration upon the discontinuance of oxygen, the oxygen breathing periods should be changed to 20 minutes on oxygen, followed by 10 minutes breathing chamber air or alternative treatment gas mixtures with a lower percentage of oxygen should be considered. The Undersea Medical Officer may tailor the above guidelines to suit individual patient response to treatment.

17-8.11 Loss of Oxygen During Treatment. Loss of oxygen breathing capability during oxygen treatments is a rare occurrence. However, should it occur, the following actions should be taken:

If repair can be completed within 15 minutes:

- Maintain depth until repair is completed.
- After O_2 is restored, resume treatment at point of interruption.

If repair can be completed after 15 minutes but before 2 hours:

- Maintain depth until repair is completed.
- After O_2 is restored: If original table was Table 5, 6, or 6A, complete treatment with maximum number of O_2 extensions.

17-8.11.1 **Compensation.** If Table 4, 7, or 8 is being used, no compensation in decompression is needed if oxygen is lost. If decompression must be stopped because of worsening symptoms in the affected diver, then stop decompression. When oxygen is restored, continue treatment from where it was stopped.

17-8.11.2 **Switching to Air Treatment Table.** If O_2 breathing cannot be restored in 2 hours switch to the comparable air treatment table at current depth for decompression if 60 fsw or shallower. Rate of ascent must not exceed 1 fpm between stops. If symptoms worsen and an increase in treatment depth deeper than 60 feet is needed, use Treatment Table 4.

17-8.12 Treatment at Altitude. Before starting recompression therapy, zero the chamber depth gauges to adjust for altitude. Then use the depths as specified in the treatment table. There is no need to "Cross Correct" the treatment table depths. Divers serving as inside tenders during hyperbaric treatments at altitude are performing a dive at altitude and therefore require more decompression than at sea level. Tenders locking into the chamber for brief periods should be managed according to the Diving At Altitude procedures (paragraph 9-13). Tenders remaining in the chamber for the full treatment table must breathe oxygen during the terminal portion of the treatment to satisfy their decompression requirement.

The additional oxygen breathing required at altitude on Treatment Table 5, Treatment Table 6, and Treatment Table 6A is given in Table 17-7. The requirement pertains both to tenders equilibrated at altitude and to tenders flown directly from sea level to the chamber location. Contact NEDU for guidance on tender oxygen requirements for other treatment tables.

17-9 POST-TREATMENT CONSIDERATIONS

Tenders on Treatment Tables 5, 6, 6A, 1A, 2A, or 3 should have a minimum of a 18-hour surface interval before no-decompression diving and a minimum of a 24-hour surface interval before dives requiring decompression stops. Tenders on Treatment Tables 4, 7, and 8 should have a minimum of a 48-hour surface interval prior to diving.

17-9.1 Post-Treatment Observation Period. After a treatment, patients treated on a Treatment Table 5 should remain at the recompression chamber facility for 2 hours. Patients who have been treated for Type II decompression sickness or who required a Treatment Table 6 for Type I symptoms and have had complete relief should remain at the recompression chamber facility for 6 hours. Patients treated on Treatment Tables 6, 6A, 4, 7, 8 or 9 are likely to require a period of hospitalization, and the Undersea Medical Officer will need to determine a post-treatment observation period and location appropriate to their response to recompression treatment. These times may be shortened upon the recommendation of a Undersea Medical Officer, provided the patient will be with personnel who are experienced at recognizing recurrence of symptoms and can return to the recompression facility within 30 minutes. All patients should remain within 60 minutes travel time of a recompression facility for 24 hours and should be accompanied throughout that period. No patient shall be released until authorized by a UMO.

Treatment table profiles place the inside tender(s) at risk for decompression sickness. After completing treatments, inside tenders should remain in the vicinity of the recompression chamber for 1 hour. If they were tending for Treatment Table 4, 7, or 8, inside tenders should also remain within 60 minutes travel time of a recompression facility for 24 hours.

Table 17-7. *Tender Oxygen Breathing Requirements. (Note 1)*

		Altitude		
Treatment Table (TT)		Surface to 2499 ft	2500 ft. - 7499 ft.	7500 ft. - 10,000 ft.
TT5 Note (2)	without extension	:00	:00	:00
	with extension @ 30 fsw	:00	:00	:20
TT6 Note (2)	up to one extension @ 60 fsw or 30 fsw	:30	:60	:90
	more than one extension	:60	:90	:120
TT6A Note (2)	up to one extension @ 60 fsw or 30 fsw	:60	:120	:150 Note (3)
	more than one extension	:90	:150 Note (3)	:180 Note (3)

Note 1: All tender O_2 breathing times in table are conducted at 30 fsw. In addition, tenders will breathe O_2 on ascent from 30 fsw to the surface.

Note 2: If the tender had a previous hyperbaric exposure within 18 hours, use the following guidance for administering O_2:
For TT5, add an additional 20 minute O_2 breathing period to the times in the table.
For TT6 or TT6A, add an additional 60 minute O_2 breathing period to the times in the table.
For other Treatment tables contact NEDU for guidance.

Note 3: In some instances, tender's oxygen breathing obligation exceeds the table stay time at 30 fsw. Extend the time at 30 fsw to meet these obligations if patient's condition permits. Otherwise, administer O_2 to the tender to the limit allowed by the treatment table and observe the tender on the surface for 1 hour for symptoms of DCS.

17-9.2 **Post-Treatment Transfer.** Patients with residual symptoms should be transferred to appropriate medical facilities as directed by qualified medical personnel. If ambulatory patients are sent home, they should always be accompanied by someone familiar with their condition who can return them to the recompression facility should the need arise. Patients completing treatment do not have to remain in the vicinity of the chamber if the Undersea Medical Officer feels that transferring them to a medical facility immediately is in their best interest.

17-9.3 **Flying After Treatments.** Patients with residual symptoms should fly only with the concurrence of a Undersea Medical Officer. Patients who have been treated for decompression sickness or arterial gas embolism and have complete relief should not fly for 72 hours after treatment, at a minimum.

Tenders on Treatment Tables 5, 6, 6A, 1A, 2A, or 3 should have a 24-hour surface interval before flying. Tenders on Treatment Tables 4, 7, and 8 should not fly for 72 hours.

17-9.3.1 **Emergency Air Evacuation.** Some patients will require air evacuation to another treatment or medical facility immediately after surfacing from a treatment. They will not meet surface interval requirements as described above. Such evacuation is done only on the recommendation of a Undersea Medical Officer. Aircraft pressurized to one ata should be used if possible, or unpressurized aircraft flown as low as safely possible (no more than 1,000 feet is preferable). Have the patient breathe 100 percent oxygen during transport, if available. If available, an Emergency Evacuation Hyperbaric Stretcher to maintain the patient at 1ata may be used.

17-9.4 Treatment of Residual Symptoms. After completion of the initial recompression treatment and after a surface interval sufficient to allow complete medical evaluation, additional recompression treatments may be instituted. If additional recompression treatments are indicated a Undersea Medical Officer must be consulted. Residual symptoms may remain unchanged during the first one or two treatments. In these cases, the Undersea Medical Officer is the best judge as to the number of recompression treatments. Consultation with NEDU or NDSTC may be appropriate. As the delay time between completion of initial treatment and the beginning of follow-up hyperbaric treatments increases, the probability of benefit from additional treatments decreases. However, improvement has been noted in patients who have had delay times of up to 1 week. Therefore, a long delay is not necessarily a reason to preclude follow-up treatments. Once residual symptoms respond to additional recompression treatments, such treatments should be continued until no further benefit is noted. In general, treatment may be discontinued if there is no further sustained improvement after two consecutive treatments.

For persistent Type II symptoms, daily treatment on Table 6 may be used, but twice-daily treatments on Treatment Tables 5 or 9 may also be used. The treatment table chosen for re-treatments must be based upon the patient's medical condition and the potential for pulmonary oxygen toxicity. Patients surfacing from Treatment Table 6A with extensions, 4, 7, or 8 may have severe pulmonary oxygen toxicity and may find breathing 100 percent oxygen at 45 or 60 feet to be uncomfortable or even intolerable. In these cases, daily treatments at 30 feet may also be used. As many oxygen breathing periods (25 minutes on oxygen followed by 5 minutes on air) should be administered as can be tolerated by the patient. Ascent to the surface is at 20 feet per minute. A minimum oxygen breathing time is 90 minutes. A practical maximum bottom time is 3 to 4 hours at 30 feet. Treatments should not be administered on a daily basis for more than 5 days without a break of at least 1 day. These guidelines may have to be modified by the Undersea Medical Officer to suit individual patient circumstances and tolerance to oxygen as measured by decrements in the patient's vital capacity.

17-9.5 Returning to Diving after Recompression Treatment. Divers diagnosed with any POIS or DCS shall be referred to a UMO for clearance prior to returning to diving. In most cases, a waiver of the physical standards will be required from BUPERS via BUMED. Refer to Bureau of Medicine and Surgery Manual (MANMED) P117 Article 15-102 for guidance.

17-10 NON-STANDARD TREATMENTS

The treatment recommendations presented in this chapter should be followed as closely as possible unless it becomes evident that they are not working. Only a Undersea Medical Officer may then recommend changes to treatment protocols or use treatment techniques other than those described in this chapter. Any modifications to treatment tables shall be approved by the Commanding Officer. The standard treatment procedures in this chapter should be considered minimum treatments. Treatment procedures should never be shortened unless emergency situations arise that require chamber occupants to leave the chamber early, or the patient's medical condition precludes the use of standard U.S. Navy treatment tables.

17-11 RECOMPRESSION TREATMENT ABORT PROCEDURES

Once recompression therapy is started, it should be completed according to the procedures in this chapter unless the diver being treated dies or unless continuing the treatment would place the chamber occupants in mortal danger or in order to treat another more serious medical condition.

17-11.1 Death During Treatment. If it appears that the diver being treated has died, a Undersea Medical Officer shall be consulted before the treatment is aborted. Once the decision to abort is made, there are a number of options for decompressing the tenders depending on the depth at which the death occurred and the preceding treatment profile.

- If death occurs following initial recompression to 60, 165, or 225 on Treatment Tables 6, 6A, 4 or 8, decompress the tenders on the Air/Oxygen schedule in the Air Decompression Table having a depth exactly equal to or deeper than the maximum depth attained during the treatment and a bottom time equal to or longer than the total elapsed time since treatment began. The Air/Oxygen schedule can be used even if gases other than air (i.e., nitrogen-oxygen or helium-oxygen mixtures) were breathed at depth.

- If death occurs after leaving the initial treatment depth on Treatment Tables 6 or 6A, decompress the tenders at 30 fsw/min to 30 fsw and have them breathe oxygen at 30 fsw for the times indicated in Table 17-6. Following completion of the oxygen breathing time at 30 fsw, decompress the tenders on oxygen from 30 fsw to the surface at 1 fsw/min.

- If death occurs after leaving the initial treatment depth on Treatment Tables 4 or 8, or after beginning treatment on Treatment Table 7 at 60 fsw, have the tenders decompress by continuing on the treatment table as written, or consult NEDU for a decompression schedule customized for the situation at hand. If neither option is possible, follow the original treatment table to 60 fsw. At 60 fsw, have the tenders breathe oxygen for 90 min in three 30-min periods separated by a 5-min air break. Continue decompression at 50, 40 and 30 fsw by breathing oxygen for 60 min at each depth. Ascend between stops at 30 fsw/min. At 50 fsw, breathe oxygen in two 30-min periods separated by a 5-min air

break. At 40 and 30 fsw, breathe oxygen for the full 60-min period followed by a 15-min air break. Ascend to 20 fsw at 30 fsw/min and breathe oxygen for 120 min. Divide the oxygen time at 20 fsw into two 60-min periods separated by a 15 min air break. When oxygen breathing time is complete at 20 fsw, ascend to the surface at 30 fsw/min. Upon surfacing, observe the tenders carefully for the occurrence of decompression sickness.

17-11.2 Impending Natural Disasters or Mechanical Failures. Impending natural disasters or mechanical failures may force the treatment to be aborted. For instance, the ship where the chamber is located may be in imminent danger of sinking or a fire or explosion may have severely damaged the chamber system to such an extent that completing the treatment is impossible. In these cases, the abort procedure described in paragraph 17-11.1 could be used for all chamber occupants (including the stricken diver) if time is available. If time is not available, the following may be done:

1. If deeper than 60 feet, go immediately to 60 feet.
2. Once the chamber is 60 feet or shallower, put all chamber occupants on continuous 100 percent oxygen. Select the Air/Oxygen schedule in the Air Decompression Table corresponding to the maximum depth attained during treatment and the total elapsed time since treatment began.
3. If at 60 fsw, breathe oxygen for period of time equal to the sum of all the decompression stops 60 fsw and deeper in the Air/Oxygen schedule, then continue decompression on the Air/Oxygen schedule, breathing oxygen continuously. If shallower than 60 fsw, breathe oxygen for a period of time equal to the sum of all the decompression stops deeper than the divers current depth, then continue decompression on the Air/Oxygen schedule, breathing oxygen continuously. Complete as much of the Air/Oxygen schedule as possible.
4. When no more time is available, bring all chamber occupants to the surface (try not to exceed 10 feet per minute) and keep them on 100 percent oxygen during evacuation, if possible.
5. Immediately evacuate all chamber occupants to the nearest recompression facility and treat according to Figure 17-1. If no symptoms occurred after the treatment was aborted, follow Treatment Table 6.

17-12 ANCILLARY CARE AND ADJUNCTIVE TREATMENTS

WARNING Drug therapy shall be administered only after consultation with a Undersea Medical Officer and only by qualified inside tenders adequately trained and capable of administering prescribed medications.

Most U.S. military diving operations have the unique advantage over most other diving operations with the ability to provide rapid recompression for the victims of decompression sickness (DCS) and arterial gas embolism (AGE). When stricken

divers are treated without delay, the success rate of standard recompression therapy is extremely good.

Some U.S. military divers, such as Special Operations Forces, however, may not have the benefit of a chamber nearby. Diving missions in Special Operations are often conducted in remote areas and may entail a lengthy delay to recompression therapy in the event of a diving accident. Delays to treatment for DCS and AGE significantly increase the probability of severe or refractory disease. In these divers, the use of adjunctive therapy (treatments other than recompression on a treatment table) can be provided while the diver is being transported to a chamber. Adjunctive therapies may also be useful for divers with severe symptoms or who have an incomplete response to recompression and hyperbaric oxygen.

Note that the adjunctive therapy guidelines are separated by accident type, with DCS and AGE covered separately. Although there is some overlap between the guidelines for these two disorders (as with the recompression phase of therapy), the best adjunctive therapy for one disorder is not necessarily the best therapy for the other. Although both DCS and AGE have in common the presence of gas bubbles in the body and a generally good response to recompression and hyperbaric oxygen, the underlying pathophysiology is somewhat different.

17-12.1 Decompression Sickness.

17-12.1.1 **Surface Oxygen.** Surface oxygen should be used for all cases of DCS until the diver can be recompressed. Use of either a high-flow (15 liters/minute) oxygen source with a reservoir mask or a demand valve can achieve high inspired fractions of oxygen. One consideration in administering surface oxygen is pulmonary oxygen toxicity. 100% oxygen can generally be tolerated for up to 12 hours. The patient may be given air breaks as necessary. If oxygen is being administered beyond this time, the decision to continue must weigh the perceived benefits against the risk of pulmonary oxygen toxicity. This risk evaluation must consider the dose of oxygen anticipated with subsequent recompression therapy as well.

17-12.1.2 **Fluids.** Fluids should be administered to all individuals suffering from DCS unless suffering from the chokes (pulmonary DCS). Oral fluids (water, Gatorade-like drinks) are acceptable if the diver is fully conscious, able to tolerate them. If oral fluids cannot be tolerated by the patient, intravenous fluids should be administered. There is no data available that demonstrates a superiority of crystalloids (normal saline or Lactated Ringers solution) over colloids (such as Hetastarch compounds (Hespan or Hextend)) for DCS, but D5W (dextrose in water without electrolytes) should not be used. Since colloids are far more expensive than Lactated Ringers or normal saline, the latter two agents are the most reasonable choices at this time. The optimal amount of crystalloids/colloids is likewise not well-established but treatment should be directed towards reversing any dehydration that may have been induced by the dive (immersion diuresis causes divers to lose 250-500 cc of fluids per hour) or fluid shifts resulting from the DCS. Fluid overloading should be avoided. Urinary output, in the range of 0.5-1.0cc/kg/hour is evidence of adequate intravascular volume.

Chokes (pulmonary DCS) causes abnormal pulmonary function and leakage of fluids into the alveolar spaces. Aggressive fluid therapy may make this condition worse. Consult a UMO (or NEDU) for guidance.

17-12.1.3 **Anticoagulants.** Since some types of DCS may increase the likelihood of hemorrhage into the tissues, anticoagulants should not be used routinely in the treatment of DCS. One exception to this rule is the case of lower extremity weakness. Low molecular weight heparin (LMWH) should be used for all patients with inability to walk due to any degree of lower extremity paralysis caused by neurological DCS or AGE. Enoxaparin 30 mg, or its equivalent, administered subcutaneously every 12 hours, should be started as soon as possible after injury to reduce the risk of deep venous thrombosis (DVT) and pulmonary embolism in any paralyzed patients. Compression stockings or intermittent pneumatic compression are alternatives, although they are less effective at preventing DVT than LMWH.

17-12.1.4 **Aspirin and Other Non-Steroidal Anti-Inflammatory Drugs.** Routine use of anti-platelet agents in patients with neurological DCS is not recommended, due to concern about worsening hemorrhage in spinal cord or inner ear decompression illness. Use of these agents may also be risky in combat divers who may be required to return to action after treatment of an episode of DCS.

17-12.1.5 **Steroids.** Steroids are no longer recommended for the treatment of DCS. No significant reduction in neurological residuals has been found in clinical studies for DCS adjunctively treated with steroids and elevated blood glucose levels associated with steroid administration may actually worsen the outcome of CNS injury.

17-12.1.6 **Lidocaine.** Lidocaine is not currently recommended for the treatment of any type of DCS.

17-12.1.7 **Environmental Temperature.** For patients with evidence of brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of neurological DCS, whenever practical, hot environments that may cause elevation of body temperature above normal should be avoided. The patient's body temperature and vital signs should be monitored regularly.

17-12.2 Arterial Gas Embolism.

17-12.2.1 **Surface Oxygen.** Surface oxygen should be used for all cases of AGE as it is for DCS.

17-12.2.2 **Lidocaine.** Lidocaine has been shown to be potentially beneficial in the treatment of AGE. Current recommendations suggests a dosing end-point to achieve serum concentrations producing an anti-arrhythmic effect. An intravenous initial dose of 1 mg/kg followed by a continuous infusion of 2-4 mg/minute, will typically produce therapeutic serum concentrations. If an intravenous infusion is not established, intramuscular administration of 4-5 mg/kg will typically produce a therapeutic plasma concentration 15 minutes after dosing, lasting for around 90

minutes. Doses greater than those noted above may be associated with major side effects, including paresthesias, ataxia, and seizures. Therefore, Lidocaine should only be administered under the supervision of a UMO or other qualified physician.

17-12.2.3 **Fluids.** The fluid replacement recommendations for the treatment of AGE differ from those of DCS. Fluid replacement recommendations for AGE differ from DCS because the CNS injury in AGE may be complicated by cerebral edema, which may be worsened by an increased fluid load, thus causing further injury to the diver. If fluid replacement is conducted, colloids are probably the best choice due to their mechanism of action in maintaining intra-vascular volume and minimizing extra-vascular leakage. Particular care must be taken not to fluid overload the injured diver suffering from AGE by adjusting IV rates to maintain just an adequate urine output of 0.5cc/kg/hour. A urinary catheter should be inserted in the unconscious patient and urinary output measured.

17-12.2.4 **Anticoagulants.** Anticoagulants should not be used routinely in the treatment of AGE. As noted previously in paragraph 17-12.1.3 on anticoagulants in DCS, Enoxaparin 30 mg, or its equivalent, should be administered subcutaneously every 12 hours, after initial recompression therapy in patients suffering from paralysis to prevent deep venous thrombosis (DVT) and pulmonary embolism.

17-12.2.5 **Aspirin and Other Non-Steroidal Anti-Inflammatory Drugs.** Routine use of anti-platelet agents in patients with AGE is not recommended.

17-12.2.6 **Steroids.** Steroids are no longer recommended for the treatment of AGE. No significant reduction in neurologic residual has been shown with adjunctive treatment with steroids for AGE and elevated blood glucose levels associated with administration of steroids may worsen the outcome of CNS injury.

17-12.2.7 **Environmental Temperature.** For patients with evidence of brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of neurological DCS, whenever practical, hot environments that may cause elevation of body temperature above normal should be avoided. The patient's body temperature and vital signs should be monitored regularly.

17-12.3 Sleeping and Eating. The only time the patient should be kept awake during recompression treatments is during oxygen breathing periods at depths greater than 30 feet. Travel between decompression stops on Treatment Table 4, 7, and 8 is not a contra-indication to sleeping. While asleep, vital signs (pulse, respiratory rate, blood pressure) should be monitored as the patient's condition dictates. Any significant change would be reason to arouse the patient and ascertain the cause.

Food may be taken by chamber occupants at any time. Adequate fluid intake should be maintained as discussed in paragraph 17-8.3.1.

17-13 EMERGENCY MEDICAL EQUIPMENT

Every diving activity shall maintain emergency medical equipment that will be available immediately for use in the event of a diving accident. This equipment is to be in addition to any medical supplies maintained in a medical treatment facility and shall be kept in a kit small enough to carry into the chamber, or in a locker in the immediate vicinity of the chamber.

17-13.1 Primary and Secondary Emergency Kits. Because some sterile items may become contaminated as a result of a hyperbaric exposure, it is desirable to have a primary kit for immediate use inside the chamber and a secondary kit from which items that may become contaminated can be locked into the chamber only as needed. The primary emergency kit contains diagnostic and therapeutic equipment that is available immediately when required. This kit shall be inside the chamber during all treatments. The secondary emergency kit contains equipment and medicine that does not need to be available immediately, but can be locked-in when required. This kit shall be stored in the vicinity of the chamber.

The contents of the emergency kits presented here are not meant to be restrictive but are considered the minimum requirement. Additional items may be added to suit local medical preferences.

The Primary Emergency Kit is described in Table 17-8. The Secondary Emergency Kit is described in Table 17-9.

17-13.2 Portable Monitor-Defibrillator. All diving activities/commands shall maintain an automated external defibrillator (AED), preferably with heart rhythm visualization capability, from an approved Authorized Medical Allowance List (AMAL). Diving activities with assigned Undersea Medical Officer are recommended to augment with a fully capable monitor defibrillator.

CAUTION **AED's are not currently approved for use under pressure (hyperbaric environment) due to electrical safety concerns.**