CHAPTER 7

Scuba Air Diving Operations

7-1 INTRODUCTION

7-1.1 **Purpose.** The purpose of this chapter is to familiarize divers with standard and emergency procedures when diving with scuba equipment.

7-1.2 **Scope.** This chapter covers the use of open-circuit scuba, which is normally deployed in operations not requiring decompression. Decompression diving using open-circuit air scuba may be undertaken only if no other option exists and only with the concurrence of the Commanding Officer or Officer-in-Charge (OIC). Closed-circuit underwater breathing apparatus is the preferred method of performing scuba decompression dives. Operation of open-circuit, closed-circuit, and semiclosed-circuit systems designed for use with mixed-gas or oxygen is covered in Volume 4.

7-2 REQUIRED EQUIPMENT FOR SCUBA OPERATIONS

At a minimum, each diver must be equipped with the following items to safely conduct an open-circuit scuba dive:

- Open-circuit scuba.
- Face mask.
- Life preserver/buoyancy compensator.*
- Weight belt and weights as required.**
- Knife.**
- Swim fins.
- Submersible pressure gauge or Reserve J-valve.
- Submersible wrist watch. Only one is required when diving in pairs with a buddy line.**
- Depth gauge. **

* During the problem-solving pool phase of scuba training, CO_2 cartridges may be removed and replaced with plugs or expended cartridges that are painted International Orange.

** These items are not required for the pool phase of scuba training.

7-2.1 Equipment Authorized for Navy Use. Only diving equipment that has been certified or authorized for use by the NAVSEA/00C ANU list shall be used in a Navy dive. However, many items, such as hand tools, which are not specifically listed in the ANU list or do not fit under the scope of certification and are deemed valuable to the success of the dive, can be used. A current copy must be maintained by all diving activities. The ANU list can be found on the Internet at http://www.navsea.navy.mil/sea00c/doc/anu_disc.html.

7-2.2 Open-Circuit Scuba. All open-circuit scuba authorized for Navy use employ a demand system that supplies air each time the diver inhales. The basic open-circuit scuba components are:

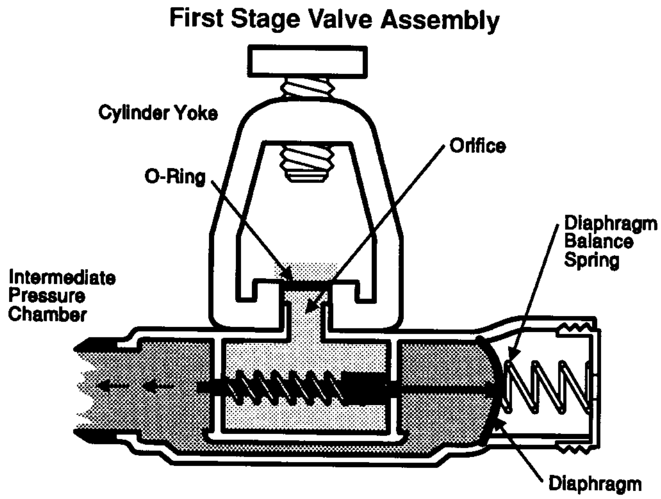
- Demand regulator assembly
- One or more air cylinders
- Cylinder valve and manifold assembly
- Backpack or harness

7-2.2.1 **Demand Regulator Assembly.** The demand regulator assembly is the central component of the open-circuit system. The regulator delivers air to the diver after reducing the high-pressure air in the cylinder to a pressure that can be used by the diver. There are two stages in a typical system (Figure 7-1).

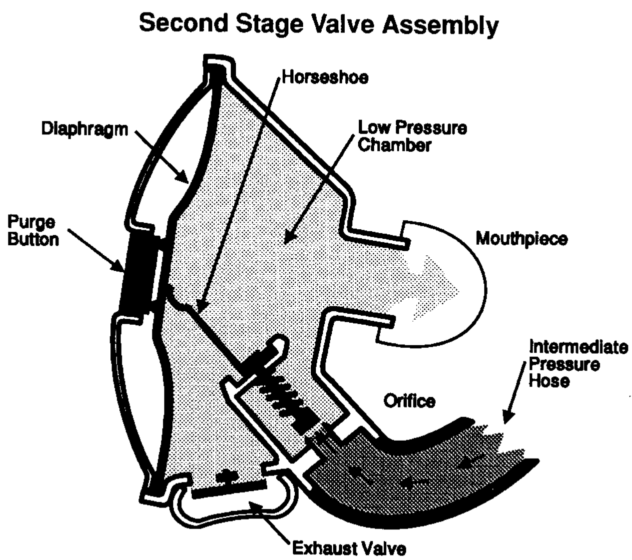
7-2.2.1.1 ***First Stage.*** In the regulator's first stage, high-pressure air from the cylinder passes through a regulator that reduces the pressure of the air to a predetermined level over ambient pressure. Refer to the regulator technical manual for the specific setting.

7-2.2.1.2 ***Second Stage.*** In the second stage of a regulator, a movable diaphragm is linked by a lever to the low-pressure valve, which leads to a low-pressure chamber. When the air pressure in the low-pressure chamber equals the ambient water pressure, the diaphragm is in the center position and the low-pressure valve is closed. When the diver inhales, the pressure in the low-pressure chamber is reduced, causing the diaphragm to be pushed inward by the higher ambient water pressure. The diaphragm actuates the low-pressure valve which opens, permitting air to flow to the diver. The greater the demand, the wider the low-pressure valve is opened, thus allowing more air flow to the diver. When the diver stops inhaling, the pressure on either side of the diaphragm is again balanced and the low-pressure valve closes. As the diver exhales, the exhausted air passes through at least one check valve and vents to the water.

7-2.2.1.3 ***Single Hose Regulators.*** In the single-hose, two-stage demand regulator the first stage is mounted on the cylinder valve assembly. The second-stage assembly includes the mouthpiece and a valve to exhaust exhaled air directly into the water. The two stages are connected by a length of low-pressure hose, which passes over the diver's right shoulder. The second stage has a purge button, which when activated allows low-pressure air to flow through the regulator and the mouthpiece, forcing out any water which may have entered the system. Buddy breathing (a diver providing air from the scuba to a partner) is more easily accomplished with the single-hose regulator. Use of an additional second stage regulator with an



First Stage. High pressure air flows through the orifice of the first stage into the intermediate chamber. When the pressure in the intermediate chamber reaches ambient plus diaphragm balance spring set pressure, the first stage assembly closes.



Second Stage. Upon inhalation the second stage diaphragm moves inward and the horseshoe lever opens the second stage valve assembly. Intermediate pressure air from the hoses is throttled across the orifice and fills the low pressure chamber to ambient pressure and flow is provided to the diver. Upon exhalation the diaphragm is pushed outward and the second stage in closed. Expired air is dumped from the low pressure chamber to the surrounding water through the exhaust valve.

Figure 7-1. Schematic of Demand Regulator.

octopus hose is an alternative and preferred method to accomplish buddy breathing. The principal disadvantages of the single-hose unit are an increased tendency to freeze up in very cold water and the exhaust of air in front of the diver's mask. While the Navy PMS system provides guidance for repairing and maintaining scuba regulators, the manufacturer's service manual should be followed for specific procedures.

7-2.2.1.4 ***Full Face Mask.*** The AGA/Divator full face mask may be used with an approved single-hose first-stage regulator with an octopus, to the maximum approved depth of the regulator, as indicated in the NAVSEA/00C ANU list (Figure 7-2).

Figure 7-2. Full Face Mask.

7-2.2.1.5 ***Mouthpiece.*** The size and design of scuba mouthpieces differ between manufacturers, but each mouthpiece provides relatively watertight passageways for delivering breathing air into the diver's mouth. The mouthpiece should fit comfortably with slight pressure from the lips.

7-2.2.2 **Cylinders.** Scuba cylinders (tanks or bottles) are designed to hold high pressure compressed air. Because of the extreme stresses imposed on a cylinder at these pressures, all cylinders used in scuba diving must be inspected and tested periodically. Seamless steel or aluminum cylinders which meet Department of Transportation (DOT) specifications (DOT 3AA, DOT 3AL, DOT SP6498, and DOT E6498) are approved for Navy use. Each cylinder used in Navy operations must have identification symbols stamped into the shoulder (Figure 7-3).

7-2.2.2.1 ***Sizes of Approved Scuba Cylinders.*** Approved scuba cylinders are available in several sizes and one or two cylinders may be worn to provide the required quantity of air for the dive. The volume of a cylinder, expressed in actual cubic feet or

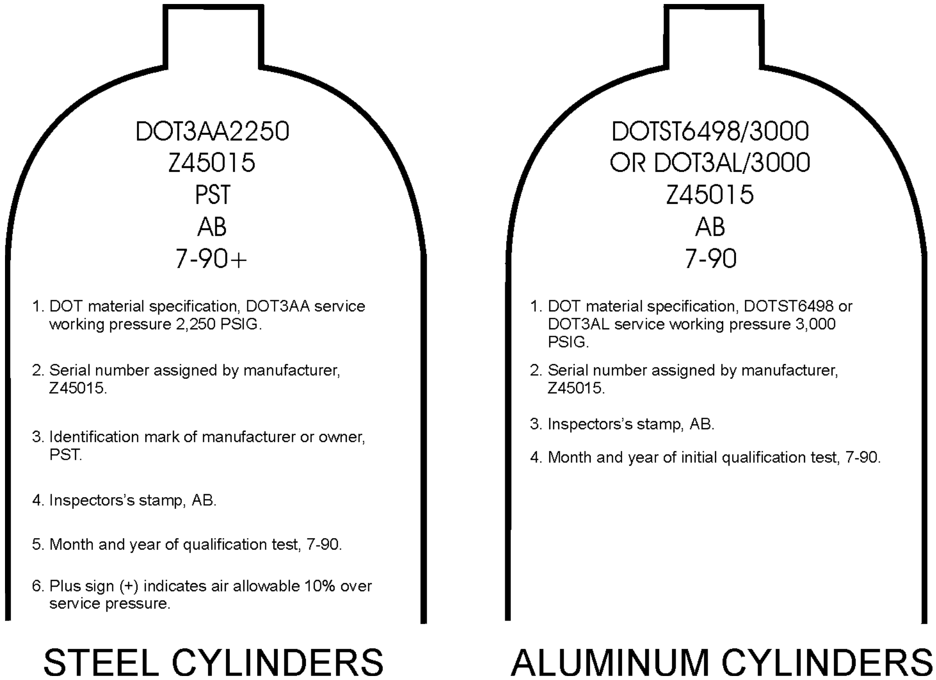


Figure 7-3. Typical Gas Cylinder Identification Markings.

cubic inches, is a measurement of the internal volume of the cylinder. The capacity of a cylinder, expressed in standard cubic feet or liters, is the amount of gas (measured at surface conditions) that the cylinder holds when charged to its rated pressure. Table 7-1 lists the sizes of some standard scuba cylinders. Refer to the NAVSEA/00C ANU list for a list of approved scuba cylinders.

Table 7-1. *Sample Scuba Cylinder Data.*

Open-Circuit Cylinder Description (Note 1)	Rated Working Pressure (PSIG)	Internal Volume (Cu.Ft.)	Absolute Air Capacity at Rated Pressure (Cu.Ft.)	Reserve Pressure	Outside Dimensions (Inches)	
					(Dia.)	(Length)
Steel 72	2,250	0.420	64.7	500	6.80	25.00
Aluminum 50	3,000	0.281	48.5	500	6.89	19.00
Aluminum 63	3,000	0.319	65.5	500	7.25	21.75
Aluminum 80	3,000	0.399	81.85	500	7.25	26.00

Note 1: Fifty cubic feet is the minimum size scuba cylinder authorized. SEAL teams are authorized smaller cylinders for special operations.

7-2.2.2.2 ***Inspection Requirements.*** Open-circuit scuba cylinders must be visually inspected at least once every 12 months and every time water or particulate matter is suspected in the cylinder. Cylinders containing visible accumulations of corrosion must be cleaned before being placed into service. Commercially available steel and aluminum scuba cylinders, as specified in the NAVSEA/00C ANU list, which meet DOT specifications, as well as scuba cylinders designed to Navy specifications, must be visually inspected at least annually and must be hydrostatically tested at least every five years in accordance with DOT regulations and Compressed Gas Association (CGA) pamphlets C-1 and C-6.

7-2.2.2.3 ***Guidelines for Handling Cylinders.*** General safety regulations governing the handling and use of compressed gas cylinders aboard Navy ships are contained in NAVSEA 0901-LP-230-0002, NSTM Chapter 550, "Compressed Gas Handling." Persons responsible for handling, storing, and charging scuba cylinders must be familiar with these regulations. Safety rules applying to scuba cylinders are contained in paragraph 7-4.5. Because scuba cylinders are subject to continuous handling and because of the hazards posed by a damaged unit, close adherence to the rules is mandatory.

7-2.2.3 **Cylinder Valves and Manifold Assemblies.** Cylinder valves and manifolds make up the system that passes the high-pressure air from the cylinders to the first-stage regulator. The cylinder valve serves as an on/off valve and is sealed to the tank by a straight-threaded male connection containing a neoprene O-ring on the valve's body.

7-2.2.3.1 ***Blowout Plugs and Safety Discs.*** The cylinder valve contains a high-pressure blowout plug or safety disc plug in the event of excessive pressure buildup. When a dual manifold is used, two blowout plugs or safety disc plugs are installed as specified by the manufacturers' technical manual.

For standard diving equipment, a safety disc plug similar to new issue equipment is recommended. The safety disc plug and safety disc are not always identified by a National Stock Number (NSN), but are available commercially.

7-2.2.3.2 ***Manifold Connectors.*** If two or more cylinders are to be used together, a manifold unit is needed to provide the necessary interconnection. Most manifolds incorporate an O-ring as a seal, but some earlier models may have a tapered (pipe) thread design. One type will not connect with the other type.

7-2.2.3.3 ***Pressure Gauge Requirements.*** A cylinder valve with an air reserve (J valve) is preferred. When a cylinder valve without an air reserve (K valve) is used, the scuba regulator must be equipped with a submersible pressure gauge to indicate pressure contents of the cylinder. The dive must be terminated when the cylinder pressure reaches 500 psi for a single cylinder or 250 psi for twin manifold cylinders. The air reserve mechanism alerts the diver that the available air supply is almost exhausted and provides the diver with sufficient reserve air to reach the surface. The air reserve mechanism contains a spring-loaded check valve. When it becomes increasingly difficult to obtain a full breath, the diver must reach over the left shoulder and push down the reserve lever, opening the reserve valve to make the remaining air available.

Dive planning should not extend bottom time by including the use of reserve air. The diver should never assume that the reserve air supply will be provided. When the resistance to breathing becomes obvious, the diver should notify the dive partner that the air supply is low and both should start for the surface immediately. **The dive must be terminated when either diver shifts to reserve air.**

7-2.2.4 **Backpack or Harness.** A variety of backpacks or harnesses, used for holding the scuba on the diver's back, have been approved for Navy use. The backpack may include a lightweight frame with the cylinder(s) held in place with clamps or straps. The usual system for securing the cylinder to the diver uses shoulder and waist straps. All straps must have a quick-release feature, easily operated by either hand, so that the diver can remove the cylinder and leave it behind in an emergency.

7-2.3 Minimum Equipment.

7-2.3.1 **Face Mask.** The face mask protects the diver's eyes and nose from the water. Additionally, it provides maximum visibility by putting a layer of air between the diver's eyes and the water.

Face masks are available in a variety of shapes and sizes for diver comfort. To check for proper fit, hold the mask in place with one hand and inhale gently through the nose. The suction produced should hold the mask in place. Don the mask with the head strap properly adjusted, and inhale gently through the nose. If the mask seals, it should provide a good seal in the water.

Some masks are equipped with a one-way purge valve to aid in clearing the mask of water. Some masks have indentations at the nose or a neoprene nose pad to allow the diver to block the nostrils to equalize the pressure in the ears and sinuses. Several models are available for divers who wear eyeglasses. One type provides a prescription-ground faceplate, while another type has special holders for separate lenses. All faceplates must be constructed of tempered or shatterproof safety glass because faceplates made of ordinary glass can be hazardous. Plastic faceplates are generally unsuitable as they fog too easily and are easily scratched.

The size or shape of the faceplate is a matter of personal choice, but the diver should use a mask that provides a wide, clear range of vision.

7-2.3.2 **Life Preserver.** The principal functions of the life preserver are to assist a diver in rising to the surface in an emergency and to keep the diver on the surface in face-up position (Figure 7-4). The low-pressure inflation device on the preserver may be actuated by the diver, or by a dive partner should the diver be unconscious or otherwise incapacitated.

All models used by the Navy must be authorized by NAVSEA/00C Authorized for Navy Use List and have a manual inflation device in addition to the low pressure inflation device. With the exception of the UDT (9C-4220-00-276-8929), an overinflation valve or relief valve is required to ensure against possible rupture of the life preserver on ascent. Some ANU models are available commercially while others may be procured through the Navy supply system. In selecting a life preserver for a specific task, the individual technical manuals should be consulted. The use of certain closed and semi-closed UBAs will require the wearing of a life preserver.

Figure 7-4. MK-4 Life Preserver.

The life preserver must be sturdy enough to resist normal wear and tear, and of sufficient volume to raise an unconscious diver safely from maximum dive depth to the surface.

Most life preservers currently in use employ carbon dioxide (CO_2) cartridges to provide inflation in an emergency. The cartridges must be the proper size for the life preserver. Cartridges must be weighed upon receipt and prior to use, in accordance with the planned maintenance system (PMS) for the life preserver, to ensure the actual weight is in compliance with the weight tolerance for the cartridge cylinder. Carbon dioxide cartridges used with commercially available life preservers with low-pressure inflators do not have the weight stamped on the cartridge cylinder. The actual weight of these cartridges must be inscribed on the cartridge, and be within the tolerance for weight.

7-2.3.3 **Buoyancy Compensator.** When a life preserver is not required by a specific UBA, a buoyancy compensator may be used at the Diving Supervisor’s discretion. When selecting a buoyancy compensator, a number of factors must be considered. These factors include: type of wet suit, diving depth, breathing equipment characteristics, nature of diving activity, accessory equipment, and weight belt. A list of approved buoyancy compensators is contained in the NAVSEA/00C Authorized for Navy Use List.

As a buoyancy compensating device, the compensator can be inflated by a low-pressure inflator connected to the first-stage regulator, or an oral inflation tube. Any buoyancy compensator selected for Navy use must have an over-pressure relief valve. The compensator is used in conjunction with the diver weights to control buoyancy in the water column by allowing the diver to increase displacement through inflation of the device, or to decrease displacement by venting.

Training and practice under controlled conditions are required to master the buoyancy compensation technique. Rapid, excessive inflation can cause excessive buoyancy and uncontrolled ascent. The diver must systematically vent air from the compensator during ascent to maintain proper control. Weights installed in a vest type bouyancy compesator must be jettisonable.

Refer to the appropriate technical manual for complete operations and maintenance instructions for the equipment.

7-2.3.4 **Weight Belt.** Scuba is designed to have nearly neutral buoyancy. With full tanks, a unit tends to have negative buoyancy, becoming slightly positive as the air supply is consumed. Most divers are positively buoyant and need to add extra weight to achieve a neutral or slightly negative status. This extra weight is furnished by a weighted belt worn outside of all other equipment and strapped so that it can easily released in the event of an emergency.

Each diver may select the style and size of belt and weights that best suit the diver. A number of different models are available. A weight belt shall meet certain basic standards: the buckle must have a quick-release feature, easily operated by either hand; the weights (normally made of lead) should have smooth edges so as not to chafe the diver's skin or damage any protective clothing, and the belt should be made of rot- and mildew-resistant fabric, such as nylon webbing.

7-2.3.5 **Knife.** Several types of knives are available. For EOD and other special missions, a nonmagnetic knife designed for use when diving near magnetic-influence mines is used.

Diving knives should have corrosion-resistant blades and a handle of plastic, hard rubber, or wood. Handles made of wood should be waterproofed with paint, wax, or linseed oil. Handles of cork or bone should be avoided, as these materials deteriorate rapidly when subjected to constant saltwater immersion. Cork may also float the knife away from the diver.

Knives may have single- or double-edged blades with chisel or pointed tips. The most useful knife has one sharp edge and one saw-toothed edge. All knives must be kept sharp.

The knife must be carried in a suitable scabbard and worn on the diver's life preserver, hip, thigh, or calf. The knife must be readily accessible, must not interfere with body movement, and must be positioned so that it will not become fouled while swimming or working. The scabbard should hold the knife with a positive but easily released lock.

The knife and scabbard must not be secured to the weight belt. If the weights are released in an emergency, the knife may be also dropped unintentionally.

7-2.3.6 **Swim Fins.** Swim fins increase the efficiency of the diver, permitting faster swimming over longer ranges with less expenditure of energy. Swim fins are made of a variety of materials and styles.

Each feature—flexibility, blade size, and configuration—contributes to the relative power of the fin. A large blade will transmit more power from the legs to the water, provided the legs are strong enough to use a larger blade. Small or soft blades should be avoided. Ultimately, selection of blade type is a matter of personal preference based on the diver's strength and experience.

7-2.3.7 **Wrist Watch.** Analog diver's watches must be waterproof, pressure proof, and equipped with a rotating bezel outside the dial that can be set to indicate the elapsed time of a dive. A luminous dial with large numerals is also necessary. Additional features such as automatic winding, nonmagnetic components, and stop watch action are available. Digital watches, with a stop watch feature to indicate the elapsed time of a dive, are also approved for Navy use.

7-2.3.8 **Depth Gauge.** The depth gauge measures the pressure created by the water column above the diver and is calibrated to provide a direct reading of depth in feet of sea water. It must be designed to be read under conditions of limited visibility. The gauge mechanism is delicate and should be handled with care. Accurate depth determination is important to a diver's safety. The accuracy of a gauge must be checked in accordance with the planned maintenance system or whenever a malfunction is suspected. This can be done by taking the gauge to a known depth and checking the reading, or by placing it in a recompression chamber or test pressure chamber for depth comparison.

7-3 OPTIONAL EQUIPMENT FOR SCUBA OPERATIONS

The requirements of a specific diving operation determine which items of optional diving equipment may be necessary. This section lists some of the equipment that may be used.

- Protective Clothing
  - Wet Suit
  - Variable Volume Dry Suit
  - Gloves
  - Hoods
  - Boots or hard-soled shoes
- Whistle
- Slate and pencil
- Tools and light
- Signal flare
- Tool bag
- Acoustic beacons
- Lines and floats
- Wrist compass

- Witness float
- Snorkel
- Submersible cylinder pressure gauge
- Chem light and strobe light

7-3.1 **Protective Clothing.** A diver needs some form of protection from cold water, from heat loss during long exposure in water of moderate temperature, from chemical or bacterial pollution in the water, and from the hazards posed by marine life and underwater obstacles. Protection can be provided by wet suit, or a dry suit with or without thermal underwear in Figure 7-5.

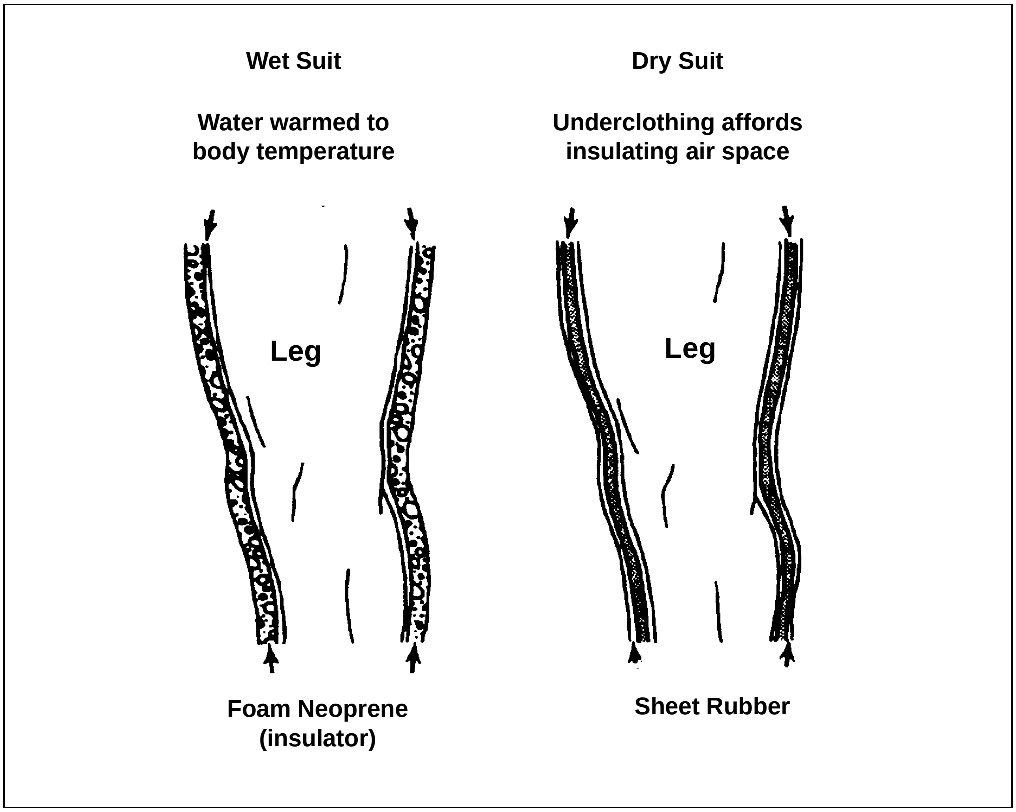


Figure 7-5. Protective Clothing.

7-3.1.1 **Wet Suits.** The wet suit is a form-fitting suit, usually made of closed-cell neoprene. The suit traps a thin layer of water next to the diver's skin, where it is warmed by the diver's body. Wet suits are available in thicknesses of 1/8-, 3/16-, 3/8-, and 1/2-inch, with the thickest providing better insulation. The selection of the type of wet suit used is left to each diver. Standard size suits are available at most commercial diving shops. Proper fit is critical in the selection of a wet suit. The suit must not restrict the diver's movements. A custom-fitted suit is recommended. The performance of a suit depends upon suit thickness, water temperature, and water depth.

7-3.1.2 **Dry Suits.** The Variable Volume Dry Suit (VVDS) has proven to be effective in keeping divers warm in near-freezing water. It is typically constructed of 1/4-inch closed-cell neoprene with nylon backing on both sides. Boots are provided as an integral part of the suit, but the hood and three finger gloves are usually separate. The suit is entered by means of a water- and pressure-proof zipper. Inflation is controlled using inlet and outlet valves which are fitted into the suit. Air is supplied from a pressure reducer on an auxiliary cylinder or from the emergency gas supply or the scuba bottle. About 0.2 actual cubic foot of air is required for normal inflation. Because of this inflation, slightly more weight than would be used with a wet suit must be carried. Normally, thermal underwear can be worn under the suit for insulation.

7-3.1.3 **Gloves.** Gloves are an essential item of protective clothing. They can be made of leather, cloth, or rubber, depending upon the degree and type of protection required. Gloves shields the hands from cuts and chafing, and provide protection from cold water. Some styles are designed to have insulating properties but may limit the diver's dexterity.

Wet or dry suits can be worn with hoods, gloves, boots, or hard-soled shoes depending upon conditions. If the diver will be working under conditions where the suit may be easily torn or punctured, the diver should be provided with additional protection such as coveralls or heavy canvas chafing gear.

7-3.1.4 **Writing Slate.** A rough-surfaced sheet of acrylic makes an excellent writing slate for recording data, carrying or passing instructions, and communicating between divers. A grease pencil or graphite pencil should be attached to the slate with a lanyard.

7-3.1.5 **Signal Flare.** A signal flare is used to attract attention if the diver has surfaced away from the support crew. Any waterproof flare that can be carried and safely ignited by a diver can be used, but the preferred type is the MK 124 MOD 0 (NSN 1370-01-030-8330). These are day-or-night signals that give off a heavy reddish or orange smoke for daytime and a brilliant red light at night. Each signal lasts for approximately 20 seconds. The "night" end of the flare is identified by a ring of raised beads. Flares should be handled with care. For safety, each diver should carry a maximum of two flares.

7-3.1.6 **Acoustic Beacons.** Acoustic beacons or pingers are battery-operated devices that emit high-frequency signals when activated. The devices may be worn by divers to aid in keeping track of their position or attached to objects to serve as fixed points of reference. The signals can be picked up by hand-held sonar receivers, which are used in the passive or listening mode, at ranges of up to 1,000 yards. The hand-held sonar enables the search diver to determine the direction of the signal source and swim toward the pinger using the heading noted on a compass.

7-3.1.7 **Lines and Floats.** A lifeline should be used when it is necessary to exchange signals, keep track of the diver's location, or operate in limited visibility. There are three basic types of lifelines: the tending line, the float line, and the buddy line.

A single diver will be tended with either a tending line or a float line. When direct access to the surface is not available a tending line is mandatory. A float line may not be used.

The float line reaches from the diver to a suitable float on the surface. This float can be a brightly painted piece of wood, an empty sealed plastic bottle, a life ring, or any similar buoyant, visible object. An inner tube with a diving flag attached makes an excellent float and provides a hand-hold for a surfaced diver. If a pair of divers are involved in a search, the use of a common float gives them a rendezvous point. Additional lines for tools or other equipment can be tied to the float. A buddy line, 6 to 10 feet long, is used to connect the diver partners at night or when visibility is poor.

Any line used in scuba operations should be strong and have neutral or slightly positive buoyancy. Nylon, Dacron, and manila are all suitable materials. Always attach a lifeline to the diver, never to a piece of equipment that may be ripped away or may be removed in an emergency.

7-3.1.8 **Snorkel.** A snorkel is a simple breathing tube that allows a diver to swim on the surface for long or short distances face-down in the water. This permits the diver to search shallow depths from the surface, conserving the scuba air supply. When snorkels are used for skin diving, they are often attached to the face mask with a lanyard or rubber connector to the opposite side of the regulator.

7-3.1.9 **Compass.** Small magnetic compasses are commonly used in underwater navigation. Such compasses are not highly accurate, but can be valuable when visibility is poor. Submersible wrist compasses, watches, and depth gauges covered by NAVSUPINST 5101.6 series are items controlled by the Nuclear Regulatory Commission and require leak testing and reporting every 6 months.

7-3.1.10 **Submersible Cylinder Pressure Gauge.** The submersible cylinder pressure gauge provides the diver with a continual read-out of the air remaining in the cylinder(s). Various submersible pressure gauges suitable for Navy use are commercially available. Most are equipped with a 2- to 3-foot length of high-pressure rubber hose with standard fittings, and are secured directly into the first stage of the regulator. When turning on the cylinder air, the diver should should turn the face of the gauge away in the event of a blowout. When worn, the gauge and hose should be tucked under a shoulder strap or otherwise secured to avoid its entanglement with bottom debris or other equipment. The gauge must be calibrated in accordance with the equipment planned maintenance system.

7-4 AIR SUPPLY

An important early step in any scuba dive is computing the air supply requirement. The air supply requirement is a function of the expected duration of the dive at a specific working depth. The duration of the air supply in the scuba cylinders depends on the depth at which the air is delivered. Air consumption rate increases with depth.

7-4.1 Duration of Air Supply. The duration of the air supply of any given cylinder or combination of cylinders depends upon:

- The diver's consumption rate, which varies with the diver's work rate,
- The depth of the dive, and
- The capacity and recommended minimum pressure of the cylinder(s).

Temperature is usually not significant in computing the duration of the air supply, unless the temperature conditions are extreme. When diving in extreme temperature conditions, Charles'/Gay-Lusac's law must be applied.

There are three steps in calculating how long a diver's air supply will last:

1. Calculate the diver's consumption rate by using this formula:

$$C = \frac{D + 33}{33} \times RMV$$

Where:

C	=	Diver's consumption rate, standard cubic feet per minute (scfm)
D	=	Depth, fsw
RMV	=	Diver's Respiratory Minute Volume, actual cubic feet per minute (acfm) (from Figure 7-6)

2. Calculate the available air capacity provided by the cylinders. The air capacity must be expressed as the capacity that will actually be available to the diver, rather than as a total capacity of the cylinder. The formula for calculating the available air capacity is:

$$V_a = \frac{P_c - P_{rm}}{14.7} \times (FV \times N)$$

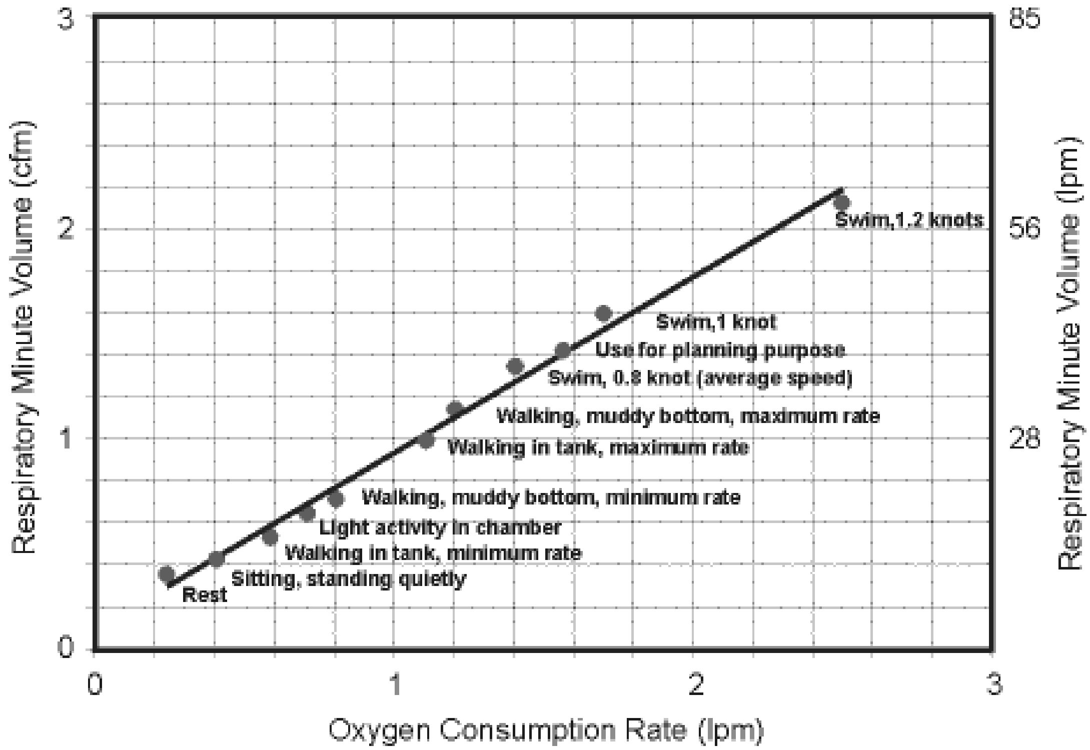
Where:

P_c	=	Measured cylinder pressure, psig
P_{rm}	=	Recommended minimum pressure of cylinder, psig
FV	=	Internal volume (scf)
N	=	Number of cylinders
V_a	=	Capacity available (scf)

3. Calculate the duration of the available capacity (in minutes) by using this formula:

$$\text{Duration} = \frac{V_a}{C}$$

Where:



Work	VO_2 (lpm)	RMV (acfm)	RMV (lpm)	Work Level
Rest	0.24	0.35	10	—
Sitting, standing quietly	0.40	0.42	12	Light
Walking in tank, minimum rate	0.58	0.53	15	Light
Light activity in chamber	0.70	0.64	18	Light
Walking, muddy bottom, minimum rate	0.80	0.71	20	Moderate
Walking in tank, maximum rate	1.10	0.99	28	Moderate
Walking, muddy bottom, maximum rate	1.20	1.14	32	Moderate
Swim, 0.8 knot (average speed) (use for planning purposes, round up to 1.4)	1.40	1.34	38	Moderate
Swim, 1 knot	1.70	1.59	45	Heavy
Swim, 1.2 knot	2.50	2.12	60	Severe

Figure 7-6. Oxygen Consumption and RMV at Different Work Rates.

V_a = Capacity available, scf
C = Consumption rate, scfm

Sample Problem. Determine the duration of the air supply of a diver doing moderate work at 70 fsw using twin 72-cubic-foot steel cylinders charged to 2,250 psig.

1. Calculate the diver's consumption rate in scfm. According to Figure 7-6, the diver's consumption rate at depth is 1.4 acfm.

$$C = \frac{D + 33}{33} \times RMV$$
$$= \frac{70 + 33}{33} \times 1.4$$
$$= 4.37 \text{ scfm}$$

2. Calculate the available air capacity provided by the cylinders. Table 7-1 contains the cylinder data used in this calculation:

- Floodable Volume = 0.420 scf
- Rated working pressure = 2250 psig
- Reserve pressure for twin 72-cubic-foot cylinders = 250 psig

$$V = \frac{P_c - P_{rm}}{14.7} \times (FV \times N)$$
$$= \frac{2250 - 250}{14.7} \times (0.420 \times 2)$$
$$= 114 \text{ scf}$$

3. Calculate the duration of the available capacity.

$$\text{Duration} = \frac{V_a}{C}$$
$$= \frac{114 \text{ scf}}{4.37 \text{ scfm}}$$
$$= 26 \text{ minutes}$$

The total time for the dive, from initial descent to surfacing at the end of the dive, is limited to 26 minutes.

7-4.2 Compressed Air from Commercial Sources. Compressed air meeting the established standards can usually be obtained from Navy sources. In the absence of appropriate Navy sources, air may be procured from commercial sources. Usually, any civilian agency or firm which handles compressed oxygen can provide pure compressed air. Air procured from commercial sources must meet the requirements of Grade A Source I or Source II air as specified by FED SPEC BB-A-1034B. Refer to Table 4-2 in Chapter 4 for the air purity requirements.

7-4.3 Methods for Charging Scuba Cylinders.

NOTE Paragraph 7-4.5 addresses safety precautions for charging and handling cylinders.

Scuba cylinders shall be charged only with air that meets diving air purity standards. A diving unit can charge its own cylinders by one of two accepted methods: (1) by cascading or transferring air from banks of large cylinders into the scuba tanks; or (2) by using a high-pressure air compressor. Cascading is the fastest and most efficient method for charging scuba tanks. The NAVSEA/00C ANU list lists approved high-pressure compressors and equipment authorized for scuba air sources.

The normal cascade system consists of supply flasks connected together by a manifold and feeding into a scuba high-pressure whip. This whip consists of a scuba yoke fitting, a pressure gauge, and a bleed valve for relieving the pressure in the lines after charging a cylinder. A cascade system, with attached whip, is shown in Figure 7-7.

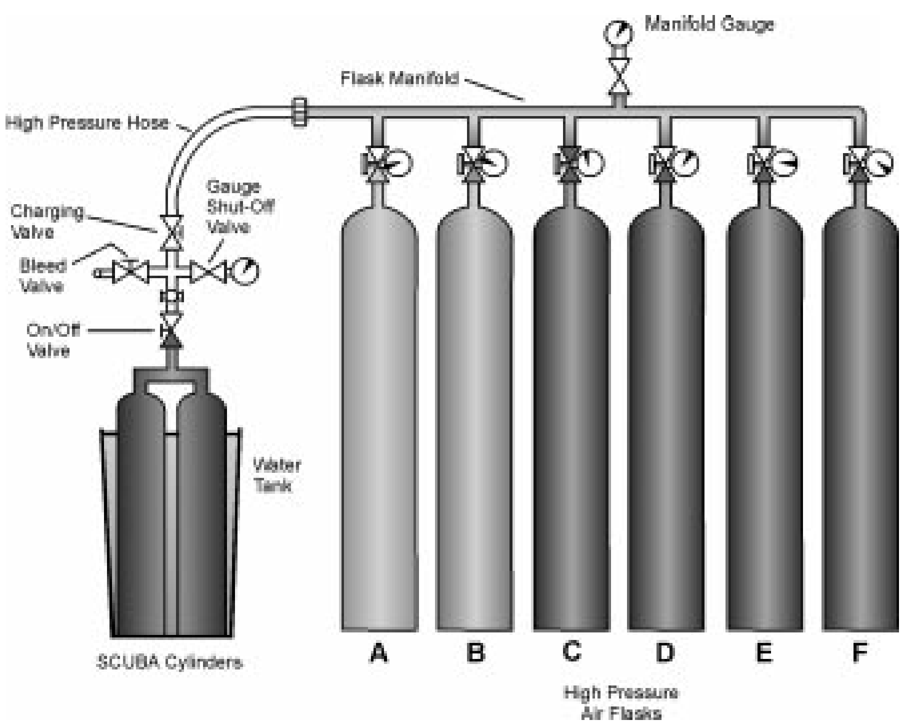


Figure 7-7. Cascading System for Charging Scuba Cylinders.

Scuba charging lines shall be fabricated using SAE 100R7 hose for 3,000 psi service and SAE 100R8 hose for 5,000 psi service. The service pressure of the scuba charging lines shall be no greater than the working pressure of the hose used.

The working pressure of a hose is determined as one-fourth of its burst pressure. While this criteria for working pressure was developed based on the characteristics of rubber hose, it has also been determined to be appropriate for use with the plastic hoses cited above.

Fleet units using charging lines shall not exceed the rated working pressure of the hose. If the charging line working pressure rating does not meet service requirements, restrict the service pressure of the hose to its working pressure and initiate replacement action immediately.

The use of strain reliefs made from cable, chain, 21-thread, or 3/8-inch nylon, married at a minimum of every 18 inches and at the end of the hose, is a required safety procedure to prevent whipping in the event of hose failure under pressure. Marrying cord shall be 1/8-inch nylon or material of equivalent strength. Tie wraps, tape, and marlin are not authorized for this purpose.

7-4.4 Operating Procedures for Charging Scuba Tanks. Normally, scuba tanks are charged using the following operating procedures (OPs), which may be tailored to each unit:

1. Determine that the cylinder is within the hydrostatic test date.

2. Check the existing pressure in the scuba cylinder with an accurate pressure gauge.

3. Attach the cylinder to the yoke fitting on the charging whip, and attach the safety strain relief.

4. For safety and to dissipate heat generated in the charging process, when facilities are available, immerse the scuba cylinder in a tank of water while it is being filled. A 55-gallon drum is a suitable container for this purpose.

5. Tighten all fittings in the system.

6. Close the bleed valve.

7. Place reserve mechanism lever in the open (lever down) position.

8. Open the cylinder (on/off) valve. This valve is fully opened with about two turns on the handle, counter-clockwise. However, the valve must not be used in a fully open position as it may stick or be stripped if force is used to open a valve that is incorrectly believed to be closed. The proper procedure is to open the valve fully and then close or back off one-quarter to one-half turn. This will not impede the flow of air.

9. Open the supply flask valve.

10. Slowly open the charging valve. The sound of the air flowing into the scuba cylinder is noticeable. The operator will control the flow so that the pressure in the cylinder increases at a rate not to exceed 400 psig per minute. If unable to submerge scuba cylinders during charging, the charging rate must not exceed 200 psig per minute. The rate of filling must be controlled to prevent overheating; the cylinder must not be allowed to become too hot to touch.

11. Monitor the pressure gauge carefully. When the reading reaches the rated pressure for the scuba cylinder, close the valve on the first cylinder and take a reading.

12. Close the charging valve.

13. Close the on/off valve on the scuba cylinder.

14. Ensure that all valves in the system are firmly closed.

15. Let the scuba cylinder cool to room temperature. Once the cylinder is cool, the pressure will have dropped and you may need to top off the scuba cylinder.

7-4.4.1 **Topping off the Scuba Cylinder.** Follow this procedure to top off a scuba cylinder:

1. Open the on/off valve on the scuba cylinder.

2. Select a supply flask with higher pressure than the scuba rated limit.

3. Open the supply valve on the flask.

4. Throttle the charging valve to bring the scuba cylinder up to the rated limit.

5. Close all valves.

6. Open the bleed valve and depressurize the lines.

7. When air has stopped flowing through the bleed valve, disconnect the scuba cylinder from the yoke fitting.

8. Reset the reserve mechanism (lever in up position).

In the absence of high-pressure air systems, large-volume air compressors can be used to charge scuba cylinders directly. However, few compressors can deliver air in sufficient quantity at the needed pressure for efficient operation. Small compressors should be used only if no other suitable source is available.

If a suitable compressor is available, the basic charging procedure will be the same as that outlined for cascading except that the compressor will replace the bank of cylinders. Special considerations that apply when using air compressors are:

- The compressor must be listed in the NAVSEA/00C ANU list if it is not part of a certified system.

- The compressor must deliver air that meets the established purity standards.

- The compressor shall be equipped with ANU particulate filters. Chemically active filters are not authorized.

- An engine-driven compressor must always be mounted so there is no danger of taking in exhaust fumes from the engine, stack gas, or other contaminated air from local sources.

- Only approved diving compressor lubricants are to be used in accordance with PMS procedures or manufacturer's recommendations.

Additional information on using air compressors is found in paragraph 8-6.2.2.

7-4.5 Safety Precautions for Charging and Handling Cylinders. The following safety rules apply to charging and handling scuba cylinders:

- Carry cylinders by holding the valve and body of the cylinder. Avoid carrying a cylinder by the backpack or harness straps as the quick-release buckle can be accidentally tripped or the straps may fail.

- Do not attempt to fill any cylinder if the hydrostatic test date has expired or if the cylinder appears to be substandard. Dents, severe rusting, bent valves, frozen reserve mechanisms, or evidence of internal contamination (e.g., water scales or rust) are all signs of unsuitability. See CGA Pamphlet C-6, Standards for Visual Inspection of Compressed Gas Cylinders.

- Always use gauges to measure cylinder pressure. Never point the dial of a gauge to which pressure is being applied toward the operators face.

- Never work on a cylinder valve while the cylinder is charged.

- Make sure that the air reserve mechanism is open (lever down) before charging.

- Use only compressed air for filling conventional scuba cylinders. Never fill scuba cylinders with oxygen. Air is color-coded black, while oxygen is color-coded green.

- Tighten all fittings before pressurizing lines.

- When fully charged, close the air reserve (lever up). Mark the filled tank to indicate the pressure to which it was charged.

- Handle charged cylinders with care. If a charged cylinder is damaged or if the valve is accidentally knocked loose, the cylinder tank can become an explosive projectile. A cylinder charged to 2,000 psi has enough potential energy to propel itself for some distance, tearing through any obstructions in its way.

- Store filled cylinders in a cool, shaded area. Never leave filled cylinders in direct sunlight.

- Cylinders should always be properly secured aboard ship or in a diving boat.

7-5 PREDIVE PROCEDURES

Predive procedures for scuba operations include equipment preparation, diver preparation, and conducting a predive inspection before the divers enter the water.

7-5.1 Equipment Preparation. Prior to any dive, all divers must carefully inspect their own equipment for signs of deterioration, damage, or corrosion. The equipment must be tested for proper operation. Predive preparation procedures must be standardized, not altered for convenience, and must be the personal concern of each diver.

7-5.1.1 **Air Cylinders.**

- Inspect air cylinder exteriors and valves for rust, cracks, dents, and any evidence of weakness.

- Inspect O-ring.

- Verify that the reserve mechanism is closed (lever in up position) signifying a filled cylinder ready for use.

- Gauge the cylinders according to the following procedure:

  1. Attach pressure gauge to O-ring seal face of the on/off valve.

  2. Close gauge bleed valve and open air reserve mechanism (lever in down position). Slowly open the cylinder on/off valve, keeping a cloth over the face of the gauge.

  3. Read pressure gauge. The cylinder must not be used if the pressure is not sufficient to complete the planned dive.

  4. Close the cylinder on/off valve and open the gauge bleed valve.

  5. When the gauge reads zero, remove the gauge from the cylinder.

  6. Close the air reserve mechanism (lever in up position).

  7. If the pressure in cylinders is 50 psi or greater over rating, open the cylinder on/off valve to bleed off excess and regauge the cylinder.

7-5.1.2 **Harness Straps and Backpack.**

- Check for signs of rot and excessive wear.
- Adjust straps for individual use and test quick-release mechanisms.
- Check backpack for cracks and other unsafe conditions.

7-5.1.3 **Breathing Hoses.**

- Check the hoses for cracks and punctures.
- Test the connections of each hose at the regulator and mouthpiece assembly by tugging on the hose.
- Check the clamps for corrosion and damage; replace as necessary and in accordance with PMS procedures.

7-5.1.4 **Regulator.**

1. Attach regulator to the cylinder manifold, ensuring that the O-ring is properly seated.
2. Crack the cylinder valve open and wait until the hoses and gauges have equalized.
3. Next open the cylinder valve completely and then close (back off) one-quarter turn.
4. Check for any leaks in the regulator by listening for the sound of escaping air. If a leak is suspected, determine the exact location by submerging the valve assembly and the regulator in a tank of water and watch for escaping bubbles. Frequently the problem can be traced to an improperly seated regulator and is corrected by closing the valve, bleeding the regulator, detaching and reseating. If the leak is at the O-ring and reseating does not solve the problem, replace the O-ring and check again for leaks.

7-5.1.5 **Life Preserver/Buoyancy Compensator (BC)**

- Orally inflate preserver to check for leaks and then squeeze out all air. The remaining gas should be removed after entry into the water by rolling onto the back and depressing the oral inflation tube just above the surface. Never suck the air out, as it may contain excessive carbon dioxide.
- Inspect the carbon dioxide cartridges to ensure they have not been used (seals intact) and are the proper size for the vest being used and for the depth of dive.
- The cartridges shall be weighed in accordance with the Planned Maintenance System.

- The firing pin should not show wear and should move freely.
- The firing lanyards and life preserver straps must be free of any signs of deterioration.
- When the life preserver inspection is completed, place it where it will not be damaged. Life preservers should never be used as a buffer, cradle, or cushion for other gear.

7-5.1.6 **Face Mask.**

- Check the seal of the mask and the condition of the head strap.
- Check for cracks in the skirt and faceplate.

7-5.1.7 **Swim Fins.**

- Check straps for signs of cracking.
- Inspect blades for signs of cracking.

7-5.1.8 **Dive Knife.**

- Test the edge of the knife for sharpness.
- Ensure the knife is fastened securely in the scabbard.
- Verify that the knife can be removed from the scabbard without difficulty, but will not fall out.

7-5.1.9 **Snorkel.**

- Inspect the snorkel for obstructions.
- Check the condition of the mouthpiece.

7-5.1.10 **Weight Belt.**

- Check the condition of the weight belt.
- Make sure that the proper number of weights are secure and in place.
- Verify that the quick-release buckle is functioning properly.

7-5.1.11 **Submersible Wrist Watch.**

- Ensure wrist watch is wound and set to the correct time.
- Inspect the pins and strap of the watch for wear.

7-5.1.12 **Depth Gauge and Compass.**

- Inspect pins and straps.
- If possible, check compass with another compass.
- Make comparative checks on depth gauges to ensure depth gauges read zero fsw on the surface.

7-5.1.13 **Miscellaneous Equipment.**

- Inspect any other equipment that will be used on the dive as well as any spare equipment that may be needed during the dive including spare regulators, cylinders, and gauges.
- Check all protective clothing, lines, tools, flares, and other optional gear.

7-5.2 Diver Preparation and Brief. When the divers have completed inspecting and testing their equipment, they shall report to the Diving Supervisor. The divers shall be given a predive briefing of the dive plan. This briefing is critical to the success and safety of any diving operation and shall be concerned with only the dive about to begin. All personnel directly involved in the dive should be included in the briefing. Minimum items to be covered are:

- Dive objectives
- Time and depth limits for the dive
- Task assignments
- Buddy assignments
- Work techniques and tools
- Phases of the dive
- Route to the work site
- Special signals
- Anticipated conditions
- Anticipated hazards
- Emergency procedures (e.g., unconscious diver, trapped diver, loss of air, aborted dive, injured diver, lost diver, etc.)

When the Diving Supervisor determines all requirements for the dive have been met, the divers may dress for the dive.

7-5.3 Donning Gear. Although scuba divers should be able to put on all gear themselves, the assistance of a tender is encouraged. Dressing sequence is important as the weight belt must be outside of all backpack harness straps and other equipment in order to facilitate its quick release in the event of an emergency. The following is the recommended dressing sequence to be observed:

1. Protective clothing. Ensure adequate protection is provided with a wet suit.

2. Booties and hood.

3. Dive knife.

4. Life preserver, with inflation tubes in front and the actuating lanyards exposed and accessible.

5. Scuba. Most easily donned with the tender holding the cylinders in position while the diver fastens and adjusts the harness. The scuba should be worn centered on the diver’s back as high up as possible but not high enough to interfere with head movement. All quick-release buckles must be positioned so that they can be reached by either hand. All straps must be pulled snug so the cylinders are held firmly against the body. The ends of the straps must hang free so the quick-release feature of the buckles will function. If the straps are too long, they should be cut and the ends whipped with small line or a plastic sealer. At this time, the cylinder on/off valve should be opened fully and then backed off one-quarter to one-half turn. Ensure buoyancy compensator whip is connected to the buoyancy compensator.

6. Accessory equipment (diving wrist watch, depth gauge, snorkel).

7. Weight belt.

8. Gloves.

9. Swim fins.

10. Face mask or full face mask.

7-5.4 **Predive Inspection.** The divers must report to the Diving Supervisor for a final inspection. During this final predive inspection the Diving Supervisor must:

1. Ensure that the divers are physically and mentally ready to enter the water.

2. Verify that all divers have all minimum required equipment (scuba, face mask, life preserver or buoyancy compensator, weight belt, dive knife, scabbard, swim fins, watch and depth gauge). When diving scuba and a buddy line is used, only one depth gauge and one watch per dive team is required.

3. Verify that the cylinders have been gauged and that the available volume of air is sufficient for the planned duration of the dive.

4. Ensure that all quick-release buckles and fastenings can be reached by either hand and are properly rigged for quick release.

5. Verify that the weight belt is outside of all other belts, straps, and equipment and will not become pinched under the bottom edge of the cylinders.

6. Verify that the life preserver or buoyancy compensator is not constrained and is free to expand, and that all air has been evacuated.

7. Check position of the knife to ensure that it will remain with the diver no matter what equipment is left behind.

8. Ensure that the cylinder valve is open fully and backed off one-quarter to one-half turn.

9. Ensure that the hose supplying air passes over the diver's right shoulder and the exhaust hose on the double-hose unit passes over the left shoulder. Double-hose regulators are attached so that the exhaust ports face up when the tank is standing upright.

10. With mouthpiece or full face mask in place, breathe in and out for several breaths, ensuring that the demand regulator and check valves are working correctly.

11. With a single-hose regulator, depress and release the purge button at the mouthpiece and listen for any sound of leaking air. Breathe in and out several times ensuring valves are working correctly.

12. Give the breathing hoses and mouthpiece a final check; ensure that none of the connections have been pulled open during the process of dressing.

13. Check that the air reserve mechanism lever is up (closed position).

14. Conduct a brief final review of the dive plan.

15. Verify that dive signals are displayed and personnel and equipment are ready to signal other vessels in the event of an emergency.

7-6 WATER ENTRY AND DESCENT

The divers are now ready to enter the water, where their scuba shall be given another brief inspection by their dive partners or tenders prior to descent.

7-6.1 Water Entry. There are several ways to enter the water, with the choice usually determined by the nature of the diving platform (Figure 7-8a and Figure 7-8b). Whenever possible, entry should be made by ladder, especially in unfamiliar waters. Several basic rules apply to all methods of entry:

- Look before jumping or pushing off from the platform or ladder.

Front jump or step-in. On edge of platform, one hand holding face mask and regulator, the other holding the cylinders, the diver takes a long step forward, keeping his legs astride.

Rear roll. The diver, facing inboard, sits on the gunwale. With chin tucked in, holding his mask, mouthpiece, and cylinders, the diver rolls backwards, basically completing a full backward somersault.

Side roll. Tender assists diver in taking a seated position. Tender stands clear as diver holds his mask and cylinders and rolls into the water.

Front roll. Diver sits on edge of platform with a slight forward lean to offset the weight of the cylinders. Holding his mask and cylinders, the diver leans forward.

Figure 7-8a. Scuba Entry Techniques.

- Tuck chin into chest and hold the cylinders with one hand to prevent the manifold from hitting the back of the head.

- Hold the mask in place with the fingers and the mouthpiece in place with the heel of the hand.

7-6.1.1 **Step-In Method.** The step-in method is the most frequently used, and is best used from a stable platform or vessel. The divers should simply take a large step out from the platform, keeping legs in an open stride. They should try to enter the water with a slightly forward tilt of the upper body so that the force of entry will not cause the cylinder to hit the back of the head.

Rear step-in. The diver steps backward pushing himself away with his feet.

Figure 7-8b. Scuba Entry Techniques (continued).

7-6.1.2 **Rear Roll Method.** The rear roll is the preferred method for entering the water from a small boat. A fully outfitted diver standing on the edge of a boat would upset the stability of the craft and would be in danger of falling either into the boat or into the water. To execute a rear roll, the diver sits on the gunwale of the boat, facing inboard. With chin tucked in and one hand holding the mask and mouthpiece in place, the diver rolls backward, basically moving through a full backward somersault.

7-6.1.3 **Entering the Water from the Beach.** Divers working from the beach choose their method of entry according to the condition of the surf and the slope of the bottom. If the water is calm and the slope gradual, the divers can walk out, carrying their swim fins until they reach water deep enough for swimming. In a moderate to high surf, the divers, wearing swim fins, should walk backwards into the waves until they have enough depth for swimming. They should gradually settle into the waves as the waves break around them.

7-6.2 **Predescent Surface Check.** Once in the water, and before descending to operating depth, the divers make a final check of their equipment. They must:

- Make a breathing check of the scuba. Breathing should be easy, with no resistance and no evidence of water leaks.

- Visually check dive partner’s equipment for leaks, especially at all connection points (i.e., cylinder valve, hoses at regulator and mouthpiece).

- Check partner for loose or entangled straps.

- Check face mask seal. A small amount of water may enter the mask upon the diver's entry into the water. The mask may be cleared through normal methods (see paragraph 7-7.2).

- Check buoyancy. Scuba divers should strive for neutral buoyancy. When carrying extra equipment or heavy tools, the divers might easily be negatively buoyant unless the weights are adjusted accordingly.

- If wearing a dry suit, check for leaks. Adjust suit inflation for proper buoyancy.

- Orient position with the compass or other fixed reference points.

When satisfied that all equipment checks out properly, the divers report their readiness to the Diving Supervisor. The Diving Supervisor directs the divers to zero their watches and bottom time begins. The Diving Supervisor gives a signal to descend and the divers descend below the surface.

7-6.3 **Surface Swimming.** The diving boat should be moored as near to the dive site as possible. While swimming, dive partners must keep visual contact with each other and other divers in the group. They should be oriented to their surroundings to avoid swimming off course. The most important factor in surface swimming with scuba is to maintain a relaxed pace to conserve energy. The divers should keep their masks on and breathe through the snorkel. When surface swimming with a scuba regulator, hold the mouthpiece so that air does not free-flow from the system.

Divers should use only their legs for propulsion and employ an easy kick from the hips without lifting the swim fins from the water. Divers can rest on their backs and still make headway by kicking. Swimming assistance can be gained by partially inflating the life preserver or buoyancy compensator. However, the preserver must be deflated again before the dive begins.

7-6.4 **Descent.** The divers may swim down or they may use a descending line to pull themselves down. The rate of descent will generally be governed by the ease with which the divers will be able to equalize the pressure in their ears and sinuses, but it should never exceed 75 feet per minute. If either diver experiences difficulty in clearing, both divers must stop and ascend until the situation is resolved. If the problem persists after several attempts to equalize, the dive shall be aborted and both divers shall return to the surface. When visibility is poor, the divers should extend an arm to ward off any obstructions.

Upon reaching the operating depth, the divers must orient themselves to their surroundings, verify the site, and check the underwater conditions. If conditions appear to be radically different from those anticipated and seem to pose a hazard, the dive should be aborted and the conditions reported to the Diving Supervisor. The dive should be aborted if the observed conditions call for any major change in the dive plan. The divers should surface, discuss the situation with the Diving Supervisor, and modify the dive plan.

7-7 UNDERWATER PROCEDURES

In a scuba dive, bottom time is at a premium because of a limited supply of air. Divers must pace their work, conserve their energy, and take up each task or problem individually. At the same time they must be flexible. They must be ready to abort the dive at any time they feel that they can no longer progress toward the completion of their mission or when conditions are judged unsafe. The divers must be alert for trouble at all times and must monitor the condition of the dive partner constantly.

7-7.1 **Breathing Technique.** When using scuba for the first time, a novice diver is likely to experience anxiety and breathe more rapidly and deeply than normal. The diver must learn to breathe in an easy, slow rhythm at a steady pace. The rate of work should be paced to the breathing cycle, rather than changing the breathing to support the work rate. If a diver is breathing too hard, he should pause in the work until breathing returns to normal. If normal breathing is not restored soon, the diver must signal the dive partner and break off the operation, and together they should ascend to the surface.

Some divers, knowing that they have a limited air supply, will attempt to conserve air by holding their breath. One common technique is to skip-breathe: to insert an unnatural, long pause between each breath.

WARNING Skip-breathing may lead to hypercapnia and shall not be practiced.

Increased breathing resistance results from the design of the equipment and increased air density. For normal diving, a marked increase of breathing resistance should not occur until the primary air supply has been almost depleted. This increase in breathing resistance is a signal to the diver to activate the reserve air supply and to begin an ascent with the partner immediately. When equipped with a submersible bottle gauge, the diver shall monitor his air supply pressure and must terminate the dive whenever bottle pressure is reduced to 500 psi for a single bottle or 250 psi for a set of double bottles.

7-7.2 **Mask Clearing.** Some water seepage into the face mask is a normal condition and is often useful in defogging the lens. From time to time the quantity may build to a point that it must be removed. On occasion, a mask may become dislodged and flooded. To clear a flooded mask not equipped with a purge valve, the diver should roll to the side or look upward, so that the water will collect at the side or bottom of the mask. Using either hand, the diver applies a firm direct pressure on the opposite side or top of the mask and exhales firmly and steadily through the nose. The water will be forced out under the skirt of the mask. When the mask has a purge valve, the diver tilts his head so that the accumulated water covers the valve, presses the mask against the face and then exhales firmly and steadily through the nose. The increased pressure in the mask will force the water through the valve. Occasionally, more than one exhalation will be required.

7-7.3 **Hose and Mouthpiece Clearing.** The mouthpiece and the breathing hoses can become flooded if the mouthpiece is accidentally pulled from the mouth. With a

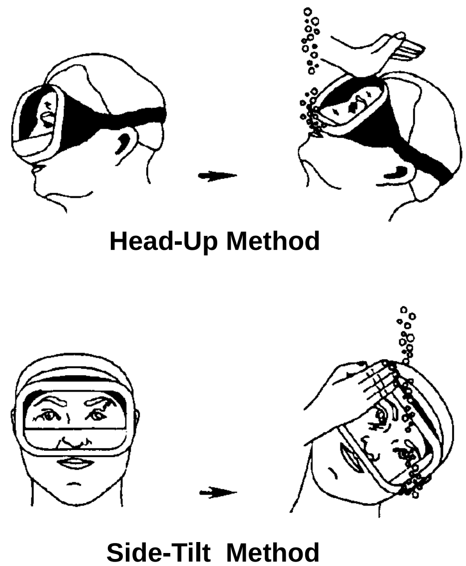


Figure 7-9. Clearing a Face Mask. To clear a flooded face mask, push gently on the upper or side portion of the mask and exhale through the nose into the mask. As water is forced out, tilt the head backward or sideway until the mask is clear.

single-hose scuba this is not a serious problem since the hose (carrying air at medium pressure) will not flood and the mouthpiece can be cleared quickly by depressing the purge button as the mouthpiece is being replaced.

To clear a double-hose scuba regulator that has flooded, the diver, swimming in a horizontal position, should grasp the mouthpiece. The diver should then blow into the mouthpiece, forcing any water trapped in it out through the regulator's exhaust ports. The diver should carefully take a shallow breath. If water is still trapped in the mouthpiece, the diver should blow through it once more and resume normal breathing. If the diver is out of breath, he should roll over onto his back and the regulator will free flow.

7-7.4 **Swimming Technique.** In underwater swimming, all propulsion comes from the action of the legs. The hands are used for maneuvering. The leg kick should be through a large, easy arc with main thrust coming from the hips. The knees and ankles should be relaxed. The rhythm of the kick should be maintained at a level that will not tire the legs unduly or bring on muscle cramps.

7-7.5 **Diver Communications.** Some common methods of diver communications are: through-water communication systems, hand signals, slate boards, and line-pull signals. Communication between the surface and a diver can be best accomplished with through-water voice communications. However, when through-water communications are not available, hand signals or line-pull signals can be used.

7-7.5.1 **Through-Water Communication Systems.** Presently, several types of through-water communication systems are available for scuba diving operations. Acoustic systems provide one-way, topside-to-diver communications. The multidirectional audio signal is emitted through the water by a submerged transducer. Divers can hear the audio signal without signal receiving equipment. Amplitude Modulated (AM) and Single Sideband (SSB) systems provide round-robin, diver-to-diver, diver-to-topside, and topside-to-diver communications. Both the AM and SSB systems require transmitting and receiving equipment worn by the divers. AM systems provide a stronger signal and better intelligibility, but are restricted to line-of-sight use. SSB systems provide superior performance in and around obstacles. Before any through-water communication system is used, consult the NAVSEA/00C Authorized for Navy Use (ANU) list.

7-7.5.2 **Hand and Line-Pull Signals.** Navy divers shall only use hand signals that have been approved for Navy diving use. Figure 7-10a and Figure 7-10b present the U.S. Navy approved hand signals. Under certain conditions, special signals applicable to a specific mission may be devised and approved by the Diving Supervisor. If visibility is poor, the dive partners may be forced to communicate with line-pull signals on a buddy line. Line-pull signals are discussed in Table 8-2. Hand signals and line-pull signals should be delivered in a forceful, exaggerated manner so that there is no ambiguity and no doubt that a signal is being given. Every signal must be acknowledged.

7-7.6 **Buddy Diver Responsibilities.** The greatest single safety practice in Navy scuba operations is the use of the buddy system. Dive partners operating in pairs are responsible for both the assigned task and each other's safety. The basic rules for buddy diving are:

- Always maintain contact with the dive partner. In good visibility, keep the partner in sight. In poor visibility, use a buddy line.
- Know the meaning of all hand and line-pull signals.
- If a signal is given, it must be acknowledged immediately. Failure of a dive partner to respond to a signal must be considered an emergency.
- Monitor the actions and apparent condition of the dive partner. Know the symptoms of diving ailments. If at any time the dive partner appears to be in distress or is acting in an abnormal manner, determine the cause immediately and take appropriate action.
- Never leave a partner unless the partner has become trapped or entangled and cannot be freed without additional assistance. If surface assistance must be sought, mark the location of the distressed diver with a line and float or other locating device. Do not leave a partner if voice communications or line-pull signals are being used; contact the surface and await assistance or instructions.
- Establish a lost-diver plan for any dive. If partner contact is broken, follow the plan.

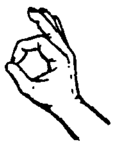
	Meaning/Signal	Comment
	**STOP** Clenched fist.	
	**SOMETHING IS WRONG** Hand flat, fingers together, palm out, thumb down then hand rocking back and forth on axis of forearm.	This is the opposite of Okay. The signal does not indicate an emergency.
 	**I AM OKAY or ARE YOU OKAY?** Thumb and forefinger making a circle with three remaining fingers extended (if possible).	Divers wearing mittens may not be able to extend three remaining fingers distinctly. Short range use.
 	**OKAY ON THE SURFACE (CLOSE)** Right hand raised overhead giving Okay signal with fingers. **OKAY ON THE SURFACE (DISTANT)** Both hands touching overhead with both arms bent at 45° angle.	Given when diver is close to pickup boat. Given when diver is at a distance from the pickup boat.
	**DISTRESS or HELP or PICK ME UP** Hand waving overhead (diver may also thrash hand in water).	Indicates immediate aid is required.
	**WHAT TIME? or WHAT DEPTH?** Diver points to either watch or depth gauge.	When indicating time, this signal is commonly used for bottom time remaining.
	**GO DOWN or GOING DOWN** Two fingers up, two fingers and thumb against palm.	
	**GO UP or GOING UP** Four fingers pointing up, thumb against palm.	
 	**I'M OUT OF AIR.** Hand slashing or chopping at throat. **I NEED TO BUDDY BREATHE** Fingers pointing to mouth or regulator.	Indicates signaler is out of air. Signaler's regulator may be in or out of mouth.

Figure 7-10a. Scuba Hand Signals.

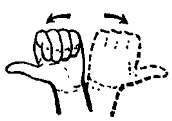
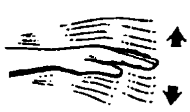
	Meaning/Signal	Comment
	**COME HERE** Hand to chest, repeated.	
	**ME or WATCH ME** Finger to chest, repeated.	
	**OVER, UNDER, or AROUND** Fingers together and arm moving in and over, under, or around movement.	Diver signals intention to move over, under, or around an object.
	**LEVEL OFF or HOW DEEP?** Fingers and thumb spread out and hand moving back and forth in a level position.	
	**GO THAT WAY** Fist clenched with thumb pointing up, down, right, or left.	Indicates which direction to swim.
	**WHICH DIRECTION?** Fingers clenched, thumb and hand rotating right and left.	
	**EAR TROUBLE** Diver pointing to either ear.	Divers should ascend a few feet. If problem continues, both divers must surface.
	**I'M COLD** Both arms crossed over chest.	
	**TAKE IT EASY OR SLOW DOWN** Hand extended, palm down, in short up-and-down motion.	
	**YOU LEAD, I'LL FOLLOW** Index fingers extended, one hand forward of the other.	

Figure 7-10a. Scuba Hand Signals.

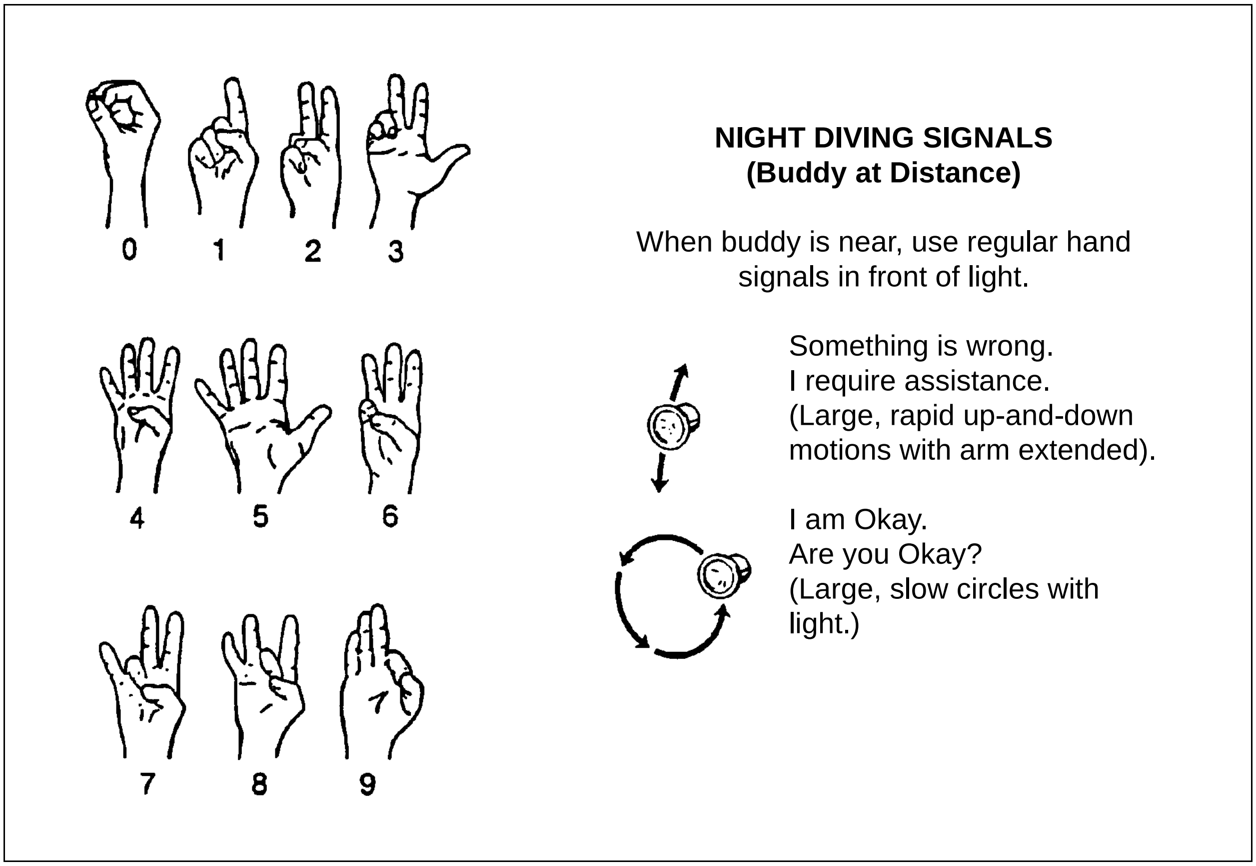


Figure 7-10b. Scuba Hand Signals (continued).

- If one member of a dive team aborts a dive, for whatever reason, the other member also aborts and both must surface.

- Know the proper method of buddy breathing.

7-7.7 **Buddy Breathing Procedure.** If a diver runs out of air or the scuba malfunctions, air may be shared with the dive partner. The most efficient method of buddy breathing is for the two divers to face each other, each alternately breathing from the same mouthpiece while ascending. Buddy breathing may be used in an emergency and must be practiced so that each diver will be thoroughly familiar with the procedure.

1. The distressed diver should remain calm and signal the partner by pointing to scuba mouthpiece.

2. The partner and the distressed diver should hold on to each other by grasping a strap or the free arm. The divers must be careful not to drift away from each other.

3. The partner must make the first move by taking a breath and passing the mouthpiece to the distressed diver. The distressed diver must not grab for the

dive partner's mouthpiece. The dive partner guides it to the distressed diver's mouth. Both divers maintain direct hand contact on the mouthpiece.

4. The mouthpiece may have flooded during the transfer. In this case, clear the mouthpiece by using the purge button (if single-hose) or by exhaling into the mouthpiece before a breath can be taken. If using a double-hose regulator, the mouthpiece should be kept slightly higher than the regulator so that free-flowing air will help keep the mouthpiece clear.

5. The distressed diver should take two full breaths (exercising caution in the event that all of the water has not been purged) and guide the mouthpiece back to the partner. The partner should then purge the mouthpiece as necessary and take two breaths.

6. The divers should repeat the breathing cycle and establish a smooth rhythm. No attempt should be made to surface until the cycle is stabilized and the proper signals have been exchanged.

WARNING **During ascent, the diver without the mouthpiece must exhale to offset the effect of decreasing pressure on the lungs which could cause an air embolism.**

7. Buddy breathing may also be accomplished by use of an "octopus" (secondary second-stage regulator). Approved secondary second stage regulators are contained in the diving equipment Authorized for Navy Use (ANU) list.

7-7.8 Tending.

7-7.8.1 **Tending with a Surface or Buddy Line.** When a diver is being tended by a line from the surface or a buddy line, several basic considerations apply.

- Lines should be kept free of slack.
- Line signals must be given in accordance with the procedures given in Table 8-2.
- Any signals via the line must be acknowledged immediately by returning the same signal.
- The tender should signal the diver with a single pull every 2 or 3 minutes to determine that the diver is all right. A return signal of one pull indicates that the diver is all right.
- If the diver fails to respond to line-pull signals after several attempts, the standby diver must investigate immediately.
- The diver must be particularly aware of the possibilities for the line becoming snagged or entangled.

7-7.8.2 **Tending with No Surface Line.** If a surface line is not being used, the tender must keep track of the general location of the divers by observing the bubble tracks or the float or locating device (such as a pinger or strobe light). When tending a single diver, the tender shall continually monitor the diver float for diver location and line pull signals.

7-7.9 Working with Tools. The near-neutral buoyancy of a scuba diver poses certain problems when working with tools. A diver is at a disadvantage when applying leverage with tools. When applying force to a wrench, for example, the diver is pushed away and can apply very little torque. If both sides of the work are accessible, two wrenches—one on the nut and one on the bolt—should be used. By pulling on one wrench and pushing on the other, the counter-force permits most of the effort to be transmitted to the work. When using any tool that requires leverage or force (including pneumatic power tools), the diver should be braced with feet, a free hand, or a shoulder.

NOTE When using externally powered tools with scuba, the diver must have voice communications with the Diving Supervisor.

Any tools to be used should be organized in advance. The diver should carry as few items as possible. If many tools are required, a canvas tool bag should be used to lower them to the diver as needed. Further guidelines for working underwater are provided in the *U.S. Navy Underwater Ship Husbandry Manual* (NAVSEA S0600-AA-PRO-010). Authorized power tools are listed in the NAVSEA/00C ANU list.

7-7.10 Adapting to Underwater Conditions. Through careful and thorough planning, the divers can be properly prepared for the underwater conditions at the diving site and be provided with appropriate auxiliary equipment, protective clothing, and tools. However, the diver may have to employ the following techniques to offset the effects of certain underwater conditions:

- Stay 2 or 3 feet above a muddy bottom; use a restricted kick and avoid stirring up the mud. A diver should be positioned so that the current will carry away any clouds of mud.
- Avoid coral or rocky bottoms, which may cause cuts and abrasions.
- Avoid abrupt changes of depth.
- Do not make excursions away from the dive site unless the excursions have been included in the dive plan.
- Be aware of the peculiar properties of light underwater. Depth perception is altered so that an object appearing to be 3 feet away is actually 4 feet away, and objects appear larger than they actually are.

- Be aware of unusually strong currents, particularly rip currents near a shoreline. If caught in a rip current, relax and ride along with it until it diminishes enough to swim clear.

- If practical, swim against a current to approach a job site. The return swim with the current will be easier and will offset some of the fatigue caused by the job.

- Stay clear of lines or wires that are under stress.

7-8 ASCENT PROCEDURES

When it is time to return to the surface, either diver may signal the end of the dive. When the signal has been acknowledged, the divers shall ascend to the surface together at a rate not to exceed 30 feet per minute. For a normal ascent, the divers will breathe steadily and naturally. Divers must never hold their breath during ascent, because of the danger of an air embolism. While ascending, divers must keep an arm extended overhead to watch for obstructions and should spiral slowly while rising to obtain a full 360 degree scan of the water column.

7-8.1 **Emergency Free-Ascent Procedures.** If a diver is suddenly without air or if the scuba is entangled and the dive partner cannot be reached quickly, a free ascent must be made. Guidelines for a free ascent are:

1. Drop any tools or objects being carried by hand.

2. Abandon the weight belt.

3. If the scuba has become entangled and must be abandoned, actuate the quick-release buckles on the waist, chest, shoulder, and crotch straps. Slip an arm out of one shoulder strap and roll the scuba off the other arm. An alternate method is to flip the scuba over the head and pull out from underneath. Ensure that the hoses do not wrap around or otherwise constrict the neck. The neck straps packed with some single-hose units can complicate the overhead procedure and should be disconnected from the unit and not used.

4. If the reason for the emergency ascent is a loss of air, drop all tools and the weight belt and actuate the life preserver to surface immediately. Do not drop the scuba unless it is absolutely necessary.

5. If a diver is incapacitated or unconscious and the dive partner anticipates difficulty in trying to swim the injured diver to the surface, the partner should activate the life preserver or inflate the buoyancy compensator. The weight belt may have to be released also. However, the partner should not lose direct contact with the diver.

6. Exhale continuously during ascent to let the expanding air in the lungs escape freely.

7-8.2 **Ascent From Under a Vessel.** When underwater ship husbandry tasks are required, surface-supplied lightweight equipment is preferred. Scuba diving is permitted under floating hulls; however, a tending line to the scuba diver must be provided. In the event of casualty and the lack of immediate assistance by the dive partner, the scuba diver will be able to return to the surface using the tending line. Ships are often moored against closed-face piers or heavy camels and care must be exercised to ensure that the tending line permits a clear path for emergency surfacing of the diver.

Due to the unique nature of EOD operations involving limpet search and neutralization, the use of tending lines is not practical and is not required. During EOD limpet mine training, the use of tending lines is required.

Scuba dive plans on deep-draft ships should restrict diving operations to one quadrant of the hull at a time. This theoretical quartering of the ship's hull will minimize potential diver disorientation caused by multiple keel crossings or fore and aft confusion.

When notified of a lost diver, a search shall be conducted by a tended diver in the area where the lost diver was last seen.

Predive briefs must include careful instruction on life preserver use when working under a hull to prevent panic blowup against the hull. Life preservers should not be fully inflated until after the diver passes the turn of the bilge.

7-8.3 **Decompression.** Open-circuit scuba dives are normally planned as no-decompression dives. Open-circuit scuba dives requiring decompression may be made only when considered absolutely necessary and authorized by the Commanding Officer or Officer in Charge (OIC). Under this unique situation, the following provides guidance for scuba decompression diving.

The Diving Supervisor shall determine the required bottom time for each dive. Based upon the time and depth of the dive, the required decompression profile from the tables presented in Chapter 9 shall be computed. The breathing supply required to support the total time in the water must then be calculated. If the air supply is not sufficient, a backup scuba will have to be made available to the divers. The backup unit can be strapped to a stage or tied off on a descent line which also has been marked to indicate the various decompression stops to be used.

When the divers have completed the assigned task, or have reached the maximum allowable bottom time prescribed in the dive plan, they must ascend to the stage or the marked line and signal the surface to begin decompression. With the stage being handled from the surface, the divers will be taken through the appropriate stops while the timekeeper controls the progress. Before each move of the stage, the tender will signal the divers to prepare for the lift and the divers will signal back when prepared. When using a marked line, the tender will signal when each stop has been completed, at which point the divers will swim up, signaling their arrival at the next stop. Stop times will always be regulated by the Dive Supervisor.

In determining the levels for the decompression stops, the sea state on the surface must be taken into consideration. If large swells are running, the stage or marker line will be constantly rising and falling with the movements of the surface-support craft. The depth of each decompression stop should be calculated so that the divers' chests will never be brought above the depths prescribed for the stops in the decompression tables.

In the event of an accidental surfacing or an emergency, the Diving Supervisor will have to determine if decompression should be resumed in the water or if the services of a recompression chamber are required. The possibility of having to make such a choice should be anticipated during the planning stages of the operation (Chapters 1 and 5).

7-8.4 **Surfacing and Leaving the Water.** When approaching the surface, divers must not come up under the support craft or any other obstruction. They should listen for the sound of propellers and delay surfacing until satisfied that there is no obstruction. On the surface, the diver should scan immediately in all directions and check the location of the support craft, other divers, and any approaching surface traffic. If they are not seen by the support craft, they should attempt to signal the support craft with hand signals, whistle, or flare.

On the surface, the divers can rest while waiting to be picked up. For buoyancy, life vests or buoyancy compensators can be inflated orally or the diver can use a snorkel for breathing.

As the divers break the surface, the tender and other personnel in the support craft must keep them in sight constantly and be alert for any signs of trouble. While one diver is being taken aboard the support craft, attention must not be diverted from the divers remaining in the water. The dive is completed when all divers are safely aboard.

Usually, getting into the boat will be easier if the divers remove the weight belts and scuba and then hand them to the tenders. If the boat has a ladder, swim fins should also be removed. Without a ladder, the swim fins will help to give the diver an extra push to get aboard. A small boat may be boarded over the side or over the stern depending on the type of craft and the surface conditions. As each diver comes aboard a small boat or a raft, other personnel in the boat should remain seated.

7-9 POSTDIVE PROCEDURES

The Diving Supervisor should debrief each returning diver while the experience of the dive is still fresh. The Diving Supervisor should determine if the assigned tasks were completed, if any problems were encountered, if any changes to the overall dive plan are indicated and if the divers have any suggestions for the next team.

When satisfied with their physical condition, the divers' first responsibility after the dive is to check their equipment for damage and get it properly cleaned and stowed. Each diver is responsible for the immediate postdive maintenance and proper disposition of the equipment used during the dive. The Planned Maintenance System provides direction for postdive maintenance.

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