ON USING SELF-CONTAINED UNDERWATER BREATHING APPARATUS

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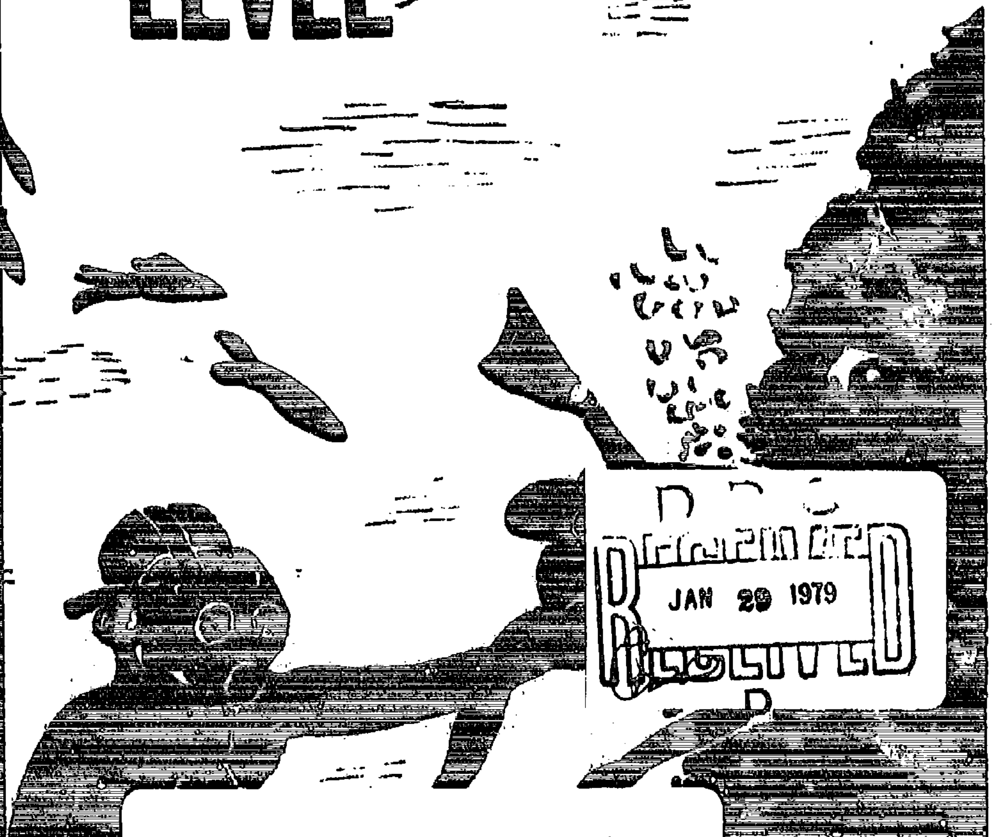

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(6) ON USING

SELF CONTAINED UNDERWATER BREATHING APPARATUS

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PREFACE

This report is not a training manual. It is a record of the opinions of a number of experienced underwater swimmers, who are concerned with promoting the safe use of self contained underwater breathing apparatus (SCUBA). To the authors' knowledge no authoritative and general set of safety precautions specifically designed to meet the needs of the underwater swimmer using SCUBA yet exists. It is hoped that this report will contribute toward that eventual end and that it will stimulate comment among its readers.

The material contained in this report comes from too many diverse sources to include specific references. Parts of it were originally written for military swimmers during World War II; others for a team of research personnel studying the respiratory physiology of underwater man. The several revisions of the manuscript were reviewed by physiologists engaged in studying problems of underwater swimmers, members of U. S. Navy Underwater Demolition Teams, personnel from the U. S. Navy Experimental Diving Unit, oceanographers and other research personnel who use SCUBA in their work, and by sports swimmers and spearfishermen from the West Coast. It is not, however, an official document of any of the above mentioned groups. Probably no one group or even any single individual agrees with every item contained in the report to follow; knowledge and experience in this relatively new field is as yet too meager to expect general agreement. We do believe, however, that it represents a fair cross-section of current thinking on using self contained underwater breathing apparatus.

The reader is cautioned not to take his SCUBA and this report and attempt to teach himself to swim underwater. The proper way to learn the safe use of SCUBA is under the personal tutelage of a competent and experienced underwater swimmer. It is hoped that this material will be a useful supplement in that process. Readers are urged to send their comments and suggestions to the Panel on Underwater Swimmers, National Research Council, 2101 Constitution Avenue, Washington, D. C. If sufficient interest is shown, it may be possible to prepare a revision or expansion of this report in the light of wider and longer experience.

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TABLE OF CONTENTS

INTRODUCTION

Within the last 3-5 years we have witnessed in this country a rapid increase in the numbers of self contained underwater breathing apparatus (SCUBA) in use. Not only are these devices useful to the military underwater demolition teams and explosive ordnance disposal units but they are finding increased use as research tools in universities, particularly the oceanographic institutions. SCUBA are now in relatively large scale use by spearfishermen and sports swimmers, particularly along the California coast. Perhaps the SCUBA best known to civilians is the French "Aqualung", an open circuit apparatus using compressed air. In addition to this type of open circuit apparatus, there are also semi-closed and closed circuit SCUBA, but these later units are not yet in widespread civilian use in this country.

Since these types of SCUBA are relatively new, perhaps it would be best to define them at this point. All are individual self contained breathing apparatuses for use by underwater swimmers and need no attachments to the surface such as life lines, air hoses, or other features common to the deep-sea divers' dress. It is this absence of attachments to the surface that distinguishes the self contained diver or underwater swimmer from the deep-sea or shallow water diver. Self contained underwater breathing apparatus may be conveniently divided into the following three categories:

Open circuit. Open circuit equipment is in general the simplest type of SCUBA. Air or a pre-set mixture of oxygen and nitrogen is stored under high pressure (about 2000 psi) in cylinders. This high pressure gas is reduced to an intermediate pressure (about 55 to 85 psi) by a first stage reduction valve. The gas is obtained by the swimmer on inspiration through a second demand-type reduction valve which is actuated by respiratory action. The pressure of gas delivered to the swimmer is about equal to the ambient hydrostatic pressure. In some equipments (Aqualung and Northill) the two stages of pressure reduction are accomplished within the same valve casing. Other units (Scott, Emerson Aga) have two valves in different locations. The entire exhalation is discharged as a stream of bubbles into the water and the utilization of gas from the supply cylinder is therefore equal to the mass exhaled.

Closed circuit. In the simplest type of closed circuit equipment, oxygen is stored in cylinders under high pressure, and is admitted to a breathing bag either 1) through a manually operated valve, 2) by a slow steady flow through a pressure reducing valve, or 3) through a demand valve system similar in construction to that described for the open circuit equipment. When methods (2) or (3) (automatic oxygen supply) are used, a manually operated emergency valve is also fitted. Oxygen admitted into the breathing bag mixes with the reservoir of purified, exhaled gas. The swimmer inhales from the breathing bag through a check valve. The slight pressure of exhalation closes the inhaling valve and opens an exhaling valve causing the exhaled gas to re-enter the breathing bag through a canister which contains carbon dioxide absorbent, normally soda-lime or baralyme. The rate of oxygen utilization from the cylinders is determined by the diver's metabolic consumption of oxygen rather than by the larger volume of gas required for ventilation as in the open circuit type. Because of the danger of oxygen toxicity the use of closed circuit oxygen apparatus is presently limited to a depth of 30 feet for a period of 45 minutes. Mixed gas equipment for closed circuit operations at depths greater than 30 feet is under long term study. Such equipment might employ a mixing valve which could be used to vary the rate of flow from two gas cylinders (oxygen and air or nitrogen) and an oxygen analyzer to control the mixing valves. The use of a mixture of gas would reduce the physiological danger from oxygen poisoning, which is present when pure oxygen is used at excessive depths but would introduce the new danger of anoxia and the problem of disposal of the excess inert gas on ascent.

Semi-closed circuit. Such apparatus can be used for breathing either air, a mixture of nitrogen and oxygen, or oxygen alone. This type of apparatus consists of the same general components as closed circuit oxygen rebreathing apparatus and in addition employs a non-return exhaust valve to allow spill over of that portion of the gas flow which is not actually consumed by the swimmer. Near the surface the volume of excess gas released into the water is approximately one-fourth to one-tenth that of open circuit apparatus. A fraction of the exhaled carbon dioxide can be exhausted, resulting in a diminished load upon the absorption cannister. In some types of semi-closed circuit equipment the breathing gas flows at a fixed rate directly into the rebreathing bag. In others, the flow is through a venturi orifice in order to facilitate recirculation of gas through the carbon dioxide absorption cannister. Oxygen and nitrogen may be pre-mixed and carried in the same cylinder; or alternatively, air or nitrogen, and oxygen may be carried in separate cylinders and mixed by a regulator. A type of SCUBA now under development (Emerson) is transitional between the open and semi-closed types. In this equipment no carbon dioxide absorption is used; instead a gas-saving mechanism is incorporated which stores the first part and discharges the last portion of each exhalation. Re-inhalation of this gas containing minimal exhaled carbon dioxide should increase the diving time available with any given cylinder capacity.

UNDERWATER SWIMMING

The material that follows pertains to the use of all three types of self contained apparatus. Additional special precautions or techniques may be required when using specific apparatus but it is felt that in general the remarks are applicable to all types of self contained underwater diving.

Most self contained underwater breathing apparatus is easy to use -- too easy. A man is in great danger if he enters the water in such equipment ignorant of potential dangers and of the ways of preventing their occurrence. As with most divers, the well-trained and experienced SCUBA user can dive safely if he knows and adheres to the basic safety precautions established for his guidance. His danger stems mainly from his environment and the possibility of his becoming careless. He must also be well aware of his own psychological and physiological limitations. Perhaps the following precautions will seem restrictive when compared to the exploits of some of the experts in underwater swimming, but they are written for that mythical being, the average swimmer.

I. The Swimmer

A. Must be psychologically and physically fit.

1. Must pass a complete physical examination which places special emphasis on the heart, lungs, ears, nose and throat. A history of sinus or respiratory ailments should almost always disqualify an underwater swimmer.

2. Must pass periodic (perhaps semi-annual) check ups, again with particular emphasis on the heart and respiratory systems.

3. Must "feel o.k." -- i.e., must not dive, nor be penalized for not diving when seriously desiring not to.

4. Must not dive after excessive drinking of alcohol until well rested and ill effects have passed.

5. Should be well rested (usually 8 hours sleep the night before dive) and when possible, should be permitted to rest after the dive.

6. It is highly desirable that the diver be "in shape". Regular exercises of running and skin diving have been found to be good conditioners for underwater swimmers.

7. Must like to dive. Underwater swimming should definitely be a volunteer activity. A reasonably reliable test of this is for the new swimmer to dive a few times with an experienced diver who can usually tell if the swimmer is enjoying himself underwater or whether he has some other motivation for diving.

B. Must be thoroughly qualified before being permitted to dive. Should be:

1. Trained in diving physiology, symptoms of diver's maladies, and acquainted with the use of decompression tables.

2. Thoroughly trained in the use of his specific equipment. Even the experienced diver needs to "check out" on a new device before being permitted to dive with it.

3. Trained in overcoming emergency situations, e.g. running out of breathing gas, loss of buoyancy control, flooded equipment, loss of sense of direction, entanglement in marine growth or underwater objects, etc.

4. Familiar with diving signals.

a. Hand signals

(1) Visual
(2) Rope pulls

b. Sound signals

II. Swimmer's Personal Equipment

A. SCUBA must always be in first class operating condition.

1. Schedules should be set up for inspection of:

a. Regulators, valves, hoses, masks, etc.

b. Cylinders, cannisters, guages, etc.

c. Harnesses, vests, belts, etc.

2. Swimmer must personally check operation and position of supply valves, reserve supply lines, and operating controls, immediately before entering the water.

3. Prior to entering water, swimmer should check seal of mask, (by inhaling).

4. Swimmers should determine proper additional weight required to provide neutral buoyancy when wearing apparatus.

5. All equipment should be washed in fresh water and properly stored on the completion of the dive.

B. In addition to the SCUBA, it is highly desirable that the minimum personal equipment worn by the swimmer include:

1. Swim fins of correct size (1 pair for skin, 1 pair for suited diving).

2. Belt with knife. (Note: slip-hitches for all straps)

3. Belt and weight for buoyancy control, if necessary.

4. Wrist watch.

5. Depth guage.

6. Retrieving lanyard on face mask (if separate). Note: rub saliva on inside of face plate and lightly rinse to aid antifogging.

C. The swimmer may also desire to wear or carry:

1. Compass

2. Plastic slate and pencil for recording instructions or observations.

3. Underwear in cool water, but where an exposure suit is not required.

4. Coral shoes and gloves when working on bottom or when emerging on shore.

D. The swimmer should have available warm dry clothes to put on after dive.

E. The swimmer should never:

1. Wear ear plugs.

2. Wear goggles.

III. Care and Loading of Cylinders.

A. Never fill cylinders beyond rated pressure.

1. Set up periodic inspection of cylinders for bulges, strains, etc.

2. Never put oxygen in air SCUBA -- beware of oil coming in contact with oxygen under high pressures.

3. Periodically inspect compressors and filters for contamination of air supply.

4. Stow cylinders so as to avoid possibility of falling, or receiving heavy shocks of any kind during storage, transit or use.

B. Always use correct size wrenches on all fittings, and never force them.

C. Periodically calibrate guages used for pressure measurements. Avoid oil in oxygen guages.

IV. Underwater Swimming

A. An underwater swimmer should never swim alone, but always be accompanied by a "buddy". Buddys must have confidence in each other's ability.

1. Day -- stay within visual range of each other. (Note: in shallow clear water the buddy may be a surfaced swimmer, or in a boat.)

2. Night -- or reduced visibility -- use a buddy line (6' to 10' long).

B. The use of a flotation bag and line is highly desirable where it will not interfere with the operation. Dangerous operations may even require the use of a safety line.

C. Never ditch the SCUBA underwater unless all else fails. If it should fail a free ascent may be made. If the SCUBA has positive buoyancy, keep it on, use it for support on surface; if negative, ditch it.

D. Always keep breathing while underwater, particularly on ascent when the danger of air embolism exists. Excessive breath holding can also result in shortness of breath and eventually headache and nausea from CO_2 accumulation.

E. Since gas is lost in open circuit apparatus positive buoyancy increases throughout the dive; the swimmer should adjust buoyancy to slightly positive at full inhalation.

F. Swimmer's rate of ascent should be leisurely and never forced. Thumb Rule: Never pass your small bubbles on ascent.

G. A diver must know how much breathing gas is in his SCUBA, and his own use-rate at the depth he is to operate. A margin of safety should be applied in calculating the limiting time for the dive.

H. During descent, if ears do not equalize arrest descent, ascend a few feet and attempt to clear the eustacian tube blockage. If the ears cannot be equalized, the diver should not continue to descend.

I. Underwater swimmers will meet unique situations which often cannot be anticipated. There is no cause for panic when confronted with a new situation or danger. The diver should stop and think his way out of it, for his instincts are not always reliable in the underwater environment.

J. When a swimmer loses visual contact with his swim buddy, he should first listen for his breathing noise, then signal by banging on cylinders or pieces of metal. If not located -- surface.

K. Before descending, the swimmer should check all his apparatus when immediately below the surface, signal his buddy, and if necessary -- wait for him before descending.

V. Planning and Controlling the Underwater Swim

A. Gas supply, decompression time, temperature, and fatigue are the controlling factors in the dive, and not the amount of useful work to be done.

B. At all times it is highly desirable to have an extra "stand-by" SCUBA available on the surface. When the need for decompression is a possibility it is mandatory to have an extra unit along in the event a swimmer runs out of air during decompression.

C. Swimmers must be familiar with the decompression tables and be instructed on the limitations of each specific dive. Whenever possible, the dive should be limited so as to avoid the need for decompression. In deep dives in cold water instructions should be written on the swimmer's slate.

D. When decompression becomes necessary, and when other decompression equipment is not available, a weighted line should be lowered from the surface to the decompression depth for the swimmers. In the event a swimmer should run out of air while decompressing, another unit can be taken down to him, or, in emergencies, the diver can surface, take another SCUBA without taking time to don it or to ditch the empty one and immediately return to the proper decompression depth.

E. Ideally a qualified man should be in charge of the dive on the surface and responsible for the safety of swimmers. If he signals the swimmers to surface, they must do so immediately, but at a reasonable rate of ascent and within decompression restrictions if applicable. Regardless of his normal position of authority, a submerged swimmer should not be in charge of the operation nor allowed to disobey the order of the one who is.

BACKGROUND INFORMATION

One of the most important of the foregoing precautions is the requirement that the underwater swimmer be "trained in diving physiology, symptoms of diver's maladies, and acquainted with the use of decompression tables". The following brief outline includes items to be covered in the training of an underwater swimmer. Much of this material concerned with man's survival under the surface of the water, is not unique to the underwater swimmer but applies as well to the deep-sea diver.

I. Physics of Diving (books, lectures, movies)

A. Composition of air (O_2, N_2, other inert gases, partial pressures).

B. Boyles Law (variation of volume and density with pressure).

C. Kinetic Theory (buoyancy, Cartesian Diver).

II. Diving Physiology

A. Normal respiratory physiology-breathing air at sea level.

1. Composition of air. Function of its components in human body.

2. The anatomy and the function of the human respiratory system, including circulatory transport of gases, solubility of gases.

3. Accessory structures -- ears, sinuses.

B. Underwater Respiration

1. Abnormalities of underwater environment.

a. Include increased hydrostatic pressure, increased gas partial pressures.

C. Potential Problems of Underwater Breathing

1. Occurring on descent

a. Squeeze -- including ear, sinus, and face plate squeeze.

2. Occurring at diving depth.

a. Nitrogen narcosis

b. Oxygen toxicity

3. Occurring as result of ascent

a. Bends

b. Aeroembolism

4. Related to design or use of SCUBA

a. Anoxia

b. Carbon dioxide excess

c. Respiratory fatigue

5. Related to watery nature of environment

a. Low temperature exhaustion (usually below 59° F.)

b. High temperature exhaustion (usually above 90° F.)

c. Fungus infection of skin or external ear canal.

d. Bacterial infection of external ear canal.

III. Potential Marine Hazards

A. Related to the sea itself

1. Surges

2. Surf

3. Rocks and coral

4. Caves

5. Kelp

B. Related to underwater life

1. Sea Urchins

2. Moray, Conger and Electric eels

3. Rays and Manta

4. Sharks

5. Barracuda

} "mind your own business"

TRAINING IN THE USE OF <u>OPEN CIRCUIT</u> SCUBA

In the precautions presented earlier were also the requirements that the swimmer be thoroughly trained in the use of his specific equipment and in overcoming emergency situations. These differ slightly for the several apparatuses. The following outlines include the material believed essential for the safe and efficient operation of two types of SCUBA -- open circuit air breathing and closed circuit oxygen breathing SCUBA. It is as yet too soon to include similar material for mixed gas apparatus which are still in the early developmental stages. First is the open circuit SCUBA using the "Aqualung" as typical equipment.

I. Description of construction, function and maintenance of the apparatus (the unit, "exploded" photos, simplified circuit diagrams).

A. Principles of operation

B. Mechanisms

1. Demand valve

2. Cylinder valve

3. Safety lever (emergency gas supply, where available)

C. Field assembly and disassembly (Note: repair and calibration taught separately, only field maintenance and checking explained here).

D. Preparing for use

1. Cylinders (fill only to rated pressure, use oil free compressed air only, checking gas pressure, inspection, handling).

2. Gauges (periodically check gauge).

3. Harness (inspection, fit, safety-loop fastenings).

II. Entering water (swimming pool first for all techniques).

A. Putting on apparatus (unaided); all buckles made up with slip-out feature.

B. Submerge at edge of pool. Breath slowly and deeply. Exhale fully with each breath, thereby avoiding tendency toward uncomfortable hyper-inflation of lungs.

C. Adjusting buoyancy (permits maintaining depth control with minimum effort).

1. Relax and float in vertical position at edge of pool.

2. If not neutrally buoyant add weights (usually 1 pound at a time) as necessary until just positive with full breath. (Note: some persons are neutrally buoyant or even slightly negative without the use of weights.)

D. Brief swim in pool, flutter kick, no hands. ("get the feel of it".)

1. Attempt to maintain a steady kick rate. One full cycle of each foot going up and down of approximately 30 per minute and one breath every other kick or 15 breaths per minute is a rough average.

2. Swim with hands trailing at sides, clasped in front or back or outstretched in front, they are not needed for propulsion.

3. The leg should be straight but relaxed on the upward stroke and bent slightly at the knee (usually no more than 30°) on the downward stroke. In both strokes the toe should be pointed so the foot acts as a straight extension of the lower leg. It is presumed that skill in use of swim fins will be developed prior to initial training in SCUBA diving. Note: kicking is one of the most important phases of training with SCUBA. Efficient kicking reduces the effort of swimming through the water. This reduces fatigue, carbon dioxide formation, and oxygen consumption. Swimming long distances without fatigue is possible when the flutter kick is well

developed. Continuous practice is necessary to maintain proficiency.

III. Underwater Techniques -- peculiar to open circuit apparatus (to overcome emergencies due to flooding or leakage of water into apparatus).

A. Clearing water from breathing tube.

1. Inspiration tube comes over right shoulder, expiration over left, therefore, lower left shoulder. Pinch inhalation tube to right of mouthpiece, blow water out. If water is in inspiratory side, while in horizontal position, roll from right to left so water runs to expiratory side and proceed as above.

2. In an emergency the swimmer can always swallow small amounts of water from the tube.

B. Swim without face mask until used to the resulting reduced vision and to having nose uncovered in water.

C. Clearing flooded face mask.

1. Maintain face seal at top of mask with hand, break seal at bottom and with head tipped back slightly and while holding face plate as though emptying a cup, exhale slowly through nose, allowing water to drain out the bottom (the inverted tumbler experiment).

D. Put face mask on after entering water without it, using above procedure.

E. Remove mouthpiece underwater and reinsert it.

1. Hold mouthpiece higher than regulator so air bubbles through inspiration tube. Point mouthpiece opening downward to minimize flooding. Insert mouthpiece and, if necessary, clear expiration tube as in III. C. 1. above.

2. Practice exchanging mouthpieces with a swimbuddy not equipped with SCUBA, i. e., two men use the one "lung".

F. Ditch SCUBA while submerged, carry out free ascent to surface.

1. The last thing a swimmer should do is part with the air supply that keeps him alive underwater, but "ditching" the lung should be practiced so the swimmer will gain confidence in his ability to reach the surface unaided.

2. Drop lung to bottom after last inhalation and release weights and other encumbrances let natural positive buoyancy assist in ascending. Neutral or negatively buoyant persons may need to flutter kick.

3. Air embolism caution: exhale freely throughout ascent and proceed at a leisurely pace. There is no need to forcibly exhale (buoyancy might be excessively reduced) but more important is the requirement that exhalation must not be restrained.

G. Donning open-circuit SCUBA and equipment while submerged.

1. Student skin dives to recover apparatus on pool bottom.

2. Procedure: dive to lung, turn it on, bubble water out of inspiration side of tube, insert mouthpiece and clear tubes as in III.C.1. Relax for a short period. Locate, put on, and clear face mask. Get into SCUBA harness, then weights, fins, etc. (Note: student may have to hold weights with hand or foot to remain submerged while donning apparatus). Swim around pool and emerge.

IV. UnderwaterTechniques -- Relating to Swimming and Diving (in calm clear water at first). (Note: use "buddy system" always -- "you are responsible for your buddy, he for you, and you must keep each other in sight at all times!")

A. Descent -- as fast as is comfortable to ears. (The boat's anchor line is handy for descending and gives the beginner a greater feeling of security).

1. Equalizing pressure in the middle ear.

a. Previous "blowing of ears"on surface assists in equalizing pressures on descent.

b. If ear pain occurs, check descent, or even rise slightly. Ear popping is assisted by swallowing, wiggling jaws, by holding mask tightly to face and blowing through nose, or as a last resort, by removing face mask, pinching nose and exhaling.

c. Never continue descent without clearing ears. A Benzedrix inhaler, 0.25% neosynephrine, 1.0% ephedrine sulphate, 0.05% privine, etc., all assist in clearing eustachian tube blockages.

d. If an eardrum should perforate while submerged, in cold water unequal caloric excitation of the vestibular apparatus may result in a real hazard in that nausea and dizziness (the "twirly beds") can occur. The swimmer is safe if he keeps his mouthpiece in place and remains calm a few minutes until the cold water entering the ear becomes warm and the violent vertigo is ended. Holding on to a submerged object, or even hugging oneself might assist.

2. Face mask squeeze. When a face mask not connected to the breathing apparatus is used increased water pressure outside and the constant volume of air inside the face mask can force the mask tightly against the

swimmer's face, wrinkles of the skin may cause the mask to leak, the nose may begin to bleed and the swimmer's eyes start to "pop". This "squeeze" is easily corrected by slight exhalation through the nose to equalize air pressure inside mask with water pressure outside.

3. Para-nasal sinuses -- normally air enters and leaves the nasal sinuses freely. If blocked by congested membranes or secretions no voluntary method is available for equalizing pressure in the sinuses. When equalization does not occur naturally and pain is experienced, check descent even if it means discontinuing the dive. Forcing the descent can result in bleeding or serious damage to the delicate tissues. A nasal spray or nose drops (see. IV, A .1(c)) will open sinuses and can be used in absence of acute nasal infection.

B. Duration of dives during air breathing.

1. Swimmers should be familiar with diving tables and decompression times. Dives with self contained apparatus using air should be planned so that decompression to avoid bends is not required.

TABLE OF DIVING TIME ALLOWABLE WITHOUT
SUBSEQUENT DECOMPRESSION
(air breathing)

DEPTH	MAXIMUM NO. MINUTES FOR DIVE
40	180
50	120
60	70
70	50
80	40
90	30
100	25
110	20
120	18
130	15

2. The volume of cylinder air required for breathing depends on exertion and upon depth. While the volume of air breathed per minute for a given amount of work is about the same at the surface as at 100 feet depth, air at 100 feet is compressed to one-fourth its volume so the supply in the bottle is used four times as fast at 100 feet as at the surface. The swimmer's breathing rate and volume, the degree of exertion required, the depth of the dive, and the size of the cylinder used must all be taken into account in determining the duration of the divers air supply for a particular diving situation.

C. Rate of ascent

1. Do not "shoot" to surface, proceed at a leisurely pace. A useful thumb rule might be: "never beat your small bubbles to the surface".

2. Throughout the dive, and particularly on ascent, continue to breath naturally (refer to III.F.3).

V. Leaving Water

A. A swimmer is often very tired after a strenuous dive. He may need assistance in getting out of the water since his equipment is considerably heavier in air than water. Alternatively, the diver can take off the equipment in the water.

B. Shut off air and stow where it is safe from damage and where it cannot fall or cause damage to personal or other units. Check pressure before re-using.

C. Disassemble apparatus and wash all equipment and clothing in fresh water.

1. Protect against entry of water into high pressure air connection to gas regulator (hold thumb over it).

2. After flushing, drain water from the breathing tubes and hang regulators up to dry (protect from dust and corrosive gases).

D. As soon as possible after a dive, the swimmer should take a shower, clean any cuts or abrasions, rinse ears with 50% alcohol, and change into dry clothing.

TRAINING IN USE OF CLOSED CIRCUIT SCUBA (using the "new" (1952) Lambertsen Amphibious Respiratory Unit (LARU) as typical equipment).

I. Description of the construction, function, and maintenance of the apparatus (the unit, "exploded" photos, simplified circuit diagrams, etc.).

A., Principles of operation.

B. Mechanisms

1. Removal of respiratory apparatus from vest.

2. Air breathing valve.

3. Demand valve.

4. Water drain valve.

5. Overpressure valve.

6. Shut-off valve.

C. Field assembly and disassembly. (Note: repair and calibration taught separately, only field maintenence and checking taught here).

D. Preparation for use.

1. Oxygen cylinder (fill to rated pressure, avoid contact of high pressure connections with oil,) inspection, handling, attaching to respiratory unit, testing valve for leaks.

2. Soda lime cannister (always use fresh absorbent).

a. Fill with soda lime (4-8 mesh) or Baralyme; using wire screen funnel to remove most of any dust present.

b. Blow any remaining dust from cannister.

3. Vest and straps

a. Check straps and snap fasteners for freedom from wear and corrosion.

b. Check CO_2 cylinder for attached life preserver -- flotation bladder.

4. Mask and hoses

a. Straps and rubber in good condition.

b. Lens clean.

c. Valves in operable condition.

II. Entering Water

A. Donning apparatus (unaided).

1. Adjust belt and crotch straps to proper length -- note "one-way release" feature of snaps.

2. Put about a teaspoon of water in rim under eye pieces for anti-fogging.

3. Air breathing valve open, oxygen breathing valve closed.

4. Demonstration of carbon dioxide absorption (under medical supervision only). CO_2 excess can be caused by over used absorbent or

empty cannister. Prepare one unit properly and one unit with empty cannister. Two students stand before class, put on above units. Within two minutes one will show signs of CO_2 accumulation. Conversation shows mental clearness but when respiratory distress becomes intolerable the student may remove the mask and describe sensations to class. Other student demonstrator will be breathing normally.

5. Demonstration of oxygen lack -- anoxia (under medical supervision only). Anoxia can be caused by failure to remove air (nitrogen) from breathing bag and lungs before commencing breathing in closed system. Two students don apparatus correctly loaded with CO_2 absorbent and oxygen. First man uses proper procedure of emptying bag and lungs of air and turning off air breathing valve prior to introduction of oxygen into the closed circuit system. Second student inhales full breath of air through air breathing valves, exhales it into bag, then shuts off air breathing valve and turns on oxygen. Both commence breathing in the closed circuit, adding small amounts of oxygen as necessary. Instructor turns off oxygen cylinder of both units simulating condition of running out of oxygen.

Demonstrator who properly empties breathing bag and lungs goes on in clear state, with comfortable respiration. In about 5 minutes the second demonstrator, who failed to empty bag and lungs of air before closing air valve will begin to feel lightheaded, complain of "dizziness" on questioning, and become unsteady on his feet. No discomfort is felt in contrast to the carbon dioxide effect. Respiration is only slightly increased. He begins to feel silly, is very slow in answering questions. Skin becomes bluish (cyanotic). Sags to the floor. Mask should be removed immediately and obstruction of respiratory passages prevented. Demonstrator may be unconscious, with mouth and nose reflexly gasping for air. With a few spontaneous breaths, color returns to skin, consciousness returns quickly, and he will have no recollection of collapsing. Demonstrator is asked to state his feelings during the demonstration. An explanation is made by the instructor with very strong reiteration of the dangerous nature of this type of careless technique. Death is a possible result with no true warning in the form of undesirable sensations. Attention is now called to the first man who is still breathing the oxygen which was in the bag when his cylinder was shut off. He is, of course, perfectly clear mentally, in no discomfort, and breathing normally. He continues to use his breathing bag oxygen until so little remains that he can no longer take a full breath. The reflex resulting from the "pull" on the lungs gradually becomes intolerable. With this strong indicator as a warning, he removes the mask, still in perfectly clear mental state. He has breathed pure oxygen until he took off the mask, making unconsciousness or mental dullness impossible. Therefore, with proper technique, it is impossible to lose consciousness or die from lack of oxygen.

The two demonstrations are compared and explained. Students are told that, "Carelessness or ignorance are the only causes of unconsciousness from anoxia with closed circuit oxygen apparatus".

B. After properly starting unit as in II.A.5 above, submerge at edge of pool. (swimming pool first for all techniques). Breath slowly and deeply. Exhale fully with each breath, thereby avoiding tendency toward uncomfortable hyper-inflation of lungs.

1. Buoyancy control (permits maintaining depth control with minimum effort).

a. Add the proper number of lead plates for neutral buoyancy with demand valve operating. This adjustment, once made will suffice more or less indefinitely for a particular individual and will not vary with depth.

b. Become familiar with sensations of empty breathing-bag and too full breathing-bag by exhausting and then over inflating breathing bag.

III. Underwater Techniques -- Peculiar to closed circuit apparatus.

A. Exhausting excess oxygen from breathing bag (as on ascent) via water drain valve or air breathing valve.

B. Discharging water from respiratory unit via "non-return" water drain valve.

C. Floating on back on surface with mask off, breathing bag inflated with oxygen or air.

D. Removal of unit in water and replacement.

E. Swimming with inflated unit under chest.

F. Two men using one unit underwater -- "suckling", by means of breathing bag oral inflation tube.

G. Ditch SCUBA when submerged, free ascent to surface.

1. The last thing a swimmer should do is part with the oxygen supply that keeps him alive underwater, but "ditching" the lung should be practiced so the swimmer has confidence in his ability to reach surface unaided.

2. Float lung to surface after last inhalation and release weights and other encumberances, let natural positive buoyancy assist in ascending. Neutral or negatively buoyant persons may need to flutter kick.

3. Air embolism caution: exhale freely throughout ascent and proceed at a leisurely pace. There is no need to forcibly exhale (buoyancy might be excessively reduced) but more important is the requirement that exhalation must not be restrained. Note: actually one should not ditch the LARU for it has built in "life preserver" qualities. Section included here to cover case where closed circuit unit does not have characteristics for surface flotation.

IV. Underwater Techniques -- Swimming and Diving.

A. Descent -- as fast as is comfortable to ears. (The boat's anchor line is handy for descending and gives the beginner a greater feeling of security).

1. Equalizing pressure in the middle ear.

a. Previous "blowing" of ears on surface assists in equalizing pressures on descent.

b. If ear pain occurs, check descent, -- or even rise slightly. Ear popping is assisted by swallowing, wiggling jaws, or as a last resort, pinching nose through the mask and exhaling against the closed nostrils.

c. Never continue descent without clearing ears. A Benzedrix inhaler, 0.25% neosynephrine, 1.0% ephedrine sulphate, 0.05% privine, etc., all assist in clearing eustachian tube blackages.

d. If an eardrum should perforate while submerged in cold water unequaled caloric excitation of the vestibular apparatus may result in a real hazard in that nausea and dizziness (the "twirly beds") can occur. The swimmer should remain still for a few minutes until the cold water entering the ear becomes warm and the violent vertigo is ended. Holding on to a submerged object, or even hugging himself might assist.

2. Face mask squeeze. This is prevented where the mask is an integral part of the respiratory system and when a demand valve automatically adds oxygen on descent.

3. Sinuses -- Normally air enters and leaves the nasal sinuses freely. If blocked by congested membranes or secretions no voluntary method is available for equalizing pressure in the sinuses. When equalization does not occur naturally and pain is experienced, check descent even if it means discontinuing the dive. Forcing the descent can result in bleeding or serious damage to the delicate tissues. A nasal spray or nose drops (see IV A 1(c)) will open sinuses and can be used in absence of acute nasal infection.

B. Duration of Dives and Depth Limitations.

1. At present, diving with pure oxygen as the gas breathed, should be limited to depths of 30 feet and for a period of no longer than 45 minutes for a single dive. Practical experience indicates that an interval of about 15 to 30 minutes breathing air at the surface is sufficient to permit the above limits to be repeated.

C. Rate of ascent

1. Do not "shoot" to surface, proceed at a leisurely pace. Let the buoyancy of expanding oxygen in the apparatus carry you to the surface.

2. Throughout the dive, and particularly on ascent, continue to breath naturally (refer to III.G.3)

V. Leaving Water

A. A swimmer is often very tired after a strenuous dive. He may need assistance in getting out of the water since his equipment is considerably heavier in air than water. Alternatively, the diver can take off the equipment in the water.

B. Shut off oxygen cylinder and stow where it is safe from damage. Check pressure before re-using.

C. With mask shut-off valve closed, dip or rinse entire apparatus in fresh water, empty carbon dioxide absorbent cannister and hang equipment to dry. (protect from dust and corrosive gases). Periodically (e.g., weekly) dis-assemble apparatus and wash inside of bag and tubing.

D. As soon as possible after a dive, the swimmer should take a shower, clean any cuts or abrasions, rinse ears with 50% alcohol, and change into dry clothing.

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