THE LARU

Lambertsen Amphibious Respiratory Unit

A self-contained respiratory apparatus for shallow water swimming and diving, and for use in atmospheres containing noxious gases

INSTRUCTIONS FOR USE AND MAINTENANCE

November 1955

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I. INTRODUCTION

The T-4 LARU is a further development of the breathing apparatus employed in World War II. It is one of several basic types of self-contained, underwater breathing apparatus (SCUBA), so-called because they meet the respiratory requirements of oxygen supply and carbon dioxide removal without need for air lines to the surface. Designed for long or repeated periods of operation in relatively shallow water or on land the LARU utilizes pure oxygen in a closed rebreathing system with chemical absorption of exhaled carbon dioxide. This combination provides maximum working duration per unit of equipment weight.

By means of adaptors the LARU can be converted into apparatus for air hose diving where this is required. It may also be employed on land in atmospheres containing noxious gases where it provides a suitable breathing system for a much longer period than other units designed for the same purpose.

II. DESCRIPTION AND FUNCTION

Three main components make up the amphibious respiratory unit - a nylon vest, an oxygen supply system and a closed circuit, rebreathing system.

A. VEST

The Vest supports the respiratory system, ballast plates, life preserver and auxiliary equipment. Waist and crotch straps secure the vest to the body of the wearer. Snap fasteners, zippers and elastic straps permit rapid attachment or removal of all components of the respiratory system. Cellular neoprene shoulder pads distribute the weight of the apparatus on the shoulders of the wearer before submersion. The nylon fabric of the vest is not susceptible to fungus rot and will not ignite.

B. OXYGEN SUPPLY SYSTEM

1. Oxygen is supplied by a small oxygen cylinder which holds 246 liters of oxygen when filled to 2000 pounds per square inch. The full cylinder contains sufficient oxygen for almost four hours use at moderate work (oxygen consumption rate = 1 liter per minute) or eight hours at rest rate (oxygen consumption rate = 0.5 liter per minute). Practically, the useful duration of the apparatus is approximately 25 per cent less that provided by the available oxygen, due to prior exhaustion of the carbon dioxide absorbent. The additional oxygen supplied is normally expended as waste on ascent or serves as a reserve for surface flotation.

2. The oxygen cylinder is mounted vertically on the nylon vest but transverse mounting can be provided. The World War II vertical position of the cylinder, retained in the present model, was chosen for three reasons: (a) improved streamlining (b) minimal lateral projection or interference with passage through restricted openings, and (c) ability to use a magnetic compass with the apparatus in spite of its steel cylinder (mounting compass in long axis of cylinder minimizes effect of cylinder's magnetic lines of force). The standard nickel steel cylinder of this apparatus can be replaced by a non-magnetic cylinder of aluminum alloy or stainless steel when this is desired.
3. The pressure of oxygen in the cylinder is indicated by a luminous pressure gauge which can be read when submerged. This gauge registers only when the cylinder valve is open. Only one-half turn is required to open the cylinder valve.

4. The high oxygen pressure within the cylinder is reduced by a pressure regulator to 20 to 50 p.s.i., this low pressure not requiring critical adjustment. The amount of oxygen supplied to the breathing bag is normally controlled by an automatic, demand-type valve activated by inhalation. The demand valve mechanism, connected to the low pressure side of the pressure regulator by flexible tubing, is located within the breathing bag and is protected on three sides by its metal case. The fourth aspect is exposed to contact with the anterior wall of the breathing bag. When the bag contains adequate oxygen for a full inhalation, the demand valve remains closed and admits no oxygen. As the diver's metabolism utilizes oxygen and the exhaled carbon dioxide is absorbed by the canister, the volume of oxygen in the breathing bag diminishes, inhalation causes the anterior wall of the bag to contact the demand valve trigger and a jet of oxygen enters the breathing system. The entry of additional oxygen increases the bag volume, providing for adequate inhalation. At the same time the anterior wall of the breathing bag is lifted from the demand valve trigger, causing the oxygen flow to cease. This sequence occurs repeatedly during use of the apparatus, at intervals of about every four to five inhalations. Because the volume of the breathing bag is controlled within narrow limits by the demand valve, near-neutral buoyancy is maintained automatically at the same time that oxygen is admitted at the rate required for the diver's metabolism. During descent, when the oxygen in the breathing system is being compressed, due to increasing hydrostatic pressure, the tendency for the breathing bag to collapse activates the demand valve, assuring an adequate volume for breathing, prevents squeeze and prevents loss of buoyancy control.

By means of a perforated metal disc incorporated into the anterior wall of the breathing bag and overlying the demand valve trigger, the sensitive automatic oxygen supply mechanism is protected against excessive activation by external forces. This perforated disc is removable, permitting repair or replacement of demand valve components.

5. For use in emergencies or during surface flotation, the hand operated, self-closing by-pass valve on the pressure regulator delivers a rapid flow of oxygen into the breathing system via a flexible hose leading directly from the regulator into the breathing bag. It can serve as a manual supplement to the demand valve during underwater swimming.

C. BREATHING SYSTEM

1. The breathing bag is horse-shoe shaped to combine features required for underwater respiration and for emergency use as a surface flotation aid. The internal or gas pressure of a closed circuit rebreathing system is equal to the water pressure at the level of the lowermost compressible portion of the system, i.e., the lowermost gas-containing point on the breathing bag. This pressure is transmitted through breathing bag, tubes and mask to the lungs. It therefore determines the pressure about which the pressure within the lungs fluctuates. Empirically it has been found that when the lowermost functioning point of the breathing bag is placed at a level approximately even with the suprasternal notch (top of the breastbone) underwater respiration is least fatiguing to the muscles of respiration. In the T-4 LARU the demand valve, representing functionally the lowermost portion of the bag on inspiration, is placed at this level. Under these
conditions the pressure of gas within the lungs (as determined by water pressure on the breathing bag) should be best balanced by the forces exerted upon the exterior of the swimmer's chest. A breathing bag placed too high on the body results in exhausting inspiratory effort with excessive negative pressure within the chest. Capacity for work will consequently be markedly reduced. Should the breathing bag be placed too low on the chest the reverse situation occurs; inspiration is facilitated but exhalation would require greater effort by the respiratory muscles. Increased inspiratory effort appears to be somewhat better tolerated than increased expiratory effort but neither is desirable.

The posterior portion of the breathing bag serves no respiratory function during normal underwater swimming. It provides positive buoyancy to balance the underwater weight of heavy components of the apparatus. Its major purpose is to provide an adequate buoyant support for the head when the apparatus is used as a life jacket during or following prolonged operation in open water. The posterior portion of the bag contains a septum which divides the bag into an exhalation half and an inhalation half. These portions are connected to the respective ends of the carbon dioxide absorption canister. The need for breathing tubes within the bag is thereby eliminated, and the exhalation portion of the bag serves as a trap for water.

The breathing bag is constructed of two-ply nylon fabric with a layer of neoprene between the two plies, and another on the inner surface. On the anterior aspect are the fittings which receive the breathing tube unions. On the posterior aspect of the breathing bag are the two fittings for connecting the bag to the carbon dioxide absorption canister, the small opening for the oxygen demand valve connection, a connector for the emergency oxygen supply, two drainage tubes for use in draining the bag of water after washing and an oral inflation tube for inflation or deflation of the bag. All large fittings are "O" ring sealed and constructed for manual or wrench operation.

2. The breathing valves, inhaling and exhaling, are mounted in metal housings removably attached to the breathing bag fittings. These breathing valves permit inhalation only from the breathing bag and allow exhalation into the bag only by way of prior passage through the canister provided for carbon dioxide removal. They are rubber, Acushnet type, 1 1/2" diameter valves selected for low resistance, positive seating and low noise level.

3. The breathing tubes connecting the mask valve assembly to the inhaling and exhaling valve housings are one inch inside diameter corrugated neoprene. The inspiratory tube (right) receives oxygen directly from the breathing bag. The expiratory tube (left) delivers expired air, containing carbon dioxide, to the exhalation portion of the breathing bag for subsequent passage through the carbon dioxide absorption canister.

4. The carbon dioxide absorption canister is 4 inches in inside diameter and has an effective internal length of 9 inches. Its capacity for 4-8 mesh soda lime or baralyme is therefore about 1.36 kgs. (3 lbs).

In the circuit breathing system most of the volume of an exhalation is stored in the canister during the succeeding inspiration, thereby providing time for efficient chemical combination of exhaled carbon dioxide with the absorbing agent (this is in contrast to pendulum or "to and fro" systems in which much of an exhalation is reinhaled directly from the canister with the result that an extremely short period of time is provided for carbon dioxide absorption).

Channeling of gas through the canister is prevented by two features (a) spring
The edge of the mask seals against entry of water or air into the breathing system in the usual manner. Since in underwater use the tendency is primarily that of outward leakage of gas beneath the mask edge rather than inward leakage of water, a rubber flap is incorporated into the inner aspect of the mask periphery to act as a valve seating against the face of the user and to prevent loss of oxygen.

Provision is made for attachment of an accessory underwater speaking diaphragm or a telephone unit.

An air breathing valve located high on the mask, above the lenses, provides a means of breathing air while donning the mask, standing by to submerge or floating on the surface and permits evacuation of the air in the lungs before beginning oxygen breathing.

The face mask can, if desired, be modified to incorporate a mouthpiece, and, of course, the entire face mask and mask valve assembly can be replaced with a simple mouthpiece where the convenience and safety of the mask and valve are not desired.

III. PREPARATION FOR USE

The diving unit is prepared for use by loading the canister with fresh carbon dioxide absorbent and filling the oxygen cylinder.

A. FILLING CARBON DIOXIDE ABSORPTION CANISTER

Use Baralyme or 4-8 mesh, high-moisture soda lime. Soda lime of 8-14 mesh requires canister screens with smaller interspaces. Low moisture soda lime can be used but it is less effective during the first few minutes of use than the high moisture type. Refill canister after each expenditure of one full cylinder of oxygen or if for any reason the absorbent is allowed to become wet. No tools are required.

1. Unzip canister carrier and lift out canister.

2. Unscrew the two knurled union nuts attaching canister to rear portion of breathing bag. This allows canister to be separated completely from the remainder of the apparatus.

3. Unscrew knurled knob on lid of canister and remove lid. Lift out upper screen and shake out absorbent and two baffle plates. Do not tap canister against hard objects to jar contents loose. A dented canister may not be watertight.

4. Wipe out canister with clean, dry cloth. If absorbent has become wet, rinse entire rebreathing system with fresh water and drain thoroughly (see Maintenance).

5. Pour fresh absorbent into a wire mesh funnel and shake gently to remove any fine dust formed during shipment or handling. Vigorous shaking in a mesh funnel will grate granular absorbent and continue to produce dust.

6. Fill canister with absorbent, replacing one baffle when canister is one-third full, second baffle when two-thirds full. Continue filling until absorbent when well shaken down reaches a level three-fourths of an inch below the
end of the central canister rod. Overfilling will prevent sealing of the canister lid and will therefore result in gross water leakage.

7. Replace canister lid, engage threads on central rod, align bag connectors and tighten knurled knob by hand. Do not use pliers or other tools to tighten canister lid; "O" ring seal makes this unnecessary and damage may result.

8. Blow four or five forceful breaths through canister to remove any traces of loose absorbent dust.

9. Reattach canister to breathing bag, placing a small amount of Dow-Corning-4 silicone grease on union nut threads. Tighten by hand without use of tools, making certain rubber "O" rings are in place and taking care to align threads properly. Replace canister in its carrier and close zipper.

10. Close mask shut-off valve to prevent air from affecting fresh absorbent during period of storage.

B. FILLING OXYGEN CYLINDER

A filling device equipped with a pressure gauge is supplied with the apparatus. This device enables the oxygen cylinder to be connected to a large, commercial type cylinder for filling. The small cylinder will equalize with the full pressure within the larger reservoir cylinder. When the supply of reservoir cylinders with high oxygen pressures is limited, efficient use of available pressure is accomplished by successive boostings, i.e., by first connecting the small cylinder to a series of large cylinders which do not have a full pressure head, then completing the process by connecting it to a full (2000 to 2200 psi) reservoir cylinder. This conserves the head of pressure in the nearly full reservoir cylinders for use in the "topping" stage.

Never oil or touch with oily fingers any high pressure oxygen fittings or an explosion may result when oxygen is turned on.

1. Unzip and unsnap nylon cylinder carrier and remove cylinder.

2. Loosen union nut which attaches regulator to cylinder valve with a 1 1/8" open end wrench. Unscrew by hand.

3. Attach filling device to valve of reservoir cylinder, using wrench for final tightening of union nut.

4. Attach small cylinder to other end of filling device in same manner.

5. Open valve of small cylinder one full turn.

6. Open valve of large reservoir cylinder very slowly. Take at least two minutes to fill cylinder to a maximum pressure of 2200 psi. (Cylinders have been tested to 3000 psi.) The unit cylinder will become quite warm during filling and while warm will hold less oxygen at the existing pressure than if it is allowed to cool while still connected to the reservoir. More complete filling can be accomplished without delay by wrapping the small cylinder with a wet cloth or suspending it in a bucket of cool water during the filling process.

7. Close valve of small cylinder, then valve of reservoir cylinder, and remove unit cylinder from filling device.
8. Replace cylinder on diving unit.

9. Periodically test valves of cylinders by dipping valve end into water and inspecting for evidence of leaks.

C. PREPARING MASK LENSES

Periodically clean mask lenses with soap and water. Dry with clean cloth. Avoid getting oil, grease or grit on lenses. Failure to observe these precautions will result in exaggerated tendency for lenses to fog in use.

Just prior to donning the apparatus, rub saliva evenly over inner and outer surfaces of lenses. Rinse out with water leaving about one teaspoonful of water in the anti-fog water trap built into each lens. This water serves to clear the lenses of any fog which may develop during use of the apparatus. It is made to wash over the inner lens surface by shaking the head.

D. DONNING THE UNIT

The apparatus can be donned by the swimmer or diver without assistance. Belt and crotch straps require adjustment only once for any individual.

1. Check valves, connections, bag drains and oxygen pressure. See that mask shut-off valve is closed.

2. Pick up unit with both hands grasping front of vest beside cylinder carrier, inner side of vest facing away.

3. Swing unit behind back, holding front of vest high above head.

4. Draw vest over head and down over chest. Mask will remain behind back.

5. Fasten belt and crotch straps.

6. EVACUATE AIR FROM BREATHING BAG.

Using breathing bag oral inflation tube, suck air from bag until bag is flat (FOR EXPLANATION OF THE NECESSITY FOR THIS IMPORTANT PROCEDURE SEE 14 BELOW)

7. Turn on oxygen cylinder.

8. Draw mask over head so head is between breathing tubes. Loosen mask straps completely.

9. Open mask air breathing valve. This will permit breathing air while donning the mask.

10. Put on mask using standard gas mask technique, chin out and thumbs inside the two lateral straps on each side. Hold mask harness central pad well down and centered on back of head. Holding harness in this position with first one hand and then the other, tighten first the lateral straps, then finally, the top straps. AVOID OVERTIGHTENING of mask straps, which is unnecessary and may cause headache.
11. The apparatus can be worn in this "ready" state while standing by to submerge, the user breathing air through the air breathing valve.

12. WHEN READY TO BEGIN OXYGEN BREATHING, COMPLETELY EXHALE THE AIR IN THE LUNGS THROUGH THE AIR BREATHING VALVE, then close this valve and

13. Open the shut-off valve to breathe oxygen. It is not necessary to flush the system with oxygen.

14. NOTE: IF EXCESS AIR IS NOT REMOVED FROM THE BREATHING BAG AND EXHALED FROM THE LUNGS BEFORE BEGINNING TO BREATHE OXYGEN A CONSIDERABLE AMOUNT OF NITROGEN MAY REMAIN IN THE REBREATHERING SYSTEM. SINCE THE NITROGEN IS INERT AND NOT USED BY THE BODY, THIS NITROGEN WILL PROVIDE A BREATHABLE VOLUME EVEN AFTER THE OXYGEN CYLINDER BECOMES EMPTY AND OXYGEN IN THE BAG IS GRADUALLY USED. AS THE OXYGEN CONCENTRATION IN THE REBREATHERING BAG FALLS UNCONSCIOUSNESS OR, ULTIMATELY, EVEN DEATH MAY OCCUR FROM LACK OF OXYGEN WITHOUT UNPLEASANT SENSATIONS OR OTHER WARNINGS. THIS IS POSSIBLE IN ANY TYPE OF CLOSED CIRCUIT REBREATHERING APPARATUS WHEN IT IS USED WITHOUT REMOVAL OF AIR FROM BAG AND LUNGS.

THE FLAT BREATHING BAG AND THE OXYGEN DEMAND VALVE OF THE LARU REDUCE THIS SERIOUS DANGER OF LACK OF OXYGEN (ANOXIA). REGARDLESS OF THIS, THE DESCRIBED TECHNIQUE FOR REMOVING AIR FROM THE BAG AND LUNGS SHOULD BE FOLLOWED IN DETAIL. IF THIS IS DONE, THERE IS NO POSSIBILITY OF DEVELOPING OXYGEN LACK EVEN WHEN THE OXYGEN CYLINDER BECOMES EMPTY. IF THE USER SHOULD LOSE CONSCIOUSNESS, IT IS DUE TO IGNORANCE OF THE PROPER TECHNIQUE OR TO CARELESSNESS.

IV. USE OF THE DIVING UNIT

A. SWIMMING

Skill and safety in underwater swimming and self-contained diving depend upon familiarity with the apparatus used and the limitations imposed by the underwater environment as well as careful equipment maintenance. All details of the use of the LARU should be mastered by wearing it on land before attempting to dive. This should be followed by practice in shallow water or with a safety line before descending into deep water for free swimming.

1. Limits of Depth and Time.

While extensive field use was made of oxygen apparatus in World War II without oxygen toxicity (1), recent well-controlled laboratory studies at the U. S. Navy Experimental Diving Unit (2) indicate that the safe time for the use of oxygen during exercise at depths greater than 30 feet is very short. At depths less than 30 feet oxygen intolerance did not occur, even with exercise and exposures of considerable duration.

Nevertheless, until these studies have been extended to determine when or whether oxygen toxicity will occur at depths less than 30 feet, it is recommended that a Depth-Duration limits for underwater swimming with the LARU oxygen breathing apparatus be considered as those listed in table 8-2 of "Diving with Self-Contained Underwater Breathing Apparatus", a Special Report Series by E. H. Lanhier and J. V. Dwyer, Experimental Diving Unit, Washington, D. C., 1 April 1954. This table is reproduced as follows:

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<th>Diving Depth (ft. of sea water)</th>
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It is further recommended that when a single dive has been performed to the limits indicated in the table, at least one hour of air breathing at the surface should elapse before extensive oxygen diving is repeated.

2. Swimming Technique

A flutter kick using swim-fins with the arms resting along the sides of the body is the most effective method of underwater swimming. Development of efficiency in this method of underwater propulsion is worth considerable time and effort prior to diving. If swim fins are not available, the breast stroke may be used.

3. Buoyancy Control

Approximate neutral buoyancy is accomplished in the LARU by proper balance of components with positive and negative buoyancy. The apparatus is designed to be close to neutral buoyancy in fresh water. When used in salt water, one or two lead ballast plates may be required. Each diver should determine the amount of lead which provides him with the closest approach to neutral buoyancy during underwater swimming at a constant level. Once made, this determination should not have to be made again unless accessory equipment such as waterproof suits are worn with the LARU. These will require independent adjustment of neutral buoyancy.

Once the diver has determined his personal ballast requirements, the demand valve maintains the breathing bag at approximately constant volume during descent and at diving or swimming depths. Therefore, no adjustment of buoyancy is ordinarily required by the user under these conditions. During ascent, however, the expansion of gas in the lungs and the units respiratory system increases the breathing bag volume, resulting in the rapid development of positive buoyancy and therefore speeding ascent. The diver controls his rate of ascent by manually discharging excess gas through the water drain valve or the air breathing valve. Should he neglect to do this, gas will escape beneath the edge of the face mask, preventing excessive build-up of pressure within the breathing system.

At the surface the breathing bag can be filled with oxygen to provide positive buoyancy for surface flotation. If the oxygen supply has been exhausted air may be blown into the bag through the oral inflation tube (see IV, A, 3, Surface Techniques).

4. Surface Techniques

After closing the mask shut-off valve the air breathing valve may be opened or the mask removed to permit air breathing on the surface. Propulsion during surface flotation is most effective when the diver lies on his back and uses the flutter kick.
The emergency flotation bladders of the life preserver may be inflated while submerged by pulling one or both of the lanyards which activate discharge of the small carbon dioxide cylinders into the bladders. The increased buoyancy provided is sufficient to carry the diver to the surface without swimming effort. At the surface the combination of inflated breathing bag and life preserver provides stable flotation in a face-up position with the swimmer at complete rest. This avoids dangers arising from exhaustion in surface swimming, in current and other situations involving delay in pick up of the swimmer following underwater work. By means of the oral inflation tubes on the breathing bag and on the life preserver air may be blown into these buoyant compartments in the event the supply of gas in the CO₂ cartridges or oxygen cylinder is inadequate for inflation. While the flotation provided by the life preserver and breathing bag will support the swimmer and his apparatus, the greatest degree of positive buoyancy results when the lead ballast plates are "dumped". This may be desirable under very rough surface water conditions but is rarely necessary under ordinary circumstances.

The entire apparatus may be removed at the surface and, when held under the chest, may be used as support while flutter kicking in a forward direction.

5. Work on the Bottom

If stability is required underwater, as in walking or working on the bottom, the accessory lead weight belt should be attached to the vest belt loops. When the accessory weights are used for negative buoyancy a descending line and a safety line should be used since the diver lacks the mobility of the neutrally buoyant underwater swimmer. The lead weight belt may be "dumped", if desired, by pulling the free ends of the quick release straps.

6. Breathing

Deep and regular breathing is most satisfactory with underwater swimming apparatus, including the LARU. Shallow, rapid breathing increases the proportion of physiological (diver's) and apparatus dead-space air rebreathed and may lead to carbon dioxide accumulation in the diver's lungs, even though the inspired gas contains negligible amounts of carbon dioxide. Deep breathing minimizes this effect.

During ascent it is extremely important to avoid breathholding. If the breath is forcibly held the normal expansion of gas which takes place on ascent may overdistend the lungs. This overstretching may tear lung tissue and lead to entrance of gas bubbles into the blood stream (aerocembolism). This is not a common accident and has not been reported as occurring in underwater swimmers. Nevertheless it has occurred in submarine escape training and has produced fatal results. Simple continuation of normal breathing during the period of ascent provides the greatest protection against this accident. No such problem exists during descent or while working at a given depth.

7. Overactivity

The diver cannot be expected to perform harder work or longer periods of continuous work underwater than he is capable of doing on land. In addition to this, in any closed circuit diving apparatus the limiting factor for degree of continuous exercise is the ability of the carbon dioxide absorption canister to remove the carbon dioxide produced. The rate of carbon dioxide production by a diver increases in proportion to increases of his work effort. It is
necessary for each individual to learn by experience the maximal work rate which he, together with his apparatus, can sustain without rest periods for the diving duration provided by the LARU. He should also determine the length of time he can carry out his most strenuous activity, as well as the rest period required for breathing to return to normal immediately following this activity. When the individual has gained experience in recognizing his limits alone and in combination with his apparatus he will be able to adjust his working pace to obtain maximum effectiveness during a dive.

If, during severe underwater work, carbon dioxide tends to accumulate and the individual becomes "short of breath", a decrease in the work rate or a rest period will permit the canister to remove the excess carbon dioxide and restore comfortable breathing. In water of moderate depth a rest period may be spent on the bottom. In deep water, rest can be accomplished by manually overfilling the breathing bag and using it for support while relaxing at the surface and breathing oxygen.

8. Water Leakage

In a well maintained and properly donned diving unit no water should leak into the breathing system. However, water condenses within the apparatus from water vapor in the exhaled air. On a dive of long duration this water, or water allowed to enter through poorly tightened connections, may become annoying and should be discharged. The procedure is as follows:

a. Lean forward to allow water in breathing tubes to run into mask valve assembly and its water drain valve trap.

b. Inhale.

c. Clamp exhaling (left) tube with fingers (or close the shut-off valve).

d. Press water drain valve button and exhale slowly until a few bubbles of oxygen are discharged. The appearance of the first bubbles indicates that the water in the trap has been discharged. It is not necessary to blow large amounts of oxygen through the water drain valve to discharge water.

If, for any reason, large amounts of water enter the breathing system there is no immediate cause for alarm. This water will collect in the exhaling portion of the breathing bag. In great excess, it may, however, wet the carbon dioxide absorbent, seal its pores and greatly reduce its ability to absorb exhaled carbon dioxide. While the wet soda lime would perform reasonably well at low work rates, even moderate exercise would result in intolerable carbon dioxide accumulation. The diver should therefore terminate the dive and correct the difficulty.

After accidental flooding of the apparatus (as in the case of removing the mask in water without first closing the shut-off valve) the apparatus should be washed internally, the canister dried, and all removable water shaken and drained from the tubes and bag. The canister should then be refilled with fresh absorbent.

9. Empty Oxygen Cylinder

If during prolonged use of the LARU, the oxygen cylinder should become empty it is not an emergency situation for the following reasons:

a. The breathing bag and diver's lungs will contain sufficient oxygen for at least five or ten minutes of breathing when near the surface. If
the diver is working at a depth of 30 feet (about 2 atmospheres) the bag and diver's lungs will contain twice this amount of oxygen. Adequate time is therefore available for leisurely ascent.

b. If the diver does not notice the time when his cylinder becomes empty, he will gradually use the oxygen from the breathing bag. As the volume of oxygen in the bag becomes smaller the diver's inhalations will eventually cause the breathing bag to collapse completely at the end of an inspiration. This "hitting bottom" on the breathing bag produced a characteristic tug on the chest and mask which, over a period of many minutes becomes more and more uncomfortable. This provides a repeated and increasingly powerful warning, which cannot be ignored, of the exhaustion of the oxygen cylinder. The diver will have emptied the nitrogen from his lungs and the collapsible parts of the breathing system in the usual manner before diving. For this reason the oxygen concentration in the apparatus will remain high during the whole period of decreasing bag size. Even when the volume is completely inadequate for breathing the oxygen concentration will exceed that of ordinary air. Oxygen lack can therefore not occur and the diver's mental clarity, strength and performance remain unaffected by the emptying of the oxygen cylinder.

B. DEEP DIVING

When prolonged, deep diving is required the LARU may be adapted for air hose diving. An adaptor kit provided as accessory equipment permits conversion of the closed circuit oxygen apparatus into a surface supplied, air-breathing apparatus with a low air volume requirement.

The adaptor kit consists of the following parts:

1. Low pressure needle valve
2. Diving check valve
3. Cap for demand valve fitting
4. Clamp for exhaling tube
5. Exhaling valve with deflector

Conversion for air hose diving is accomplished by the following steps:

1. Remove oxygen cylinder with regulator valve and oxygen delivery tube to demand valve.
2. Install blank cap on demand valve inlet connection.
3. Insert plate of needle valve in special pocket within cylinder pouch, handle of valve to right. Secure with snap fastener.
4. Attach breathing bag oxygen delivery hose to needle valve.
5. Attach diving check valve to needle valve inlet.
6. Clamp exhaling tube (left tube) of breathing system with special clamp.
7. Remove water drain valve from mask valve assembly. Replace with exhaust valve and deflector.

8. Attach diving hose to check valve.

In use, air delivered from a surface air compressor (diving compressor, truck air brake system or compressed air cylinder) passes through the check valve, its rate of entry into the breathing bag being adjusted manually by the needle valve. The breathing bag functions as an air reservoir from which the diver inhales. It continues to store new air as the diver exhales and provides the air volume for the next inhalation. If the reservoir bag principle were not used air delivered by the compressor during the period of exhalation would pass out into the water along with the exhaled gas. The use of the breathing bag as a storage reservoir therefore reduces the compressor capacity required for air hose diving to about one-half by avoiding waste of air during exhalation.

In use the needle valve should be adjusted during descent to provide a full volume of air for inhalation with the least possible waste of compressor air during exhalation. The carbon dioxide canister serves no purpose when the apparatus is used for air hose diving. It can be used empty or full. Since the oxygen cylinder is removed in adapting the LARU for air hose diving the cylinder pouch may be employed as a container for tools or materials to be used in a diving task. To provide stability for work on the bottom the accessory lead weight belt should be attached to the vest for air hose diving. A descending line and a safety line should be used routinely. The air hose should be looped through a waist strap to prevent stresses from acting directly upon the connection of the hose to the check valve.

C. USE ON LAND IN CONTAMINATED ATMOSPHERE

The use of the LARU on land to permit work in atmospheres containing poisonous gases involves fewer difficulties than does underwater work since none of the problems concerned with pressure or buoyancy are encountered. Only three potential problems exist:

1. Anoxia can occur on land as well as underwater, with any type of rebreathing apparatus, if the proper technique for using the equipment is not followed. The same method of removing excess air from the breathing bag and lungs when donning the unit must be carried out for land work as for diving (see pages 8 and 9). If this is done there is no danger of anoxia.

2. Carbon dioxide excess, with resultant labored breathing, headache and fatigue may occur on land or underwater if the degree of work exceeds the capacity of the canister to absorb carbon dioxide. Moderation of work and deep respiration will prevent carbon dioxide excess. The ability of the LARU canister to absorb carbon dioxide exceeds the standards set up by the Bureau of Mines for rescue oxygen rebreathing apparatus.

3. Temperature of the oxygen breathed may rise to uncomfortable levels on land due to the heat generated in the canister by the absorption of carbon dioxide. In diving the canister is water cooled. On land, if work is extreme, heating of the oxygen may be disagreeable. This elevated inspired oxygen temperature is not harmful. It occurs in all rebreathing units now in use and in the LARU does not exceed the limits established by the Bureau of Mines for rebreathing equipment.
V. MAINTENANCE

A. STORAGE

1. Keep apparatus hanging on rack when not in use. Avoid strain on tubings or prolonged pressure on mask or bag.

2. Keep apparatus out of sunlight when not in use to prevent deterioration of rubber and nylon parts.

3. Do not allow oil to come in contact with rubber of face mask. It is natural rubber and, unlike neoprene, is rotted by oil.

4. Do not leave oxygen cylinders in the sun or near heat. Heat may raise the cylinder pressure, open the cylinder safety valve and cause the oxygen to be discharged.

B. CLEANING

1. Rinse outside of apparatus with fresh water after each use in salt water. This may be easily accomplished by dipping the entire unit into a can of water, first making certain the mask shut-off valve is closed.

2. If canister contents become wet flush out inside of entire respiratory system to remove alkaline. Oxygen delivery tubes should be disconnected from the breathing bag and demand valve for this procedure to prevent entrance of water into oxygen regulator.

Excess water should be shaken, wiped and drained from breathing tube connections, valves, canister and breathing bag to prevent wetting of carbon dioxide absorbent with the next use of the apparatus. If practical, disassembled components should be allowed to drain and dry before reassembly for the same reason.

3. Flush inside of respiratory system in the manner described in B 2 above after each five to ten dives to remove any traces of soda lime dust and to clean breathing valves.

C. LUBRICATION

1. General

   a. Avoid contact of oil or grease with high pressure oxygen fittings (cylinder valve and oxygen regulator). Explosion may result from exposure of oily fittings to cylinder oxygen pressure.

   b. Avoid contact of oil with natural rubber parts (face mask and valve disc) of apparatus. Oil rots rubber.

   c. Where available use only Dow Corning-4 silicone lubricating compound. The silicone in this grease-like substance repels water, minimizing corrosion of threads while the grease base lubricates.

2. Lubrication guide

   a. Zippers on cylinder and canister pouch. Brush sand out before lubricating. Lubricate as required.
b. All "lift-the-dot" fasteners. Lubricate as required.

c. Mask air breathing valve. Stem, guide and spiral bayonet fitting. Lubricate weekly.

d. Mask shut-off valve. Valve handle guide, spiral bayonet, stem and outer stem guide. Reached by removing valve handle. Lubricate weekly. Particular attention should be paid to lubricating stem in region of "O" ring seal at end of stem guide since this is the seal against entry of water.

Lubricate threads of shut-off valve body at points of attachment of shut-off valve outer stem guide, water drain valve and inner shut-off valve guide. The latter is reached by removing outer shut-off valve stem guide with special spanner and removal of shut-off valve mechanism. Lubricate monthly.


f. Oxygen pressure gauge. Small amounts of lubricant on gears, bearings and joints within case. Lubricate weekly. While the pressure gauge is a high pressure component, the high oxygen pressure does not come into contact with the outer surfaces of its working parts. Friction due to corrosion of the gauge mechanism is usually responsible for gauge inaccuracy and can be minimized by proper lubrication.

g. Emergency oxygen supply lever. Stem guide. Lubricate weekly from external aspect only.

h. Breathing valve cases. Inner and outer threads only. Lubricate weekly. Do not allow lubricant to contact rubber breathing valves; sticking may result.

i. Canister to bag connections. Threads only. Lubricate weekly.

j. Canister lid securing nut. Threads of central canister rod in canister and its corresponding nut on canister lid. Lubricate weekly. Brush soda lime dust from threads before lubricating.

D. CORRECTIVE ACTION FOR IMPROPER FUNCTION

(NOTE: Improper function of the apparatus is rarely due to mechanical wear upon component parts since wear is negligible under ordinary circumstances.) The most common sources of malfunction involve improper lubrication or adjustment, loss of components or loose connections. These sources of poor function can be essentially eliminated by routine pre-diving inspection of the apparatus, with periodic detailed checking of the individual valves.

l. Leakage of water into respiratory system. An overall check should be made by overinflating the breathing bag with mask shut-off valve closed and submerging entire unit to inspect for escape of bubbles. Leaks may be caused by:

a. Unequal adjustment of mask straps. Inadequate sponge rubber padding beneath mask inner flap.

b. Improper sealing of canister lid because of over-filling of canister with absorbent, inadequate tightening of canister lid nut, denting of
canister edge, uneveness of canister lid washer or soda lime granules between canister rim and canister lid gasket.

c. Looseness of overpressure valve, water drain valve body, breathing valve-to-bag connections, canister-to-bag connections, caps on bag drainage tubes, stem of water drain valve.

d. Soda lime or baralyme granules between valve and seat of overpressure valve or water drain valve.

e. Improper seating of air breathing valve due to inadequate lubrication of bayonet slide or weak spring tension.

2. Loss of oxygen from breathing system. (gas bubbles from apparatus underwater). On submerging air bubbles trapped in canister pouch and under vest may escape over a period of several minutes, giving the appearance of oxygen leakage where it does not exist. True oxygen leakage may be attributed to:

a. Factors listed under entrance of water into respiratory system, above. NOTE: Escape of gas from the rebreathing system is usually accompanied by entrance of water.

b. Insufficient tightening of cylinder valve packing nut (beneath cylinder valve handle), union nut between cylinder valve and regulator, oxygen delivery tube connections between regulator and breathing bag or demand valve. Leaks from these high pressures are not accompanied by entrance of water into the respiratory system and affect performance only by decreasing the amount of oxygen available for the diver (decreasing diving duration).

3. High resistance of demand valve to activation by inhalation.

a. Improper elevation of demand valve trigger lever. Remove demand valve protective disc. Upper surface of lever should be about 1/8" above internal protective case when demand valve is closed. The lever may be manually bent to this position without disassembly of demand valve.

b. Improper regulator setting. Regulator pressure which is too high (above 40 p.s.i.) requires excessive inspiratory effort to open demand valve. Attach regulator test gauge to oxygen delivery hose from regulator to demand valve to read regulator outlet pressure. Adjust to 20 p.s.i. ± 5 p.s.i. by turning pressure adjusting screw at end of regulator cap. Press emergency oxygen delivery valve and release to assure that pressure returns to proper level after gas flows through regulator.

4. Oversensitive demand valve.

Oversensitive demand valve may be caused by:

a. Defective demand valve helical spring. Replace demand Valve-stem unit.

b. Low regulator pressure. Since demand valve is held closed by pressure against the weight of its activating lever, a low regulator outlet pressure may be inadequate to close valve promptly at end of inhalation. Check and adjust regulator pressure as in 3b.

c. Excessive elevation of demand valve trigger lever.
5. Leak of regulator safety valve.

Excessive regulator pressure as in 3b, above, may cause leakage through its safety valve. After activation the safety valve may not again seat properly until its rubber valve disc is reversed or replaced.

6. Frozen overpressure valve.

This is recognized by failure of valve to allow oxygen to escape when bag is overdistended. Leakage may be due to:

a. Corrosion between valve stem and guide due to inadequate cleaning and lubrication.

b. Adherence of valve disc to valve seat. Since this is a preset valve it should be replaced from spare parts.

References
