DIVING MANUAL

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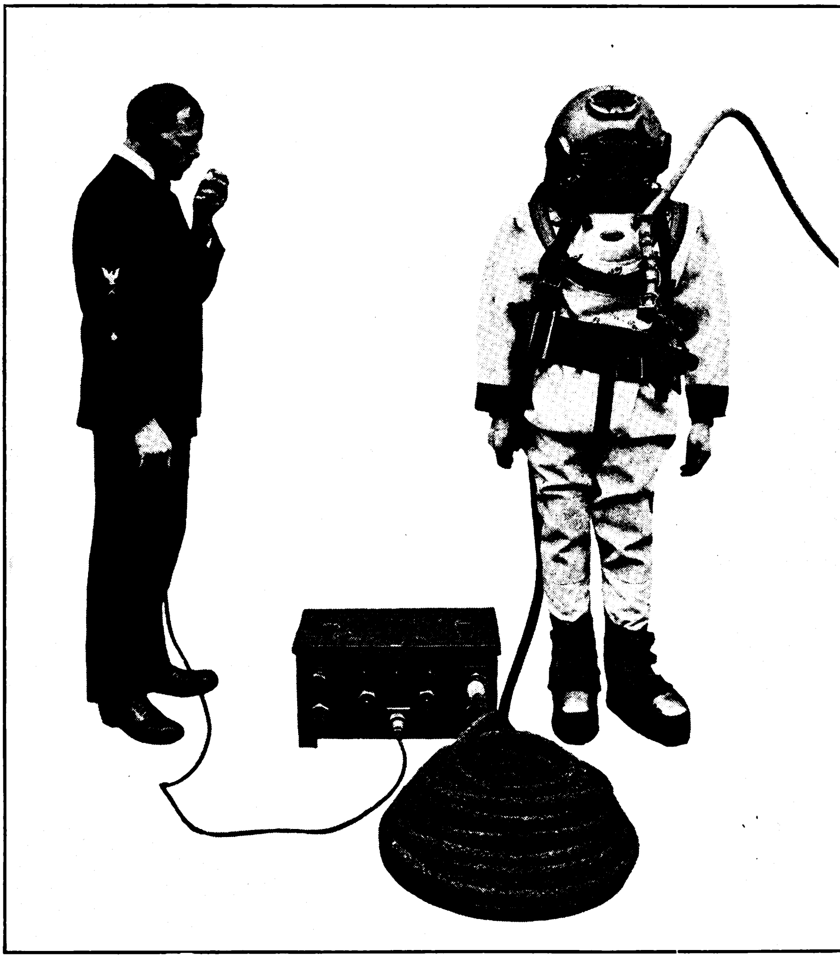
ILLUSTRATIONS.



DIVER COMPLETLY DRESSED. ATTENDANT WITH TELEPHONE.

PLATE III.

BACK VIEW. DIVER PARTLY DRESSED.

CHAPTER I.

GENERAL DESCRIPTION OF NAVY STANDARD DIVING APPARATUS.

(Pl. I.)

The principal parts of the apparatus are as follows:

(*a*) Dress.
(*b*) Breastplate.
(*c*) Helmet.
(*d*) Air hose.
(*e*) Air-control valve.
(*f*) Weights.
(*g*) Telephone equipment.
(*h*) Gloves.
(*i*) Overalls.
(*j*) Air pump.

THE DRESS.

The dress is of flexible diving dress material, made of rubber between layers of cotton twill, and reinforced at the points of wear. It is so constructed that it incloses the entire body with the exception of the head and hands.

The sleeves of the dress terminate in elastic rubber cuffs which form flexible water-tight joints at the wrists.

The neck of the dress is fitted with a rubber gasket, or collar, and an inside portion of cloth called a bib. The purpose of the collar is to attach the breastplate to the dress, the breastplate fitting between the rubber collar and the bib. The bib fits loosely and comes well up inside of the neck piece of the breastplate. The object of the bib is to collect any water that may enter the helmet through the valves and prevent this water from coming in contact with the diver's body.

BREASTPLATE.

The breastplate is that portion of the diving apparatus which connects on the lower end with the dress and on its upper end with the helmet. It is of tinned copper and so made that the lower portion fits comfortably over the shoulders, a pad usually being interposed between the shoulders and the breastplate. Its upper end is circular and comes about on a level with the larynx.

The breastplate is attached to the dress by means of screw studs which pass through holes in the rubber collar. Four sectional metal clamps conforming with the curvature of the breastplate are placed over the studs and held in place by wing nuts. When these nuts are screwed down, the collar of the dress is compressed between the straps and the edge of the breastplate, thus forming a water-tight joint.

HELMET.

The helmet, which incloses the diver's head, is attached to the circular ring at the neck of the breastplate by an interrupted screw joint. A small stop pin is provided at the back of the helmet which is turned down into a recess on the breastplate as a *precaution* against the helmet becoming accidentally detached. A gasket is interposed between the helmet and breastplate, thus forming a water-tight joint. The helmet is constructed with four windows. One is directly in front of the diver's face, and is called the faceplate. The other three windows are located as follows: One on each side of the helmet, on a level with the faceplate, so as to enable the diver to see laterally; the third in the midline of the helmet, above the faceplate, to permit the diver to look upward.

An air inlet connection, called the gooseneck, is placed at the back part of the helmet and is curved downward to give a proper lead to the diver's air hose.

A safety valve, or nonreturn valve, is screwed on to the end of the gooseneck and the air hose, in turn, is coupled on to the male threaded portion of the safety valve.

The proper functioning of the safety valve is of utmost importance. Its purpose is to prevent a diver being injured in the event of his air hose bursting above him, or the diving air pump becoming so seriously damaged as to fail to maintain an air pressure within his dress sufficient to counteract the pressure of water surrounding him. If either of these things were to happen, and there were no safety valve in place, the pressure in the air hose would fall suddenly, the compressed air in the helmet and dress would escape up the air hose, and the result would be that inside the helmet there would be less pressure than the water would be exerting through the flexible dress on the diver's unprotected body. The effect would be for the diver to be squeezed up into his own helmet in the same way that a cork is forced into an empty bottle when it is lowered in deep water. Quite a slight pressure applied in this way is known to be instantly fatal.

A regulating escape valve is fitted into the right side of the helmet between the face plate and right side window. The valve seats with the water pressure and against the air pressure within the suit. An excess of air pressure over water pressure causes the air to escape into the surrounding water with the valve open. The valve is provided with a spring and regulating screw on the water side by means of which the diver can regulate the inflation of his dress and thus his buoyancy. Operating the regulating screw changes the tension of the spring and varies pressure on the valve. The improper adjustment of this valve is the cause of a most vicious trend of circumstances to the diver. As a diver enters the water, pressure is applied to the outside of his dress and tends to force the air out the valve. Setting up on the regulating screw retards this escape in proportion to the tension of the regulating spring. If freely open, and the air supply is inadequate, the dress will collapse and the diver's breathing will be interfered with. With a normal air supply and the valve improperly closed too great an inflation of the dress may result and be followed by an excess of positive buoyancy. Over inflation in the cause of "Blowing up" of a diver, which is a *serious accident* if it occurs from any considerable depth.

A spit cock or supplementary relief valve is placed on the front part of the helmet to the left of the face plate. This valve is operated by the diver by means of a small handle and permits fine adjustment of his buoyancy and the expulsion of water which may be collected inside the helmet by the bib.

AIR HOSE.

The diving hose is $1\frac{1}{16}$ inches external diameter and $\frac{1}{2}$ inch internal diameter. It is made up in 3-feet lengths and 50-feet lengths, which are coupled together by gun-metal couplings; alternate male and female. Openings through the couplings are $\frac{3}{8}$ inch in diameter. When new the hose is capable of withstanding a test pressure (internal) of 500 pounds per square inch for 10 minutes.

AIR-CONTROL VALVE.

The air-control valve is a needle valve interposed in the air hose 3 feet from the end next to the connection at the helmet and is attached to the breastplate by a flexible link joint. This valve is operated by the diver and its purpose is to permit control of the flow of high-pressure air into the helmet.

WEIGHTS.

The weights consist of a weighted belt and leaded shoes. The object of these is to cause negative buoyancy when the diver's suit is moderately distended by air.

TELEPHONE EQUIPMENT.

The telephone outfit is of special construction and serves as the means of maintaining communication between the divers under the water and their attendants at the surface. The telephone cable and life line are combined in one line which serves as a means of supporting the diver when off the bottom. In case of accident to the telephone, the reserve code of signals may be transmitted by utilizing the cable as a signal line. In communicating with the diver by telephone, the effects of pressure are noted on the diver's voice by loss of timbre. There is, however, no difficulty in understanding him at depths as great as 306 feet if he talks in a moderate voice.

GLOVES.

The gloves are attached to the sleeves of an under jacket and protrude from under the cuffs of the sleeves of the dress. They are of waterproof material and serve as a protection from cold. In temperate waters these are not worn.

OVERALLS.

Overalls are provided to protect the diving dress from chafe and wear. By means of adjustable straps or suspenders, the distance between the helmet and the crotch of the diving dress can be regulated to keep the helmet from rising over the diver's head when the dress is inflated with air.

DIVING AIR PUMPS.

Manually-operated air pumps are provided for use when other means of air supply are not available. Except in cases of special exigencies *diving with air supplied from a single hand-driven air pump shall be limited* to depths not exceeding 72 feet. For greater depths additional pumps or other means of air supply are necessary. When hand-driven diving air pumps are used to supply air to divers, the air-control valve is not required.

CHAPTER II.

THE PHYSICS OF DIVING.

In the study of the art of diving and its effect upon the human body it is necessary to consider a few of the physical properties of air and water.

FLUIDS.

A fluid is a substance the particles of which are easily separable. Fluids are either gaseous or liquid. The ones with which we are chiefly concerned in diving are air, water, and the fluids of the body.

AIR.

Air is the fluid we breathe and which surrounds the earth; the atmosphere. It is invisible, inodorous, insipid, transparent, compressible, elastic, ponderable. Dry air when pure consists of 79.04 per cent of nitrogen (including 0.92 per cent of argon), 20.93 per cent of oxygen, and 0.03 per cent of carbon dioxide (CO_2). Air follows the law of gases.

BOYLE'S LAW.

Boyle's law states that the volume of a gas varies inversely as the pressure (absolute), while the density varies directly as the pressure. That is, an increase of pressure on a volume of gas decreases its volume and increases its density in proportion to the pressure applied and vice versa. If the pressure be doubled the volume will be decreased by one-half; if the pressure be trebled the volume will be decreased by two-thirds, etc.

CHARLES'S LAW.

Charles's law states that the volume of a gas varies $\frac{1}{273}$ of its volume for every variation of one degree Centigrade or $\frac{1}{491}$ of its volume for every degree Fahrenheit. That is, the volume for every variation increases with the rise in temperature and decreases with the fall in temperature.

WATER.

Water is the fluid which descends from the clouds in rain and forms rivers, lakes, seas, etc. Pure water consists of hydrogen and oxygen and is colorless, tasteless, transparent liquid which is very slightly compressible. At its maximum density, 39° F., it is the standard for specific gravities, 1 cubic centimeter weighing 1 gram. It freezes at 32° F. and boils at 212° F. Besides having other values it is an important ingredient in the tissue of animals and plants, the human body containing about two-thirds its weight of water.

OXYGEN.

Oxygen is a colorless, tasteless, odorless, gaseous element occurring in the free state in the atmosphere, of which it forms about 23 per cent by weight and about 21 per cent by volume, being slightly heavier than nitrogen. In combination with hydrogen it forms water. It is indispensable in respiration but can not in its pure state be breathed with safety for indefinite periods. Under high pressure oxygen becomes a deadly poison.

HYDROGEN.

Hydrogen is a gaseous element, colorless, tasteless, odorless, the lightest known substance, being 14½ times lighter than air and over 11,000 times lighter than water. It is very abundant, may be produced in many ways, is very inflammable, and is an ingredient of coal gas and water gas.

NITROGEN.

Nitrogen is a colorless, gaseous, nonmetallic element, tasteless, odorless, and comprising four-fifths of the atmosphere by volume. It is chemically very inert in the free state and as such is incapable of supporting life, but it is a constituent of all organized tissues, animal and vegetable.

CARBON DIOXIDE.

Carbon dioxide (CO_2) is a compound of carbon and oxygen and is a colorless, heavy, irrespirable gas, extinguishing flame and, when breathed, destroying life. It can be reduced to a liquid and solid form by intense cold and pressure. Plants imbibe it for their nutrition and growth, the carbon being retained and the oxygen given out.

ATMOSPHERIC PRESSURE.

Atmospheric pressure is that pressure exerted by the atmosphere and is equal, at average sea level, to 14.7 pounds per square inch. A column of mercury 30 inches high, a column of sea water 33 feet high, and a column of fresh water 34 feet high each exert a pressure of 14.7 pounds per square inch or the pressure of 1 atmosphere at the bottoms of their respective columns. By atmospheres of pressure is meant the number of times 14.7 is contained in the total number of pounds pressure per square inch. Therefore, 29.4 pounds pressure per square inch will equal (29.4 divided by 14.7) 2 atmospheres pressure; 44.1 pounds pressure per square inch equals 44.1 divided by 14.7=3 atmospheres pressure, etc. To convert atmospheres pressure into pounds pressure per square inch multiply the number of atmospheres pressure by the factor 14.7.

ABSOLUTE PRESSURE.

Absolute pressure is that pressure above a perfect vacuum or absolute pressure is gauge pressure plus atmospheric pressure or 14.7 plus excess pressure. Thus, a diver working at a depth of 33 feet under water, the equivalent pressure of 1 atmosphere, would be exposed to an absolute pressure of 29.4 pounds per square inch or 14.7 plus the excess pressure of water.

GAUGE PRESSURE.

The gauges used in diving do not record atmospheric pressure but do record the pressure above atmospheric pressure. They also indicate the corresponding depth of water in feet. If a length of air hose be attached to a diving pump, the free end of the hose lowered under water and the pump operated, the gauge on the pump will indicate the pressure of water and the depth of water at the point to which the end of the hose has been submerged. Hence, this procedure provides an accurate means of determining depth and pressure of water or, if the depth is known, a convenient method for checking the accuracy of the gauge.

WATER PRESSURE.

It is obvious that if a tank be filled with water the bottom of the tank has to support the whole weight of water, but the top has no weight of water to support; the pressure therefore on the bottom will be greater than the pressure on the top by an amount equal to the weight of water in the tank. It is also obvious that the higher the sides of the tank are raised, still keeping it filled, the greater the weight or pressure becomes on the bottom. If the sides of the tank are extended to 33 feet and the tank filled with sea water the pressure on the bottom due to the weight of water would be equal to that of the atmosphere or 14.7 pounds per square inch; however, as the atmosphere is also pressing down on top of the column of water, the absolute pressure on the bottom will be 14.7 pounds due to weight of water, plus 14.7 pounds due to the atmosphere, or a total of 29.4 pounds absolute pressure per square inch. Every foot in height of sea water produces an excess pressure of 0.445 or a little under one-half pound on the square inch. The same holds good when considering the pressure on a body immersed in water. Any such body may be looked on as having the column of water between it and the surface pressing down all round it. This pressure is transmitted to it in the form of a squeeze. If the body has appreciable length, such as a diver standing upright, the top of the body is nearer to the surface of the water than is the bottom, therefore there is less pressure upon the top of the body than at its bottom and, therefore, in the case of the diver there is less pressure on his helmet than on his shoes. If the diver is 6 feet tall there will be about 3 pounds less pressure on his helmet than on his shoes, whatever the depth of water he may happen to be in.

BUOYANCY.

A body submerged in a liquid is buoyed upward by a vertical force equal to the weight of the displaced liquid. This pressure equals 62.5 pounds in fresh water and 64 pounds in sea water for each cubic foot of the volume of the submerged body. With the diving suit distended by air, the weight of the water to be displaced is greater than the combined weight of the suit, helmet, and diver. As a result, the dress, helmet, and diver are positively buoyant and the diver is unable to descend. To overcome this positive buoyancy, weights are attached to the diver's dress in the form of a weighted belt and weighted shoes, giving the diver negative buoyancy. Ordinarily, only sufficient weight is added to overcome the positive buoyancy with the diving dress moderately distended by air. Under this condition, if the dress is overinflated the diver acquires positive buoyancy, and should he happen to be under water, he will be unable to remain on the bottom from this cause, the buoyancy will be increased, due to the diminished water pressure and the expansion of the air within the elastic dress, and his speed of ascent will be accelerated. Being carried to the surface in this manner is known as "blowing up."

HELMET VALVES.

A diving suit has essentially two portions, a compressible dress and an incompressible helmet. As a diver descends under water the pressure increases, and its effect is to squeeze the air out of the dress and into the helmet. It is necessary to the diver's physical well being that the dress be inflated sufficiently to cause the helmet to lift the weights attached to it so that it will not rest heavily upon him. To obtain this result air must be pumped into the helmet and the upper part of the dress until the pressure of air in the dress is slightly in excess of the water pressure at about the level of his chest. As the diver breathes the air in the helmet becomes foul and must be replaced by a sufficient quantity of fresh air. Therefore, it is continually necessary for a stream of fresh air to be entering the helmet. If no escape is provided for the air from the helmet, the pressure of air inside the helmet and dress would increase, and finally the diver would be positively buoyant, which for several reasons is objectionable. An escape valve for the surplus air is therefore provided. The water pressure outside the valve tends to close it and the air pressure inside opens it. As the air pressure inside the diving dress must be slightly in excess of the water pressure outside it, a spring, the tension of which is equal to the excess of air over water pressure required is fitted on the water side of the valve so that the air within the dress must reach a pressure equal to the combined spring and water pressures before the valve will open and permit escape of air. As it is the tension of this spring, then, which regulates the buoyancy of the diver and his apparatus, and as the degree of buoyancy must be altered from time to time, a regulating screw is fitted to the valve by means of which the tension of the escape valve spring, hence the buoyancy, is made adjustable.

PRESSURE EFFECTS.

The lungs are only designed to work comfortably when the pressure inside and outside them is approximately the same; very little additional pressure outside them greatly increases the labor of breathing. From this it is plain that a diver must never let the dress go flat and press in upon his chest so as to interfere with his breathing. As regards the remainder of the body, the pressure of the air at the mouth is instantly transmitted to the inside of the body, which, by the processes of breathing and circulation, automatically regulates itself to any air pressure. So that whatever depth the diver may be in, provided a proper supply of air is maintained, the pressure outside the body will never vary more than a pound or two over that inside the body. Air can not, for several reasons, be supplied inside the helmet and dress at more than a certain rate, hence, if for any reasons the water pressure be permitted to increase over the air pressure more than a small amount the diver may be subjected to a very dangerous "squeeze."

FALLS UNDER WATER.

If, through carelessness or culpable neglect, a diver should be permitted to fall an appreciable distance under water, there would be a sudden increase of water pressure and, if there should fail to be a sudden increase of air pressure, the helmet escape valve would be seated, the air within the dress would be forced from it and into the noncompressible helmet, volume diminishing with the increased pressure (Boyle's law). If this volume of air does not fill the helmet and equal the pressure of water at the depth to which the diver's body has fallen, the excess pressure exerted on the diver's body will tend to drive it into the helmet. The result is most apt to be a serious injury or immediate death for the diver. Falls from shallow to deeper depths are the most serious, as the relative difference in pressures is greater. This may be explained by the following: If a diver at the surface, in 14.7 pounds pressure to the square inch (absolute), should fall 33 feet under water, every square inch of his body would have an additional pressure of 14.7 pounds, or 29.4 pounds absolute pressure suddenly applied to it, a proportion of 2 to 1 over the pressure in the helmet. As the body has an area of about 2,000 square inches, the total pressure exerted on the diver's body and tending to drive him into the rigid helmet would be several tons (14.7). If, under the same conditions, the diver should have fallen from the surface to a depth of 66 feet under water, the increase in absolute pressure would have been trebled instead of merely doubled, so, from the foregoing, it is clear that a long fall from a shallow depth would result in a fatal squeeze for the diver. Falls from moderate depths to deeper depths under water are not apt to be so serious as falls from shallow depths; that is, in a fall from the surface to 33 feet the relative difference in pressure is as 1 is to 2, while in a fall from 168 feet to 201 feet the relative difference in pressure is as 6 is to 7. In the first case the column of air is reduced one-half and in latter case only one-seventh. The effect of a fall under water is known as a "squeeze."

TEMPERATURE EFFECTS.

The variation of volume of air and gases due to temperature is disregarded in diving, but other effects of temperature are important. When air is compressed it becomes heated. The following table shows the additional rise of temperature in degrees Farenheit for each atmosphere of additional pressure:

Heat produced by compression of dry air without cooling.

Pressure above atmospheric.	Temperature of air.
Pounds.	*Degrees.*
0	60.0
14.7	175.8
29.4	255.1
44.1	317.4
58.8	369.4
73.5	414.5
88.2	454.3
102.9	490.6
117.6	523.7
132.3	554.0
205.8	681.0
379.3	781.0

NOTE.—The presence of moisture will increase the result, as it increases both the specific heat and the heat conductive capacity.

WORK ON PUMPS.

As a diver descends under water the pumps not only have to take in and deliver a much larger quantity of air with each increase of depth, but they have also to deliver it at a rapidly increasing pressure, so that the work on the pumps is increased much more rapidly than the increase of pressure. In fact, the manual labor required to heave round the diving pumps at considerable pressures is such as to limit the extent of practical diving operations with hand-driven air pumps to moderate depths. To enable divers to accomplish useful work in deep water, without the expenditure of a great amount of manual labor, the employment of power driven air compressors to furnish an adequate air supply is essential.

CHAPTER III.

THE DIVER'S AIR SUPPLY.

An average adult man at rest breathes one-quarter cubic foot of air per minute. The volume respired is regulated as follows: At normal atmospheric pressure each person automatically regulates his breathing so that the alveolar air contains about 6 per cent of CO_2 (varying slightly in different individuals but constant for same individual). If the percentage falls, breathing is diminished or suspended until it again reaches normal. Moderate work increases the CO_2 secreted by the lungs three or four times and hard work six to eight times the normal resting amount, therefore, the air breathed is consequently increased. If the inspired air contains 3 per cent CO_2, breathing will be about doubly increased, and moderate work in such air will cause moderate dyspnea. Six per cent causes very great distress, and 10 per cent a tendency to unconsciousness.

When the pressure is abnormal, the law just stated does not hold and it is found that what does remain constant is not the percentage but the absolute pressure exercised by the CO_2. For example: A diver working at a depth of 264 feet in sea water is at an excess pressure of 8 atmospheres, or an absolute pressure of 9 atmospheres, hence, three-ninths, or one-third, of 1 per cent of CO_2 would have the same effect on him at this depth as 3 per cent of CO_2 would have at the surface.

At rest the average adult man produces about 0.014 cubic feet of CO_2 per minute (measured at atmospheric pressure). The diver at rest produces 0.019 cubic feet of CO_2 per minute, and, with moderate work, the production of CO_2 per minute amounts to 0.045 cubic feet (measured at atmospheric pressure). As a diver is constantly excreting CO_2 into the helmet, it is evident that, unless the helmet is ventilated constantly with fresh air in sufficient quantity, he would soon suffer from the effects of an accumulation of CO_2. This is found to be the case, and the difficult breathing heretofore experienced in diving is the result of CO_2 accumulation, due to an insufficient air supply.

Provided that the CO_2 in the diver's helmet does not exceed 3 per cent of an atmosphere, it is found that he can do moderate work and not suffer from respiratory distress.

To keep the CO_2 content of the helmet below this maximum allowable percentage, a minimum air supply of 1.5 cubic feet per minute (measured at the absolute pressure to which the dive is made) is necessary. As the air supply measured at the surface must increase in direct proportion to the diver's absolute pressure, the coefficient becomes $\frac{1}{33}=0.0303$ for each foot of sea water from the surface. Therefore, the minimum air supply in cubic feet per minute for any given depth may be computed by the following formula: $S=1.5(1+\overline{F\ (0.0303)})$, in which S is the required air supply in cubic feet measured at the surface, and F is the number of feet the diver is below the surface.

Better ventilation than this is imperative for hard work, and arrangements should be made for supplying three times this quantity of air if practicable.

Exclusive of self-contained diving apparatus, there are three methods of ventilating the diver's helmet. These are as follows:

(*a*) Supplying air from high-pressure accumulators (up to 2,500 pounds per square inch) charged or charging from power-driven compressors, i. e., from torpedo air flasks or accumulators.

(*b*) Supplying air from low-pressure accumulators (up to 200 pounds pressure per square inch) charged or charging from power-driven compressors, i. e., from the battery gas ejector system, or from low-pressure receivers.

(*c*) Supplying air from hand-driven air pumps.

AIR SUPPLY FROM HIGH-PRESSURE ACCUMULATORS.

In regard to high-pressure accumulators, reference is made to the air accumulators of the torpedo installation on board vessels equipped with torpedoes. When connections are made to accumulators, diving operations are to be conducted direct from or in the immediate vicinity of the diving vessel, thus obviating the necessity for the use of a long length of air hose and the dangers in connection therewith. When the accumulators are of sufficient capacity, diving should be undertaken from accumulators already fully charged to maximum capacity. When the capacity of the accumulators is insufficient for the depth to be accomplished, the compressor shall be in operation when necessary, and care taken to see that the water-cooling system is intact in order to insure a cool-air supply. The capacity of the air compressor and the accumulators must be known and taken into consideration when calculating the air supply, as per example:

Capacity of compressor equals 15 cubic feet at 2,500 pounds pressure per square inch per hour, or one-fourth cubic foot at 2,500 pounds per square inch per minute.

As 2,500 pounds pressure per square inch equals 42 cubic feet of air measured at atmospheric pressure, rated capacity of pump per minute, in a dive (one diver) to 274 feet or 8.3 atmospheres excess pressure, it is evident that, in furnishing 4.5 cubic feet of air per minute at this pressure, the air must equal 4.5×9.3 or 41.85 cubic feet of air measured at atmospheric pressure. From this it is evident that the power-driven air compressor working at full capacity would just be able to furnish this supply of air. For no reason whatever must divers ever be permitted to dive to the limit of their air supply, no matter what the method used may be. Also, sufficient air must always be held in reserve to enable the dispatch of a relief diver. To increase the capacity of the air accumulators on board, the torpedo air flasks can readily be utilized by connecting them up to the air line with stop valves opened.

AIR SUPPLY FROM TORPEDO AIR FLASKS.

In diving to any depth allowable, torpedo air flasks may be utilized to furnish air to divers, and shall be used when deep-diving operations are to be conducted at a distance from the diving vessel. In this method, at least three or more flasks must be connected ready for use, one flask to be held in reserve. An additional relief diving launch for every diving launch with diver under water at depths over 120 feet, shall be fully equipped and ready, with three air flasks fully charged, in case of emergency. The relief boat must remain within easy distance of the diving launch. In diving by this method one air flask shall be held in reserve and not used except in case of special exigency, as in the case of a fouled diver. Not more than two divers shall be permitted to dive from the same boat, and the pressure in the working flasks, as indicated on the high-pressure gauge, shall not be permitted to fall below 220 pounds per square inch in excess of that in which the divers are working while they are on the bottom. After they are clear of the bottom and safely on their way to the surface the remaining flask may be opened. In case it should be found not possible to obey these instructions the reserve flask may be opened, however, at the same time a reserve supply of air in another boat must be immediately brought up and connected to the manifold. Under these conditions the duration of air supply from one air flask is calculated as follows:

C=Capacity of one air flask in cubic feet.
A=Atmospheres excess pressure in air flask.
D=Number of divers.
E=Number of atmospheres excess pressure to which dive is made.

Allowing 1 air flask atmosphere for charging testing tank, air hose, and helmet to E; 4.5 cubic feet to each diver per minute measured at absolute pressure, or E+1 atmospheres; and reserve pressure of 220 pounds per square inch or about 15 atmospheres to remain in the air flask in excess of that in which the divers are working while on bottom or E, the calculation of time of air supply is as follows:

$$\frac{C\,(A-(15+E+1))}{4.5\,D\,(E+1)} \text{ equals duration of supply in minutes.}$$

Problem: One diver is to descend to 165 feet under water. How long will the air in one 11-cubic-foot air flask charged to 2,250 pounds per square inch last him?

$C=11.$

$A=\frac{2250}{14.7}$ or 153.

$E=\frac{165}{33}$ or 5.

$D=1.$

$\frac{11\times(153-(15+5+1))}{4.5\times1\times(5+1)}$ equals 53 minutes.

Thus it will be seen from the foregoing that, with a small sized flask using a maximum air supply, one diver can make a lengthy dive at 165 feet depth and still have sufficient air for a proper decompression. With three such air flasks in the boat one diver may remain 106 minutes on the bottom, or two divers 53 minutes, with a maximum air supply. With larger flasks, or with additional flasks, the time may be further extended.

AIR SUPPLY FROM LOW-PRESSURE ACCUMULATORS.

The method of supplying air to divers from low-pressure accumulators is applicable to vessels equipped with gas-ejector system, diving vessels specially equipped, navy yards, etc. In this method the arrangement is practically the same as for diving with air from high-pressure accumulators. The air pressure in the accumulators is maintained steadily by large capacity low pressure, steam, or electrically driven, automatically controlled air compressors. The capacity of the compressors is such that there is never a question of shortage of air supply, the maximum depths to which the divers will be able to descend will depend upon the pressure of the air. There is no accurate method of determining the exact amount of air passing through the diver's helmet in this method of diving and the only means of knowing whether adequate ventilation is being maintained is by the diver's physical well being, and the percentage of CO_2 in the air of the helmet.

When utilizing air from air accumulators or air flasks the following conditions are essential:

(*a*) The temperature of air must be such as not to cause discomfort to the diver.

(*b*) The air in the accumulator must be free from noxious fumes and as near standard purity as possible, i. e., contains as near 0.04 per cent CO_2 as practicable. In utilizing air from high-pressure accumulators it must be remembered that the air in the cylinders of the compressors is greatly heated in charging the accumulators, and oil with a high flash point must be used, castor oil if possible, so that no flashing in the cylinders will take place, producing CO and CO_2. As little oil as practicable should be used in the cliynders of a diving pump.

(*c*) Thirty to 50 pounds pressure per square inch in the testing tank above water pressure (at the depth of dive) must be maintained to insure proper ventilation of the helmet.

(*d*) The reserve air supply must always be maintained in case of accident to compressors, etc., to insure a proper stage decompression for the diver.

AIR SUPPLY FROM MANUALLY OPERATED DIVING AIR PUMPS.

In utilizing manually operated diving air pumps to furnish air for divers it is evident that the delivery of the amount of air required by a diver at various depths of submergence under water depends upon the capacities of the pumps, the number in use, and the rate of pumping.

As the capacities of the various types of two-cylinder, double-acting diving air pumps are small (see Chapters V and VI for details), and as the rate of pumping, due to the work required to operate them, may be varied only within small limits, which become less and less as the pressure of air increases, it is readily apparent that, with only one diving pump to furnish air, the depth under water to which a diver may descend and perform useful work is limited to shallow depths. If the pump so used is not efficient the possible depth of dive will be further restricted.

When it is required to dive to a certain depth, and it is not possible to furnish the requisite volume of air for that depth with a single diving pump, two or more pumps must be connected together and operated at the proper rate of speed.

Assuming a diving air pump to be 100 per cent efficient at all pressures, the rate of pumping or the number of revolutions per minute the pump should be run to furnish the minimum allowable air supply to one diver (1.5 cubic feet of air per minute, measured at the absolute pressure to which the dive is made) may be determined as follows:

When

D=Depth of sea water, in feet, to which dive is made.

N=Number of cubic inches of air the pump will furnish per revolution, measured at atmospheric pressure.

R=Number of revolutions required of pump per minute to furnish 1.5 cubic feet (2,592 cubic inches) of air per minute, measured at atmospheric pressure.

X=Number of revolutions required of pump per minute to furnish minimum allowable air supply (1.5 cubic feet, or 2,592 cubic inches, per minute) at D.

$$\frac{2592}{N}=R$$

$$R(1+D(0.0303))=X.$$

If the efficiency of a diving air pump is less than 100 per cent, and its actual per cent efficiency, at the equivalent absolute pressure at D, is represented by a symbol, as E,

Then

$$\frac{100R(1+D(0.0303))}{E}=X$$

As the value of N for the various types of two-cylinder double-acting diving air pumps, previously referred to when 100 per cent efficient, is 277.7 cubic inches, 296.3 cubic inches, and 405 cubic inches, as specified in Chapter VI;

Then R must equal 9.33, 8.75, and 6.4 revolutions, respectively.

Multiplying these respective values by the coefficient 0.0303 and the following results are obtained:

0.283, 0.265, and 0.194.

Hence, to determine the number of revolutions per minute it is necessary to run any of these pumps to furnish the minimum allowable air supply (1.5 cubic feet per minute) for one diver at any depth, proceed as follows:

Diving air pump, Mark I.—Divide 100 per cent by the actual per cent efficiency of the pump at the equivalent pressure to which the dive is made, and multiply the quotient thus obtained by the sum of the product of the number of feet depth of sea water and the constant 0.283, added to 9.33 (number of revolutions required to deliver 1.5 cubic feet of air at atmospheric pressure).

Diving air pumps, Mark I, Mod. 1; Mark I, Mod. 2; Mark II; Mark II, Mod. 1.—Divide 100 per cent by the actual per cent efficiency of the pump at the equivalent pressure to which the dive is made, and multiply the quotient thus obtained by the sum of the product of the number of feet depth of sea water and the constant 0.265, added to 8.75 (number of revolutions required to deliver 1.5 cubic feet of air at atmospheric pressure).

Diving air pump, Mark III.—Divide 100 per cent by the actual per cent of efficiency of the pump at the equivalent pressure to which the dive is made, and multiply the quotient thus obtained by the sum of the product of the number of feet depth of sea water and the constant 0.194, added to 6.4 (number of revolutions required to deliver 1.5 cubic feet of air at atmospheric pressure).

As per example: Diving air pump, Mark III, 80 per cent efficient; depth of sea water, 66 feet. How many revolutions per minute should the pump be run to furnish the minimum allowable air supply (1.5 cubic feet of air per minute), to a diver working at that depth?

$$(100 \div 80) \times \overline{(66 \times 0.194} + 6.4) = 24 \text{ revolutions per minute.}$$

The maximum rate of pumping it is possible to maintain by a pumping crew over a practical period of time is about 30 revolutions per minute, and as the depth or equivalent pressure increases this becomes less and less. Therefore, if the revolutions required are in excess of the number it is possible to maintain, the work should be divided between two or more pumps, as per example:

Diving air pumps, Mark III, each 80 per cent efficient: depth of sea water, 168 feet. How arrange for supplying requisite amount of air to one diver working at that depth?

$$(100 \div 80) \times \overline{(168 \times 0.194 + 6.4)} = 48.7,$$

or, practically 49 revolutions per minute to furnish 1.5 cubic feet of air to one diver with one pump, or 24.5 revolutions per minute with two pumps.

When utilizing manually operated diving air pumps to furnish air for divers, the following conditions shall be observed:

(*a*) Arrangements shall be made to furnish at least the minimum allowable air supply (1.5 cubic feet per minute, measured at the absolute pressure to which the dive is to be made) to each diver, and if practicable, a reserve air supply.

(*b*) Arrangements shall be made to insure the dispatch of a relief diver.

(*c*) Except in shallow depths and where there is no danger of the divers becoming foul of obstructions on the bottom, more than one diver shall not be permitted to dive with air from the same diving air pumps or group of diving air pumps.

(*d*) The rate of pumping shall be regular.

(*e*) If the air being supplied to a diver is uncomfortably warm, cold water shall be placed in the water cisterns of diving air pumps, and kept cold by the addition of ice, if necessary.

(*f*) The directions for lubricating diving air pumps (see Chapter VI) shall be carefully carried out.

CHAPTER IV

CAISSON DISEASE AND EFFECTS OF OXYGEN PRESSURES.

Caisson disease or compressed air illness is a disease from which divers and other workers in compressed air frequently suffer, as a result of improper decompression; i. e., in the case of divers it is due to ascending too rapidly to the surface. The disease has many symptoms; at times manifesting itself with attacks of dyspnea and unconsciousness, which may result in death in a few minutes or hours, at times with paralysis of the motor and sensory nervous systems, involving, as a rule, the inferior extremities and bladder. Mild attacks are much more frequent, consisting of pain in the extremities and various parts of the body, vertigo, etc. The disease rarely occurs unless the pressure has exceeded 20 pounds excess pressure (45 feet of sea water). The greater the pressure and length of exposure, the more frequent and severe will attacks of the disease result unless proper decompression has been resorted to.

The accepted theory as to the cause of caisson disease is that bubbles of nitrogen are liberated in the various tissues of the body, including the blood, upon a decrease of pressure. The blood in the lungs being in contact with alveolar air takes up nitrogen in physical solution. The circulation time of the blood is about one minute, hence the entire blood will be saturated for the partial pressure of nitrogen in one minute.

If the blood were the only tissue of the body to be considered, it is evident that saturation and desaturation would take place in one minute.

Such is not the case, however. The nitrogen in solution is given off by the blood to the various tissues of the body, and these, absorbing nitrogen, finally become saturated for that pressure. It has been estimated that one-half saturation of the body takes place in man in about one hour and total saturation in about four hours; with hard work in half this time.

With a sudden decreased pressure (high) to normal it is evident that the nitrogen in solution will at the low pressure be immediately liberated and, as in the soda-water bottle, form bubbles. Such is the case with the diver, but the bubbles are formed much more slowly, and they may take some hours to increase in size necessary to cause symptoms.

Nitrogen is five times more soluble in fats than in the other tissues of the body, and it is given off more slowly from the fatty tissues. This accounts for the spinal cord lesions, and lesions in the epiphysis of the bones, causing pains, referable to joints in caisson disease, and also for fat men being more disposed to the disease than others.

Desaturation takes place at about the same rate as saturation, hence, if it takes a man four hours to saturate for a given pressure it will take *at least* four hours for him to desaturate.

It has been found that a man can become saturated with nitrogen at one atmosphere excess pressure and then have the pressure immediately reduced to normal without any ill effects. In fact, a little higher pressure and immediate decompression to atmospheric pressure can be withstood with comparative safety; i. e., saturation at 2.3 atmospheres absolute pressure or a ratio of 2.3 to 1. Under these conditions the bubbles of nitrogen liberated are so small as to pass through the finest capillaries without damage or danger to the diver's well-being. On the foregoing theory a series of tables have been constructed, based on what is known as stage decompression (in contrast to slow or uniform decompression); that is, a change of absolute pressure to a pressure, so that absolute pressure will be to this reduced absolute pressure as 2:1, or 2.3:1.

Example: A diver working at a depth of 165 feet under water, or 5 atmospheres excess pressure, or 6 atmospheres absolute. According to the theory, absolute pressure could be diminished to 2.6 atmospheres; i. e., 6 : 2.6 :: 2.3 : 1. As we have the atmosphere exerting 1 atmosphere pressure, the diver can be safely brought up to an excess pressure of 1.6 atmospheres, a depth from the surface of 53 feet; the diver coming quickly from deep dangerous pressures to a comparatively shallow depth, and with various additional stops, at every 10 feet, to the surface. The time at each stop being such that the proportion of the relative pressure of the nitrogen in solution in the body and the combined pressure of all the gases in the alveoli (total absolute air pressure) shall never be greater than 2.3:1.

It has been determined that decompression in this manner is far more safe after short exposures than a gradual decompression; i. e., going slowly to a low pressure. With uniform decompression the diver, instead of desaturating, continues to saturate with nitrogen at the higher pressures.

The tables have been tested and proved safe, and have shown that, while they will not always prevent a slight or moderate attack of the bends, a diver decompressed according to them will be saved from any serious attack of caisson disease. These tables shall be strictly followed in all diving operations. (See Chapter X for tables.)

The tables consume a large part of the time in shallow water. As there is one increase in volume of gas from 33 feet to the surface, it is evident that these protracted stays in shallow water are most essential, as the danger point of large bubble formation is doubled.

It is evident that if a diver saturates and desaturates at the same rate, decompression must be in proportion to the compression and length of exposure to high pressure. Hence, in deep diving it is to the diver's advantage to descend as quickly as possible, limit his stay to as short a time as possible, and then hurry up to his first stage of decompression. Naval divers have taken a test pressure equal to 212 feet in 40 seconds, and in actual diving have descended 250 feet in 2 minutes.

In diving tests, previous to the preparation of this manual, the decompression tables as recommended were followed and in deeper depths tables on the same theory for the increased depths were utilized. No serious attack of caisson disease was experienced when the decompression was in accordance with the tables.

Under the usual conditions, decompression can not be hurried with safety. Muscular exercise increases circulation and hurries desaturation. This is necessary, and is taken into account in the construction of the tables.

By decreasing the partial nitrogen pressure in the diver's helmet and by supplying oxygen to the diver, desaturation can be greatly hastened. This can be used very advantageously in shallow depths. It must be remembered, however, that moderate oxygen pressures are dangerous, and, if they become high, will cause death quickly from oxygen poisoning. Two hundred per cent oxygen pressure is risky, increasing with length of exposure, and 300 per cent is extremely dangerous for any length of stay, however short. (See "Effects of oxygen pressures.") See page 26.

SYMPTOMS.

Symptoms of caisson disease usually come on a few minutes after decompression; as a rule, in the first hour. Cases have, however, been known to be delayed as long as 15 hours before the onset.

As caisson disease is the result of liberation of nitrogen bubbles in the various tissues of the body, it is evident that symptoms will depend on the amount of gas liberated, and the places of lodgement, pressure, length of exposure, time, and manner of decompression being the contributing factors.

The formation of gas bubbles in the tendons, fascia, bone, muscles, and nerve endings account for the mild symptoms, as pain in the muscles, bones, joints, etc. Vertigo and Meniere's symptoms complex, i. e., deafness, vertigo, and vomiting, depending on the liberation of gas in the labyrinth; embolism and formation of gas in the spinal cord account for the paralegias and their concomitant picture. Emboli of the cerebral vessels account for the monoplegias, hemiplegias, aphasias, sensory paralytic symptoms, etc. Large amounts of gas in the various tissues accounting for the prostration, etc.

In the analysis of over 3,500 cases of caisson disease the following classification was made:

	Per cent.
1. Cases showing pain in the various parts of the body	88.78
2. Cases with pain, also having local manifestations	.26
3. Cases with pain and prostration	1.26
4. Cases showing symptoms referable to the central nervous system:	
(1) Brain	.11
(2) Spinal cord—	
(a) Sensory disturbances; (b) Motor disturbances; Sensory and motor disturbances	2.16
5. Cases showing vertigo (staggers)	5.33
6. Cases showing dyspnea and sense of constriction in the chest	1.62
7. Cases showing partial or complete unconsciousness	.46

The fatal cases, of which there were 20 in number, occurred in those cases showing symptoms under 3, 4, and 7.

Pain in the abdomen, vomiting, subcutaneous hemorrhage, and girdle pains in the trunk are considered dangerous symptoms.

From experience with Navy divers there seems to be no definite rule as to what symptoms will appear. In the deep-diving work, previously undertaken, stage decompression, with a liberal time allowance utilized, the following cases were encountered:

CASE I.—Pressure, 110 pounds gauge. Time of exposure, 25 minutes. Decompressed in 2 hours. Onset of symptoms before completion of decompression.

Appearance of a burning dematitis over entire body reaching its maximum about 1 hour after pressure normal. Joint pains, slight in elbows, shoulder, and knees, 4 hours after. No recompression.

Joint pain wore off in 3 days. Erythema faded in 24 hours, but minute brownish areas over entire skin surface persist after 6 months.

CASE II.—Pressure, 110 pounds gauge. Time of exposure, 25 minutes. Decompressed in 2 hours. Onset of symptoms before pressure normal. Burning erythema over entire body surface increasing after pressure normal, when large areas of subcutaneous ecchymosis appeared. Joint pains slight in knees and elbows about 2 hours after pressure normal, marked weakness and prostration, severe pains in back. No recompression used. Pains wore off at end of 48 hours. All erythema and hemorrhagic areas faded in 2 weeks.

CASE III.—Pressure, 110 gauge. Exposure average 25 minutes. Decompression, 2 hours. Symptoms appeared before pressure normal. Burning erythema over body not as marked as in cases I and II. Erythema at maximum 1 hour after pressure normal. Ten minutes after pressure normal, pains in ankles and knees with muscular cramps in legs. No recompression. All symptoms disappeared in a few hours excepting erythema, which disappeared in a week.

NOTE.—Decompression time in these three cases not regular, and last stages very short.

CASE IV.—Pressure, 136 pounds. Time exposure, 20 minutes. Stage decompression in 2 hours.

Five minutes after pressure normal, pains in joints, elbow, and wrists. Recompressed to 17 pounds and decompressed in 32 minutes. Symptoms entirely disappeared. Joint pains recurred 5 hours after, very severe. Recompressed to 30 pounds and decompressed in 3 hours. No recurrence of symptoms.

CASE V.—Pressure, 120 pounds. Maximum, 136 pounds. Exposure average, 3½ hours. Decompressed in irregular stages, three stops, 40 minutes.

Symptoms.—Patient unconscious and moribund 2 minutes after reaching surface. Recompressed to 75 pounds in 5 minutes. Complete recovery at this pressure. Decompressed to 20 pounds in 1 hour by stage decompression. Joint pains and vomiting. Pressure increased to 37 pounds. Decompressed in 7 hours.

Severe joint pains persist. Symptoms increased in severity. Pain and prostration extreme. Large areas of ecchimosis developed in 2 hours over entire body. Pulse barely palpable at wrist. Patient conscious, no paralysis, marked tympanites present. Condition critical for 2 days, when reaction took place. Broncho pneumonia and a pyelitis present. All pain and hemorrhage areas disappeared in 10 days. Patient made a complete recovery at end of 2 months.

CASE VI.—Pressure, 120 pounds. Exposure, 30 minutes. Decompressed in 2 hours. One hour and 10 minutes after decompression seized with dizziness, nausea, and vomiting, heart action irregular, no joint pains and no paralysis.

Recompressed at once to 25 pounds and decompressed in 2 hours.

Gastric derangement and irregular heart action for 3 days, when recovery complete.

CASE VII.—Pressure, 120 pounds. Exposure, 40 minutes. Decompressed stage, 2 hours and 30 minutes. Weakness in arms and hands on reaching surface. Recompressed in 5 minutes to 25 pounds and decompressed in 1 hour and 25 minutes. Two hours later, vomiting and vertigo, followed several hours later with gastric distension. No further recompression. All symptoms disappeared in 3 days.

PROGNOSIS.

With immediate recompression, and a gradual decompression, properly conducted, even in severe cases, the outcome is, as a rule, complete recovery. Without decompression, the number of recoveries is remarkable, even in a very short while for the low pressures, up to 50 pounds. Insufficient data is available on extreme pressures.

TREATMENT.

In all cases of deep diving operations a compression chamber of some sort is essential, as there is no efficient means of treating caisson disease without one. Immediate recompression usually alleviates all symptoms. If several hours have elapsed after the onset of the attack, although it may help, it is not as effective as immediate recompression at the onset of symptoms. A submarine boat fitted with a diving compartment may be used to advantage for this purpose. In case a recompression chamber is not obtainable, the only recourse left to the officer in charge is to cause the diver to be recompressed as quickly as possible by sending him down again to at least half the absolute pressure at which he had been working.

A small portable recompression chamber is available at the diving school, and may be borrowed to use when required. Additional recompression chambers are to be constructed and retained at various stations for use in connection with deep-diving operations.

If recompression, with a proper decompression, does not result in recovery, the case resolves itself into treating conditions that arise.

EFFECTS OF OXYGEN PRESSURE.

In experiments on the cause of death of animals inclosed in a small space, it has been found that:

(*a*) At pressures inferior to one atmosphere, when the CO_2 is absorbed by potassium hydrate, sparrows live until the partial pressure of oxygen sinks to 3.6 per cent of an atmosphere.

(*b*) In air compressed from 2 to 9 atmospheres and superoxygenated to prevent want of oxygen, they die when the pressure of CO_2 equals 25 per cent of an atmosphere.

(*c*) In higher pressures, death is caused by the pressure of oxygen and rapidly when this equals 300 to 400 per cent.

(*d*) In pressures of 1 to 2 atmospheres death is due partly to fall of oxygen pressure and partly to increase of CO_2.

(*e*) In pressures of 3 to 4 atmospheres of air the poisonous effects of oxygen begin to appear after long exposures.

Air composed of 20 per cent oxygen exerts one-fifth of an atmosphere oxygen pressure. At 10 atmospheres pressure, the oxygen being one-fifth, would exert 2 atmospheres of oxygen pressure. Hence, 2, 3, 4 atmospheres of oxygen pressure would equal 10, 15, and 20 atmospheres of air.

Exposure of animals to a pressure of 170 to 180 per cent of an atmosphere of oxygen caused, in a short time, diminution in the power of the lungs to absorb oxygen. The tissues of the lungs showed intense congestion and an exudate into the alveolar.

High partial pressure of oxygen produces a marked irritant effect on the lungs, producing, first, congestion and, shortly afterwards, hemorrhagic exudation and consolidation, i. e., a typical pneumonia. The pneumonia is patchy, if quickly developed, and general, if slowly developed.

It requires about 24 hours' exposure to plus 7 atmospheres of air or 168 per cent atmospheres of oxygen to produce marked symptoms of pulmonary congestion.

Experiments on monkeys showed no lung troubles in sequent exposures every day for four or five hours at a time at this pressure.

With exposures to oxygen pressure of 300 to 400 per cent, symptoms of oxygen poisoning quickly intervened and, in addition to the lung irritation, convulsions tetanic in character are likely to occur.

In most types of self-contained diving and submarine escape apparatus, oxygen is used in addition to air. It is evident from the above that their construction and use will depend on the foregoing.

The simplest type of self-contained apparatus is the usual oxygen-rescue apparatus. These are constructed for work in one atmosphere and the question of oxygen poisoning does not enter. The question of deficient oxygen pressure and excess of CO_2 does enter.

This apparatus is constructed so that oxygen is supplied from a small high-pressure accumulator, usually at the rate of about 2 liters per minute. The apparatus is so constructed that air expired is forced through a chamber or cartridge containing caustic soda, which removes most of the CO_2. A small canvas or rubber sack acts as a low-pressure accumulator and the air is rebreathed, but oxygen is constantly being supplied at the rate of 2 liters per minute, the high-pressure accumulator holding from one-half to one hour's supply of oxygen, according to the type and design. With failure of the oxygen supply in this type of apparatus it is evident that as the oxygen is converted to CO_2 and this is removed, the partial pressure of oxygen is diminished. When this occurs men often become unconscious in these apparatus before they realize that anything is wrong.

It has been found that in the use of these apparatus that more than 2 liters of oxygen per minute are utilized in hard work. While a man may sit down and move around slowly in the apparatus, when it comes to doing moderately hard work his oxygen supply is entirely too little, and unless he remains quiet at intervals he will become unconscious and be in danger of losing his life.

In the construction of oxygen-rescue apparatus, for work in fire fighting, it has been found that it was necessary to supply 3 liters of oxygen per minute to permit men to climb a ladder.

CHAPTER V.

DETAILED DESCRIPTION OF DIVING APPARATUS.

DIVING OUTFITS.

Outfits of diving apparatus, as furnished to different classes of vessels, are designated as diving outfits, Nos. 1, 2, and 3. Diving outfits No. 1, are supplied to vessels of the first and second rates; diving outfits, No. 2, are issued to vessels of the destroyer class; and diving outfits, No. 3, are intended for use on submarines.

Diving outfits, No. 1, are complete in every respect, with an adequate allowance of spare parts, consist of a two-cylinder, double-acting diving air pump, and necessary equipment for two divers. Two No. 1 outfits are furnished to each large vessel, and one to each of the smaller vessels, to which diving apparatus is allowed.

Diving outfits, No. 2, are practically the same as diving outfits, No. 1, except that the diving air pump, its spare parts and accessories, are eliminated.

Diving outfits, No. 3, are small outfits, for one diver only, specially assembled and arranged for the limited stowage spaces available on board submarines.

For special purposes the foregoing allowances are sometimes varied, and special outfits are provided as circumstances may require.

The component parts of diving outfits, Nos. 1, 2, and 3, together with their correct nomenclature, are as listed in the following table:

No.	Article.	Unit.	Amounts.		
			No. 1.	No. 2.	No. 3.
1	Belts, weighted	Number	2	2	1
2	Boxes, tin, for spare parts	...do	2	1	......
3	Boxes, tin, containing spare leathers in oil, complete for 1 piston	...do	1	......	......
4	Cans, oil, feeding, ½-pint	...do	1	......	......
5	Cement, rubber, 2-pound tins	...do	1	1	......
6	Chests, helmet	...do	1	1	1
7	Chests, outfit	...do	3	2	1
8	Clamps, air hose, spare	...do	6	6	......
9	Couplings, air hose, female	...do	2	1	......
10	Couplings, air hose, male	...do	2	1	......
11	Cloth, rubber, repair	Yard	1	1	......
12	Cushions, helmet	Number	2	2	1
13	Drawers, under, woolen	...do	6	4	2
14	Dresses, diving, No. 1	...do	1	1	......
15	Dresses, diving, No. 2	...do	1	1	1
16	Dresses, diving, No. 3	...do	1	......	......

No.	Article.	Unit.	Amounts.		
			No. 1.	No. 2.	No. 3.
17	Expanders, cuff	Number	4	4	2
18	Face plates, complete, spare	do	1	1	......
19	Gaskets, cylinder head, spare	do	2	......	......
20	Gaskets, face plate, spare	do	2	2	1
21	Gaskets, helmet, spare	do	2	2	1
22	Gauges, pressure, indicating, spare	do	1	1	......
23	Glasses, helmet window, spare	do	1	1	......
24	Gloves, rubber, diving	Pair	4	2	1
25	Gloves, woolen	do	4	2	1
26	Handles, pump wheel, No. 1	Number	2	......	......
27	Handles, pump wheel, No. 2	do	2	......	......
28	Helmets, diving, complete	do	2	2	1
29	Hose, air, 50-foot lengths	do	8	6	4
30	Hose, air, 3-foot lengths	do	4	4	1
31	Jackets, under	do	2	2	1
32	Joints, union, air hose, double female	do	2	2	1
33	Joints, union, air hose, double male	do	2	2	1
34	Joints, union, telephone cable, double male	do	1	1	......
35	Knives, diving	do	2	2	1
36	Knives, diving, cases for, with fittings for attaching to weighted belt	do	2	2	1
37	Ladders, iron, galvanized, diving	do	1	......	......
38	Ladders, Jacob, diving, 10-foot sections	do	5	......	......
39	Lines, descending	do	1	1	......
40	Lines, distance	do	1	1	......
41	Manifolds	do	1	1	......
42	Nozzles, overflow	do	1	......	......
43	Nuts, pump handle, spare	do	1	......	......
44	Nuts, pump wheel, spare	do	1	......	......
45	Nuts, wing, breastplate, large, spare	do	4	4	2
46	Nuts, wing, breastplate, small, spare	do	6	6	4
47	Packing, piston rod, spare	Pound	1	......	......
48	Protecting caps, crank shaft	Number	2	......	......
49	Pumps, air, diving, complete	do	1	......	......
50	Punches, cutting, for collars of diving dresses	do	1	1	......
51	Reducers, type B	do	2	2	......
52	Reducers, type S	do	2	......	1
53	Rings, wrist, rubber	do	36	24	12
54	Screw drivers, 6-inch	do	1	1	1
55	Screw drivers, 10-inch	do	1	......	......
56	Separators, oil, for diving pump	do	2	......	......
57	Separators, oil, filters for, spare	do	12	......	......
58	Separators, oil, gaskets, for, spare	do	6	......	......
59	Separators, oil, washers for, spare	do	6	......	......
60	Shirts, under, woolen	do	6	4	2
61	Shoes, weighted, diving	Pair	2	2	1
62	Socks, woolen	do	6	4	2
63	Studs, breastplate, spare	Number	6	6	......
64	Tanks, testing, 1 cubic foot, complete	do	1	1	......
65	Tape, rubber, insulating	Pound	3	2	1
66	Telephone outfits, complete	Number	2	2	1
67	Tools, assembling, piston	do	1	......	......
68	Trousers, overall, with adjustable straps	do	2	2	1
69	Tubing, rubber, elastic, 3-foot lengths	do	2	2	......
70	Turnbuckles, securing pump	do	4	......	......
71	Valves, air control	do	3	3	1
72	Valves, outlet, helmet, valves and springs for, spare	Set	1	1	......
73	Valves, pump, complete, complete with springs, leathers and pins, spare.	Number	4	......	......
74	Valves, safety, helmet, complete, spare	do	2	2	1
75	Urinals, rubber	do	2	2	1
76	Washers, leather, air hose, spare	do	24	18	12
77	Washers, pump valve body, spare	do	3	......	......
78	Washers, safety valve, spare	do	6	6	3
79	Weights, cast iron, 25-pound	do	4	......	......
80	Weights, cast iron, 50-pound	do	1	1	......
81	Weights, cast iron, 100-pound	do	1	......	......
82	Wheels, pump, 150-pound	do	2	......	......
83	Wrenches, monkey, 6-inch	do	1	......	......
84	Wrenches, monkey, 12-inch	do	1	......	......
85	Wrenches, spanner, air-hose coupling	do	2	2	2
86	Wrenches, spanner, pump	do	1	......	......
87	Wrenches, spanner, safety valve	do	1	1	1
88	Wrenches, T, helmet	do	2	2	1

WEIGHTED BELTS.

(Plates A and I.)

The latest pattern of weighted belt for diving apparatus is shown in the illustration, Plate A.

The lead weights are so fitted that they can be easily removed or replaced as occasion may require. As indicated, metal strap hangers are cast in four of the weights; the two center ones being set at the proper angles to give the proper leads to the shoulder straps, which pass over the breast plate of the helmet and are crossed in back of the diver (See Pl. I) so as to counteract any tendency the belt may have to shift its position round the diver's waist.

The jock strap is provided for the double purpose of holding the belt down where it is wanted, and of preventing the helmet from rising over the diver's head when the dress is over inflated.

The addition of the jock strap overcomes the hitherto serious objection to the belt form of diving weight, i. e., the difficulty formerly experienced on account of it changing its position, as for instance, when the diver happened to be working with head down, the old pattern belt would have a tendency to slip from around the diver's waist to a position under the arm pits, thus his balance would be interfered with, and it would be difficult for him to regain an erect position, or, in other words, the diver would be made top heavy by the shifting weight.

The jock strap is easily made and fitted to old pattern belts, and the precaution is recommended.

The improved standard diving belt weight has been tested and found preferable to any other pattern of diving weight. In comparison to the plain lead diving weights (horseshoe or heart shaped pattern), the improved weighted belt is more comfortable to the diver, is capable of adjustment, and gives the diver a better balance.

HELMET CUSHIONS.

(Pl. IV, fig. 4.)

The helmet cushion, Plate IV, figure 4, as its name implies, is a cushion for the helmet to rest on, and protects the diver's shoulders from the weight of the helmet and attached parts when he is out of the water; the extra weight he has then to support being over 100 pounds. The cushion is made of tan colored drill, padded with a layer of best quality hair felt, 1 inch in thickness. It is worn round the neck, and inside the diving dress.

WOOLENS.

(Pl. V.)

Woolen shirts, drawers, and socks are provided with the diving gear to be worn when diving work is required in cold water; they are

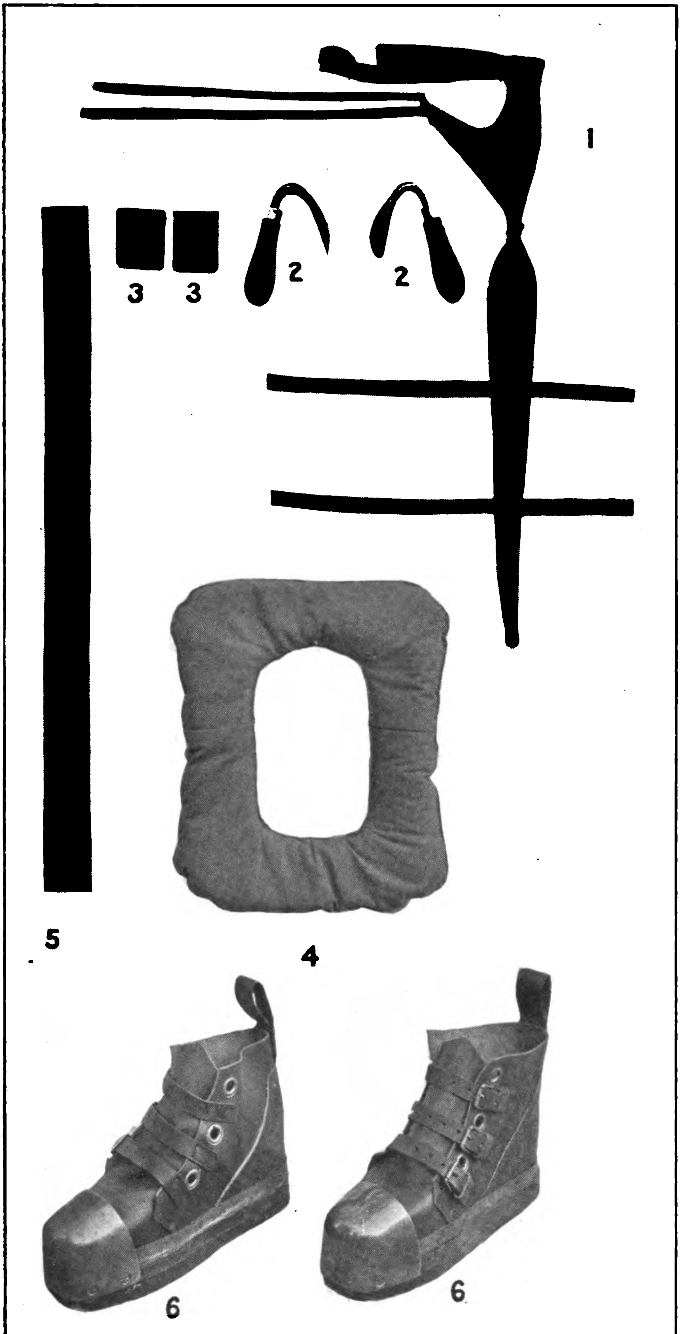
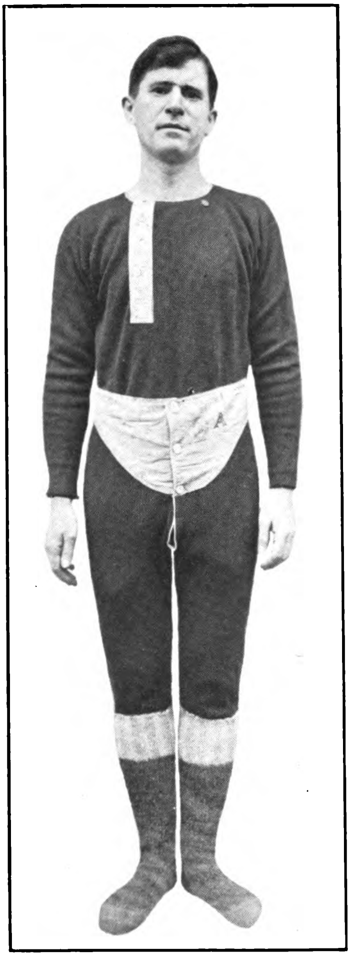
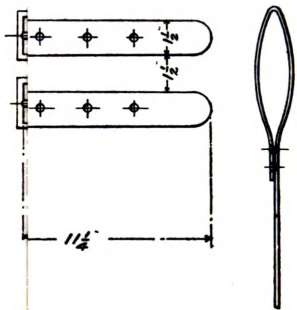


FIG. 1.—RUBBER URINAL.
FIG. 2, 2—CUFF EXPANDERS.
FIG. 3, 3.—RUBBER WRIST RINGS.
FIG. 4.—HELMET CUSHION
FIG. 5.—RUBBER TUBING.
FIG. 6, 6.—DIVING SHOES.

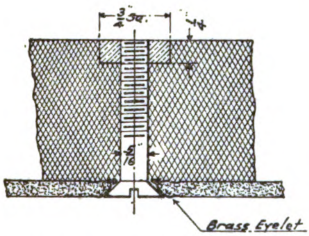
PLATE V.



DIVER PARTLY DRESSED, SHOWING UNDERWEAR.



Jock strap showing loop



Method of securing Lead Weight to Belt
Scale: Full size

for Diving Apparatus

Scale: 3" & 12" = One Foot

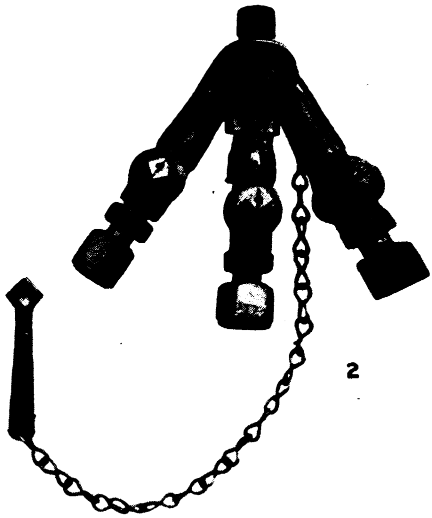
56061

53054—16

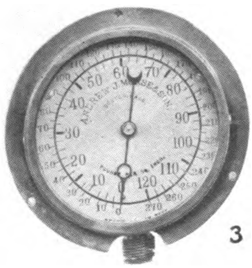
DIVING DRESS. STANDARD PATTERN.

PLATE VII.

1



2



3

4

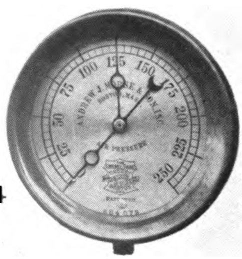
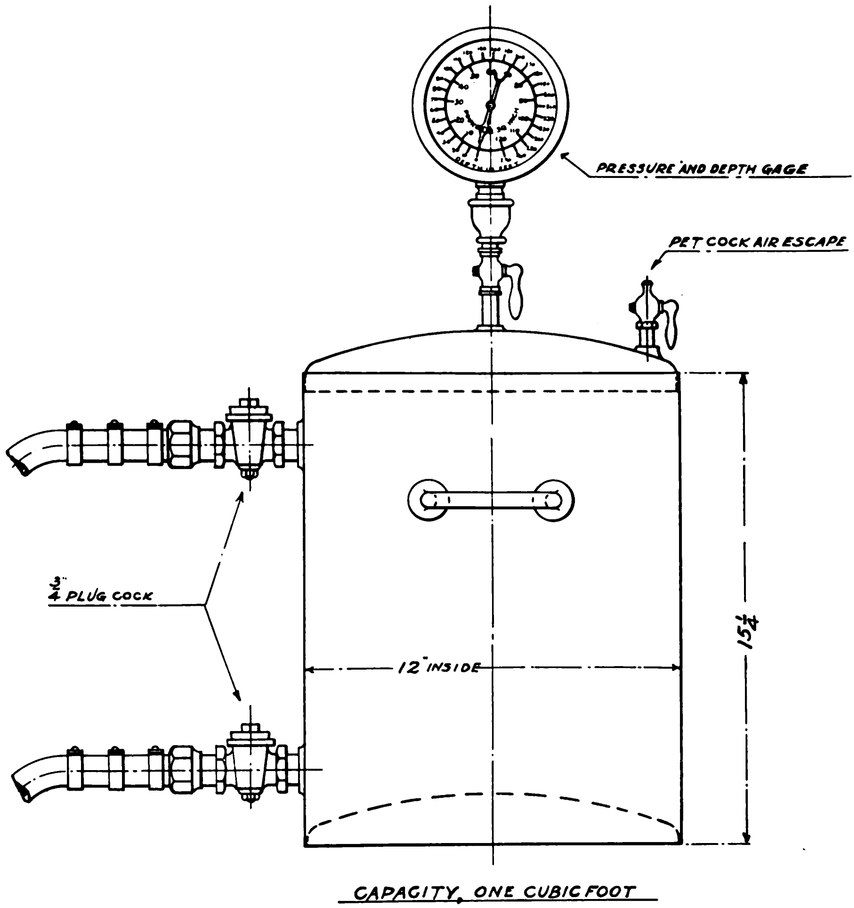


FIG. I.—AIR-CONTROL VALVE.
FIG. 2.—DIVING MANIFOLD.
FIG. 3.—PRESSURE AND DEPTH GAUGE.
FIG. 4.—PRESSURE GAUGE ON TEST TANK.

PLATE B.



TESTING TANK FOR DIVING APPARATUS.

usually worn over the diver's ordinary clothing. Woolen gloves are also supplied to protect the hands from cold, and are inside the rubber diving gloves. The shirts, drawers, and socks are of the grade known to the commercial trade as "Contacook" AA; the gloves are of a grade similar to Navy uniform pattern, but of a different color.

All colors are dyed fast, and the woolens will stand washing under ordinary conditions.

DIVING DRESSES.

(Pl. VI.)

Diving dresses are furnished to fit diving helmets, Mark I, II, III, IV, or V, and in sizes No. 1 or small size, No. 2 or medium size, or No. 3 or large size, as may be called for upon requisitions.

For the different types of helmets, the design varies only in regard to the size and shape of the rubber collars, and the differences are so slight as to be apparent only upon close observation or when trying to fit a diving dress to the wrong helmet.

The general design and construction of the improved diving dress is shown in the illustration, Plate VI.

The dresses are made of the best quality White American diving dress fabric, vulcanized, and reinforced at the points of wear by chafing patches of the same material cemented in place. A rubber collar, for attaching to the breast plate, is sewn and cemented to the upper edge of the dress, and elastic rubber cuffs, for making a water-tight joint at the wrists, are cemented to the ends of the diving dress sleeves.

Flaps, with lacings, are fitted for lacing up the legs so as to prevent an accumulation of air in the lower extremities of the dress when the diver may be working in an awkward position, as with head down, thus, this provision tends to lessen the danger of accidental "blowing up," and the risks incident to capsizing.

CUFF EXPANDERS.

(Pl. IV, fig. 2, page 30.)

The cuff expanders, as shown in the illustration, Plate IV, figure 2, are made of gun metal, with wooden handles, and are for use in opening the cuffs of the diving dresses, without injuring the latter; when dressing and undressing the diver.

PRESSURE GAUGES.

(Pls. VII and B.)

The style of pressure-indicating gauge, shown as figure 3, Plate XVIII, is installed on manually operated diving air pumps, and, when the pumps are in operation, records both the pressure of air being delivered and the corresponding depth of water.

The gauge shown in figure 4, is used in connection with the test tank, Plate B.

TEST TANK.

(Pl. B, page 31.)

The test tank is used for proving the efficiency of diving air pumps, and as an expansion tank or low pressure receiver when diving with compressed air. It is made of steel, tested to 600 pounds pressure per square inch, fitted with air inlet and outlet connections, pressure gauge, safety nonreturn valve, pet cock, and transportation handles.

UNDERJACKET.

(Pl. VIII.)

The under jacket is primarily intended for use as a means for keeping the rubber diving gloves in place on the diver's hands, but it is also useful as a protection against cold when worn over the woolen shirt provided; being of more closely woven material than the woolens it excludes the cold and confines the heat produced by the diver's body. The jacket is fitted with lacings to make it fit different sized men, but should the adjustable feature be not sufficient for the purpose, it can readily be altered or made to fit by the ship's tailor.

RUBBER DIVING GLOVES.

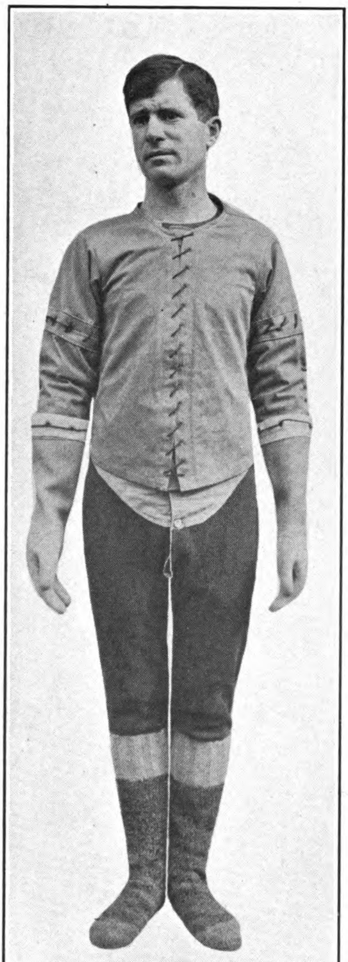
(Pl. VIII.)

The rubber diving gloves are made to be worn under the cuffs of the diving dress, and attached to the sleeves of the under jacket by lacings as indicated in the illustration. While being worn under water, should they become distended by air, it is merely necessary for the diver to lower his hands in the water when the water pressure will force the air back up the sleeve of the dress and out of the gloves.

In the case of divers having large wrists, the cuffs of the diving dress sometimes fits too tightly and interferes with circulation of blood to the hands; the remedy would be to cut a little off the ends of the rubber cuffs until the joints are made comfortable. When the dress would be again required for use without the rubber gloves, it would, of course, be necessary to fit new rubber cuffs.

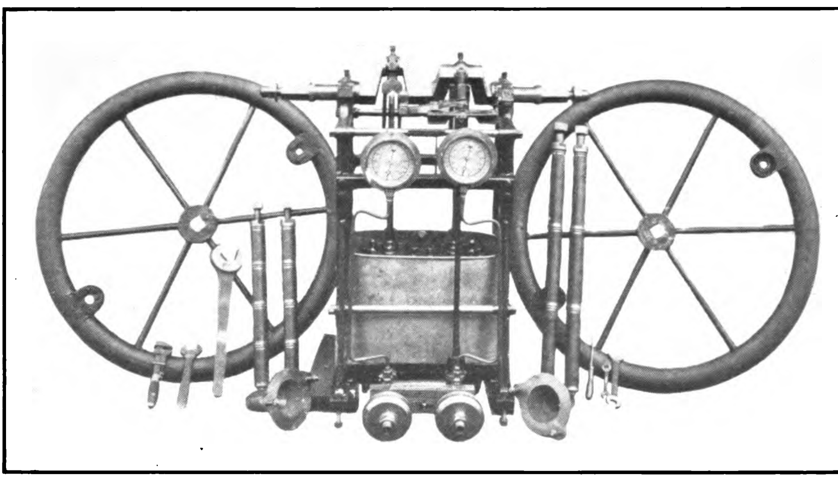
There are many outfits of diving apparatus provided with old style rubber diving mittens still in service, and with these the mittens are attached to the outside of the sleeves of the diving dresses, the joints being made by means of a set of metal rings and clamps. These are not as satisfactory as the improved pattern, for the reason that the diver does not have as free use of his hands and fingers. As fast as the old style gloves are worn out they are being replaced by the new type.

PLATE VIII.

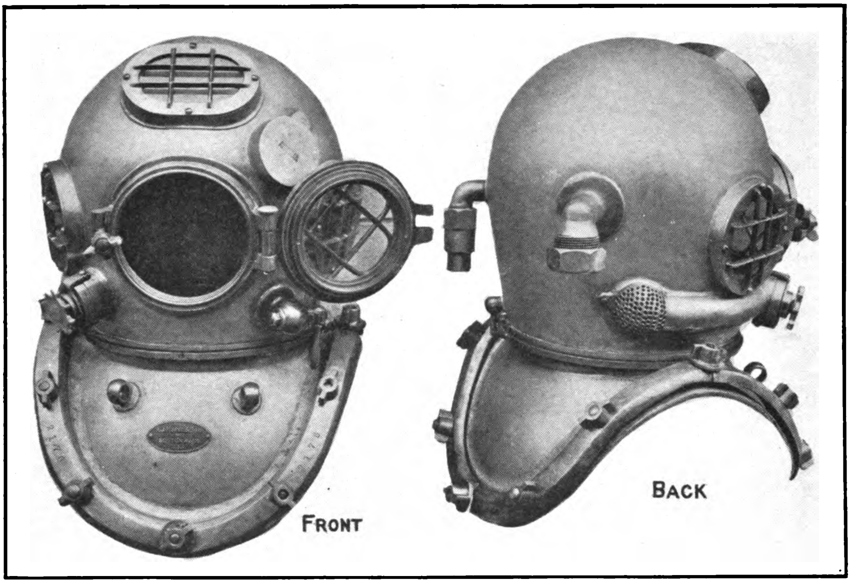


DIVER PARTLY DRESSED, SHOWING UNDERJACKET WITH RUBBER GLOVES ATTACHED.

PLATE IX.



DIVING AIR PUMP, MARK III, AND ACCESSORIES.



DIVING HELMET, MARK V.

PUMP-WHEEL HANDLES.

(Pl. IX.)

The improved type of pump-wheel handles are of the multiple quill type and are furnished in two sizes, No. 1 or large size, and No. 2 or small size. The No. 1 size handles accommodate six men on the pump, and the small size have room for four men at a time in the pumping crew. The handles bolt directly in the rims of the pump wheels, and consist of lignum-vitæ quills, mounted with brass ferrules on a steel shaft in such manner that each quill will turn independently.

DIVING HELMETS.

There are five different kinds of diving helmets in general use in the Navy. These are designated as diving helmets Mark I, II, III, IV, or V. The principal characteristics of each are as follows:

Mark I.—Bolt type; wide breastplate; screw faceplate; oval top and side windows; "Morse" type regulating escape valve, telephone, safety valve, and air inlet connection; manufactured by A. J. Morse & Son (Inc.), Boston, Mass.

Mark II.—Bolt type; wide breastplate; screw faceplate; round top and side windows; "Schrader" type regulating escape valve; safety valve and air inlet connection; manufactured by A. Schrader's Son (Inc.), Brooklyn, N. Y.

Mark III.—Interrupted screw type; otherwise same as Mark I.

Mark IV.—Interrupted screw type; otherwise same as Mark II.

Mark V.—Bureau of Construction and Repair design; adopted as standard; interrupted screw type; narrow breastplate; improved regulating escape valve; hinged faceplate; oval top window; round side windows; improved telephone connections, safety valve, air inlet connection; supplementary relief valve.

DIVING HELMET, MARK V.

(Pl. X.)

The diving helmet Mark V consists of a tinned copper helmet and breastplate. The connection between the helmet and breastplate is made by an interrupted screw joint; a leather gasket fitted in a recessed gasket seat insures the joint being made watertight. When screwed in place on the breastplate, a safety catch, located on the back of the helmet, is turned down into a recess cut into the neck flange of the breastplate to prevent the helmet being accidentally detached. The helmet is fitted with four windows; one directly in front of the diver s face, being closed by a hinged faceplate. The side and top glasses are glazed in and made watertight by red lead, held secure by gun-metal frames, and protected by gun-metal gratings. The faceplate glass is secured by a gun-metal follower ring, screwed in place by a special spanner wrench. The faceplate is held in the closed position by means of a hinge bolt and wing nut (the fingers only being used to set up on the nut), and the joint is made water-tight by a rubber gasket. An air inlet connection and a telephone cable connection are located at the back of the helmet, where they are least apt to be injured. Along the right side, below the window, an improved regulating escape valve is fitted, so that the point of exhaust is toward the rear of the helmet and the regulating screw is between the faceplate and right side window. Diametrically opposite the regulating escape valve regulating screw a supplementary relief valve or "spit cock" is located. On the inside of the helmet an air inlet channel is sweated to the top of the shell with branches leading to and terminating just over the top and side windows.

The regulating valve stem extends inside the helmet and is fitted with a push button, which may be operated by the diver pressing his head or chin against it.

The telephone transmitter is secured inside the helmet above and to the left of the faceplate, and the socket for plugging in the telephone receiver wire connection is located just inside and to the right of the center of the faceplate opening.

The breastplate is of the narrow type, with 12 screw studs and 4 metal clamps for attaching the diving dress. The clamps are held down against the rubber collar of the diving dress by 8 small and 4 large wing nuts of an approved type. Located conveniently on the front of the breastplate are 2 metal eye pads to which the life line and air hose are stopped on their respective sides.

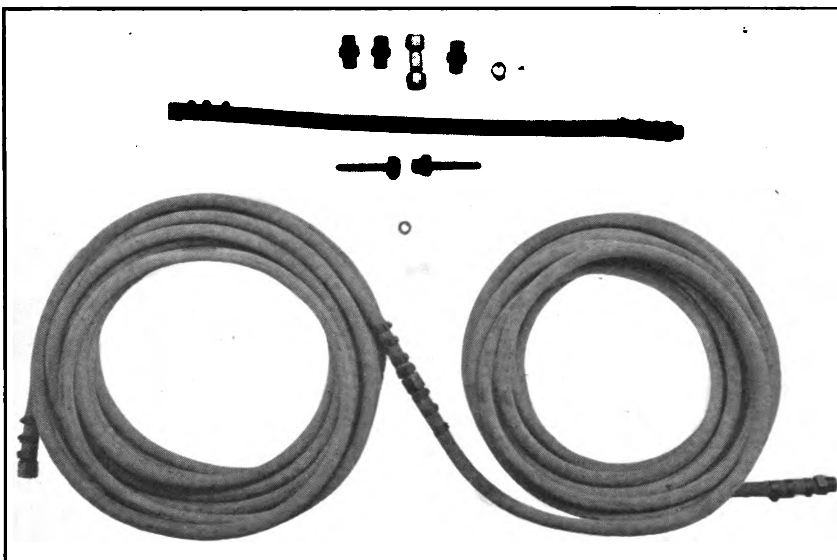
The improved standard diving helmet is made somewhat larger than the other types to accommodate the improved diving telephone equipment; it is also lighter and more comfortable to wear.

AIR HOSE.

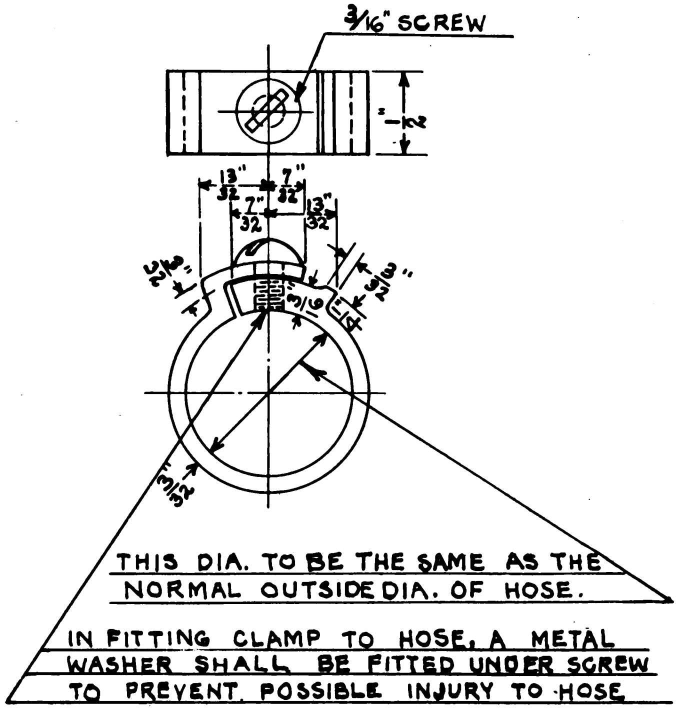
(Pl. XI.)

The standard diving air hose is of the sinking type one-half inch internal diameter, $1\frac{1}{15}$ inches external diameter; consists of a vulcanized rubber tube reinforced by five plies of 12-ounce cotton duck well frictioned with a properly vulcanized rubber compound, with plies or layers laid on the bias to prevent the hose from wriggling, twisting, or turning while under pressure, and a rubber cover, properly vulcanized, to protect the reinforcement from chafe or wear. The hose is ordinarily furnished in both 3-feet and 50-feet lengths, the 3-feet lengths being for the purpose of connecting the special air control valve next the diver's helmet. The ends of each length of air hose are capped with rubber to prevent moisture coming in contact with cotton reinforcement, and are coupled with standard diving air hose couplings. All diving hose when new is tested to a pressure of 250 pounds per square inch for a period of 30 minutes.

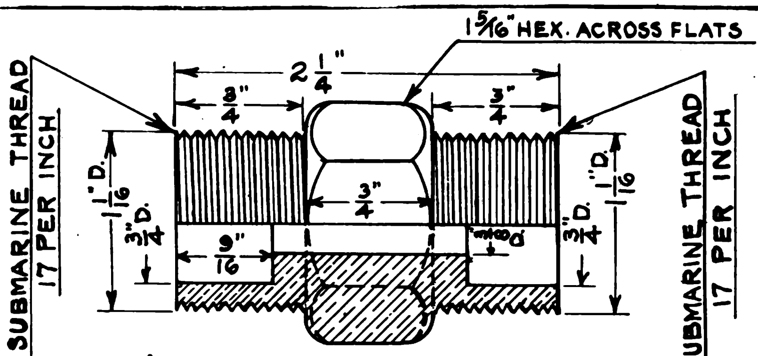
PLATE XI.



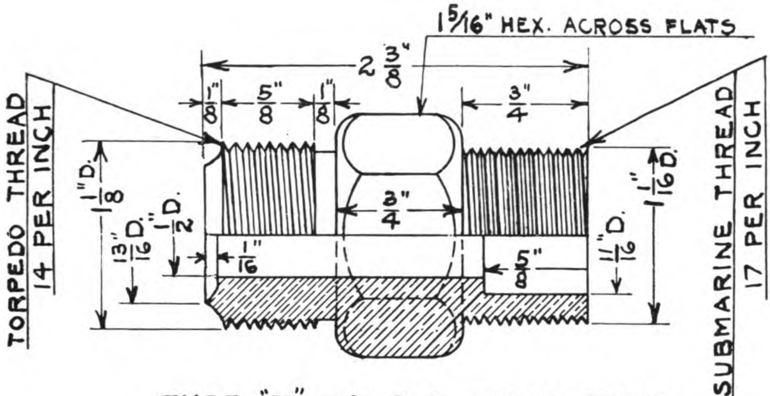
DIVING AIR HOSE AND FITTINGS.



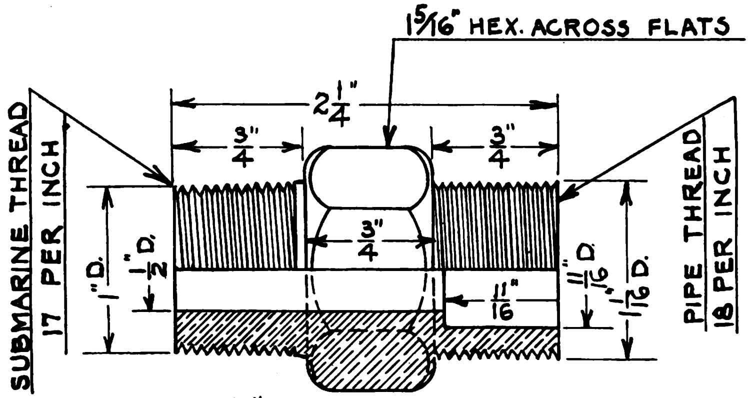
CLAMP FOR SECURING
AIR HOSE TO SHANK OF COUPLING.



ST'D DOUBLE MALE UNION

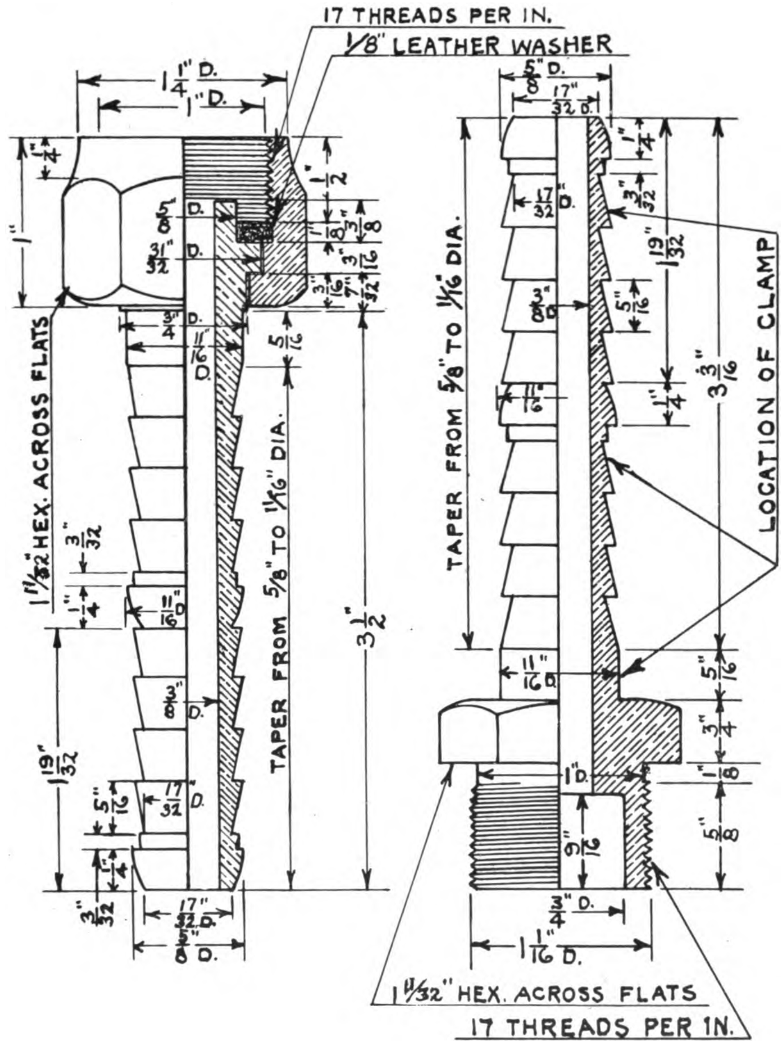


TYPE "T" DOUBLE MALE UNION



TYPE "S" DOUBLE MALE UNION

PLATE E.

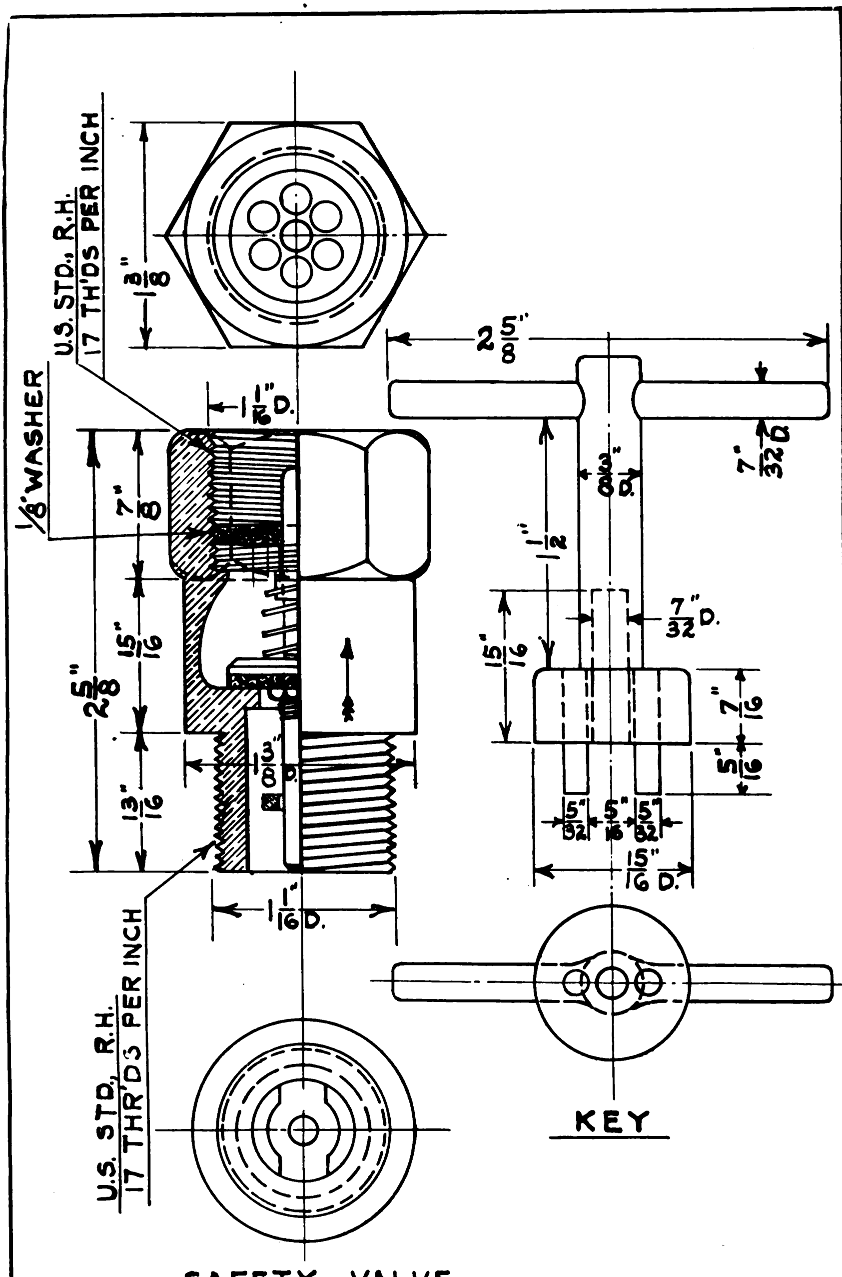


FEMALE COUPLING

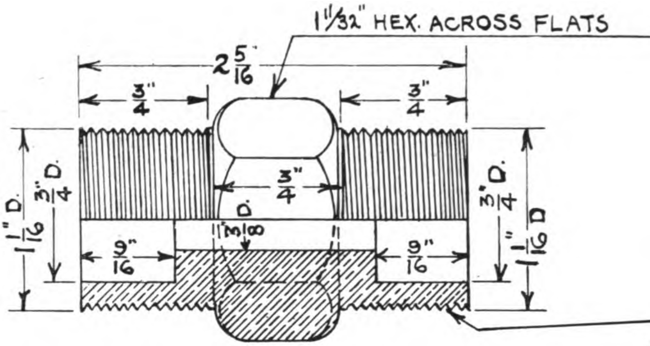
MALE COUPLING

NOTE

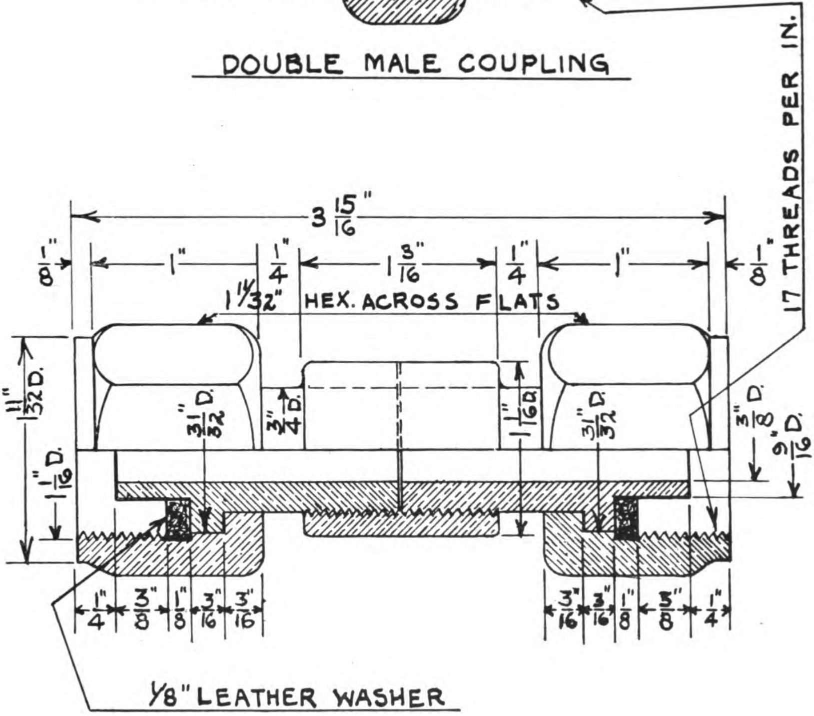
SHANK OF COUPLING TO BE COATED WITH CEMENT BEFORE INSERTING IN BORE OF HOSE.



SAFETY VALVE
FOR DIVING APPARATUS.



DOUBLE MALE COUPLING



DOUBLE FEMALE COUPLING

AIR HOSE FITTINGS.

(Pls. VII, fig. 2, XI, and C, D, E, F, and G.)

The various air hose fittings are as shown in the illustration, Plates VII, fig. 2 (p. 31), XI (p. 34) and C, D, E, F, and G. The ends of each length of air hose are fitted alternately, with male and female couplings. In fitting the couplings on the hose, three clamps are first slipped over the end of the hose, then the shank of a coupling is coated with rubber cement and forced into the bore of the hose until its shoulder brings up against the end of the hose. The hose clamps are next placed in position, a small thin copper washer placed under each screw hole to prevent the clamp screws cutting into the rubber cover of the hose, then a clamp is set in the special assembling tool, which is held in a vise. Screwing up on the vise closes the jaws of the tool, and in turn compresses the clamp and brings the screw holes in line. The clamp screw is then screwed in place and the operation repeated on the next clamp. The shank of the couplings being of slightly larger diameter than the bore of the hose, and the clamp being slightly smaller than the external diameter of the hose, the rubber tube is forced into corrugations of the shank and gripped very tight by the clamps, thus insuring the coupling having a very firm hold on the end of the hose. This is very necessary, it being readily understood that if a coupling were to pull out with a diver under water the consequences might be serious. The joints between male and female hose couplings are made water-tight by means of leather washers. Standard double male and double female air hose couplings are provided for use when it is desired to make a special connection, as when the alternations of male and female connections are not continuous.

Adapters, type T, have one end submarine male threaded, 17 threads per inch, and the opposite end cut with a Navy standard male torpedo air pipe thread.

Adapters, type S, have one end submarine male threaded and the opposite end cut with a United States standard iron pipe size thread.

The diving manifold is a brass casting, fitted with stop cocks on the triple outlets, and the inlet and triple outlet nozzles are all submarine male threaded.

In connecting up lengths of diving hose it should be remembered that the length of hose nearest the diver will be subjected to the least difference of pressure, and therefore if there is any preference the best hose should be on the end nearest the surface.

DIVING KNIVES.

(Pl. A) page 3.

The latest type of diving knife, as illustrated, is a single-edged blade, 6½ inches long, of best cutlery steel, tempered soft so as not to be easily broken, fitted with corrugated hard wood handle, properly balanced so that if dropped any distance it will fall point first, and with the various parts assembled to facilitate renewal.

The case is a brass casting, finished, nonwater-tight, fitted with an internal brass spring to hold the knife in place until it is purposely withdrawn, and provided with a leather hanger for attaching it to the weighted belt.

DIVING LADDER.

(Pls. H and I.)

The diving ladder is designed for use over the side of sailing launches and is made adjustable to fit either the 36-foot, 40-foot, or 50-foot launches. The strut for giving the correct inclination to the ladder folds up neatly to facilitate stowage of the ladder.

DECOMPRESSION LADDER.

(Pl. J.)

The decompression ladder is made up in sections to facilitate stowage and handling, after the form of a jacob's ladder, with rungs 10 feet apart corresponding to a stage of decompression. The upper ends of each section are fitted with thimbles and the lower ends with sister hooks. When making up a completed ladder the sister hooks of the lower section are hooked in the eye of a 50-pound cast-iron weight which causes the ladder to hang plumb, and the thimbles of the upper section are fitted with rope tails by which the ladder is secured. For arrangement of ladders in a diving boat see Plate P.

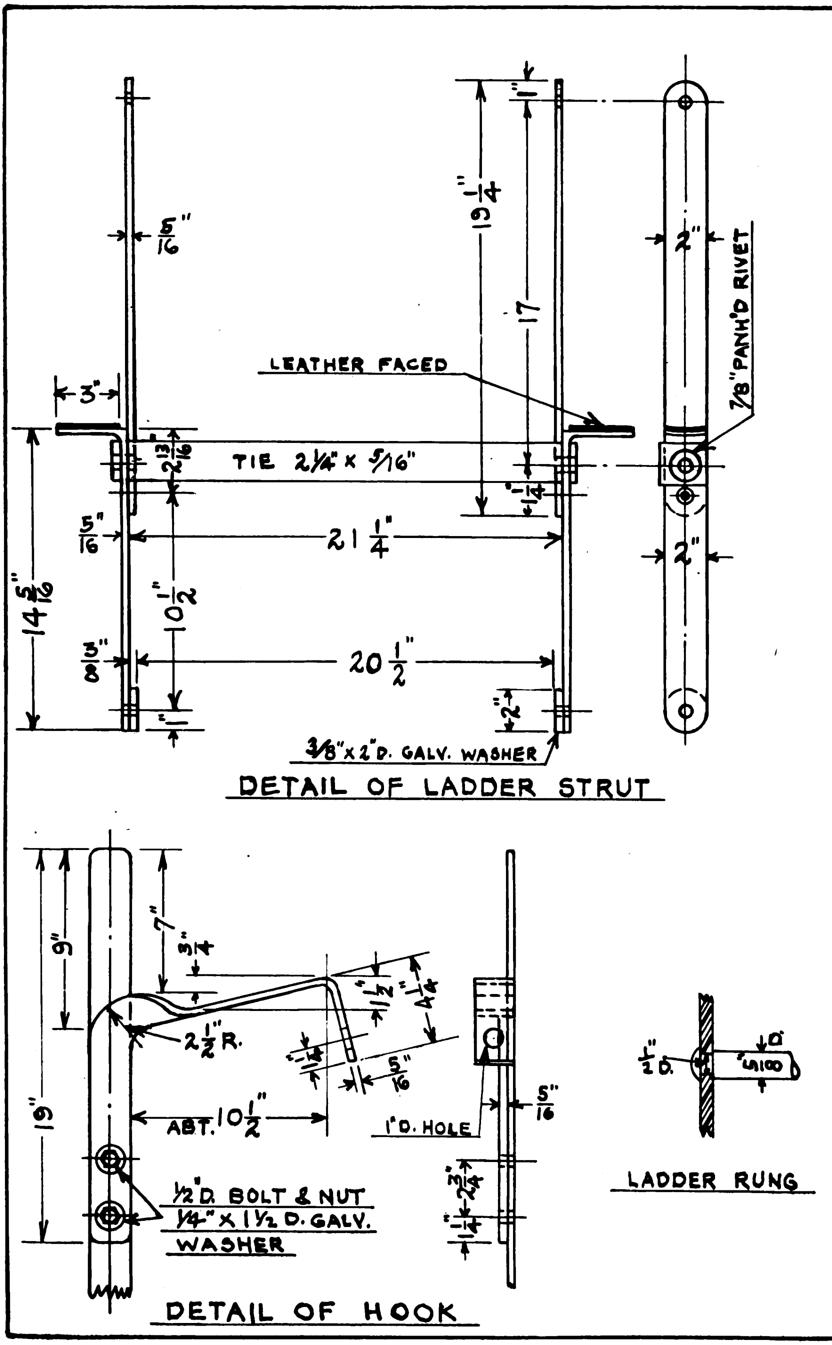
DESCENDING LINES.

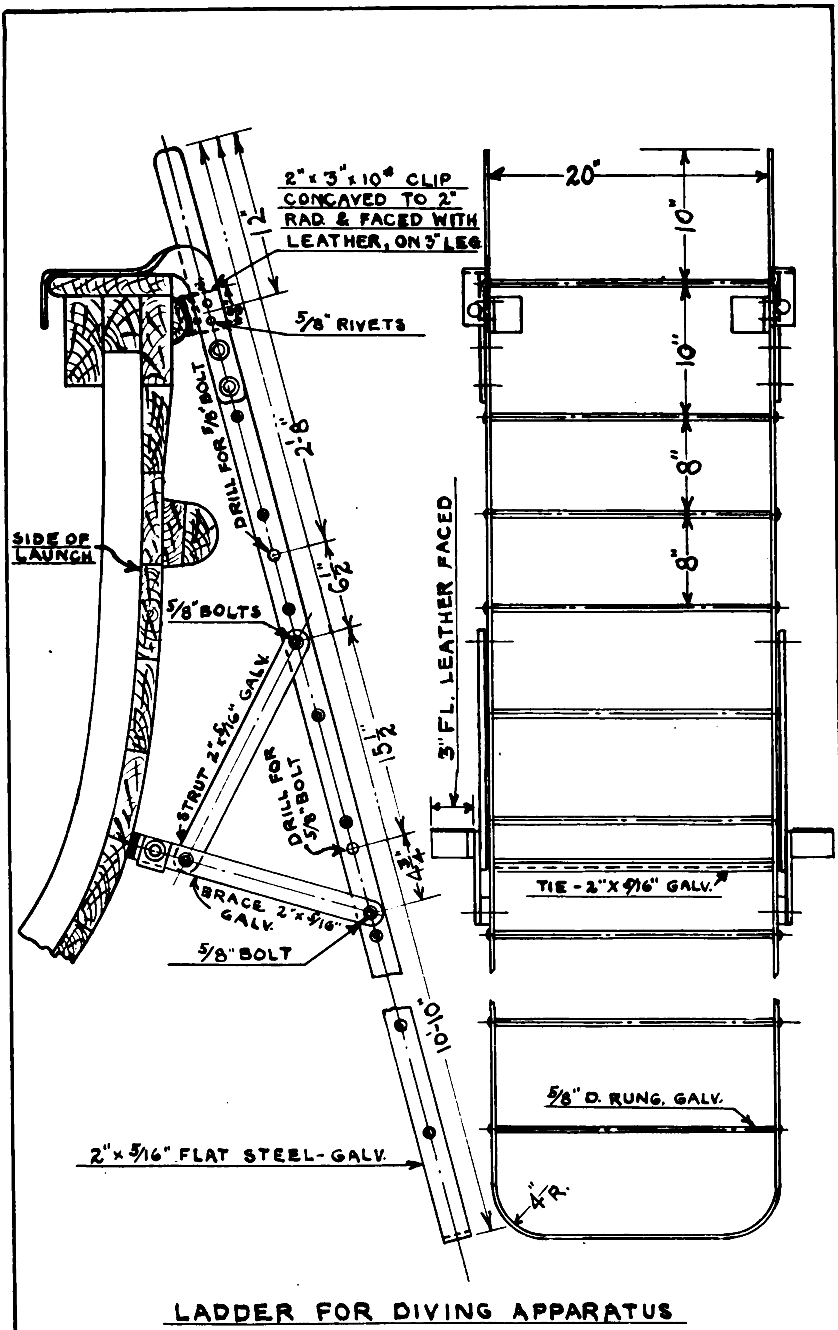
Three-inch cable laid manila lines, 200 feet long, are furnished for descending lines, one end of which is spliced into the eye of a 100-pound weight.

In strong tideways, and the weight provided does not remain on the bottom, additional weight may be added.

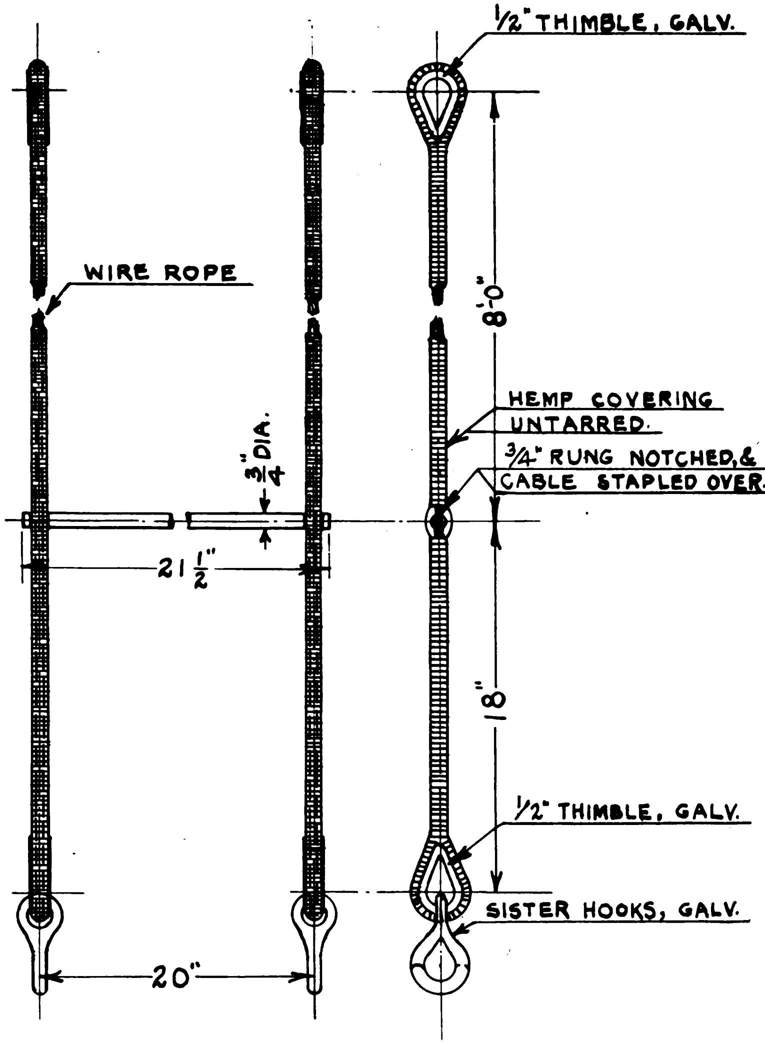
DISTANCE LINES.

Fifteen-thread cable laid manila lines, 60 feet long, are supplied for distance lines. These are bent on to the descending line, about 4 feet above the descending line weight, and made up into a loose coil for the convenience of the diver.


LEATHER FACED
TIE 2¼" × 5/16"
7/8" PANH'D RIVET
3/8" × 2" D. GALV. WASHER
DETAIL OF LADDER STRUT
2½" R.
ABT. 10½"
1" D. HOLE
½" D. BOLT & NUT
¼" × 1½ D. GALV. WASHER
LADDER RUNG
DETAIL OF HOOK

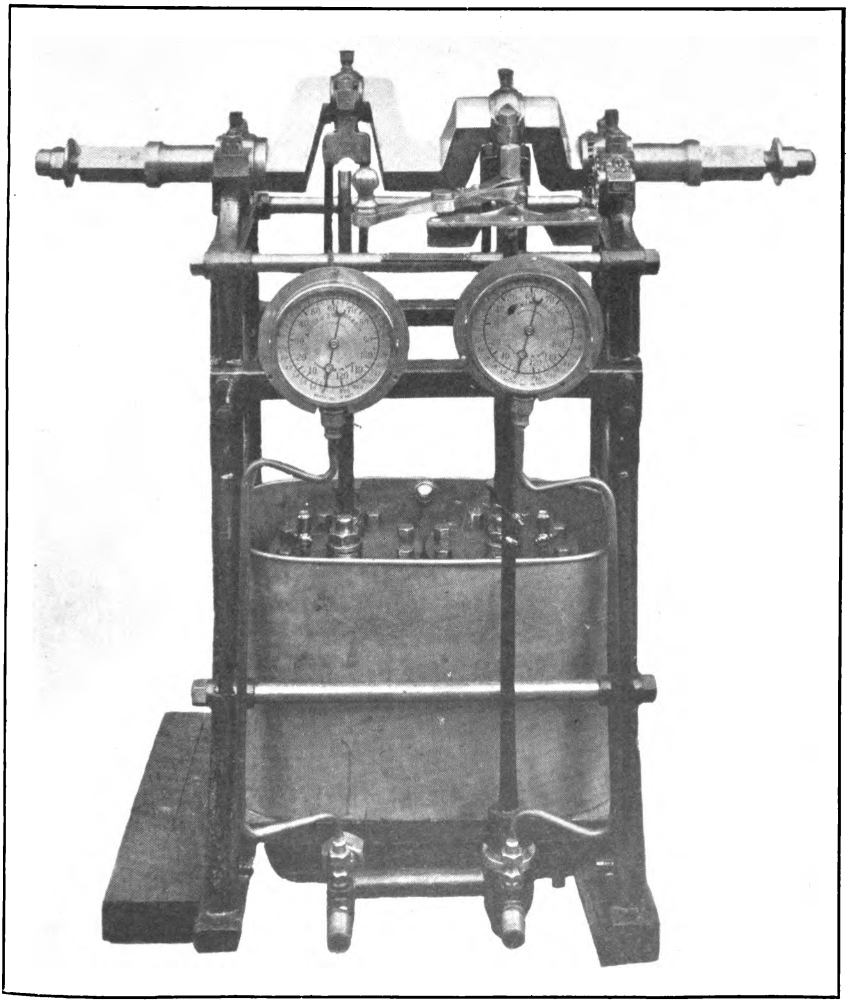


LADDER FOR DIVING APPARATUS



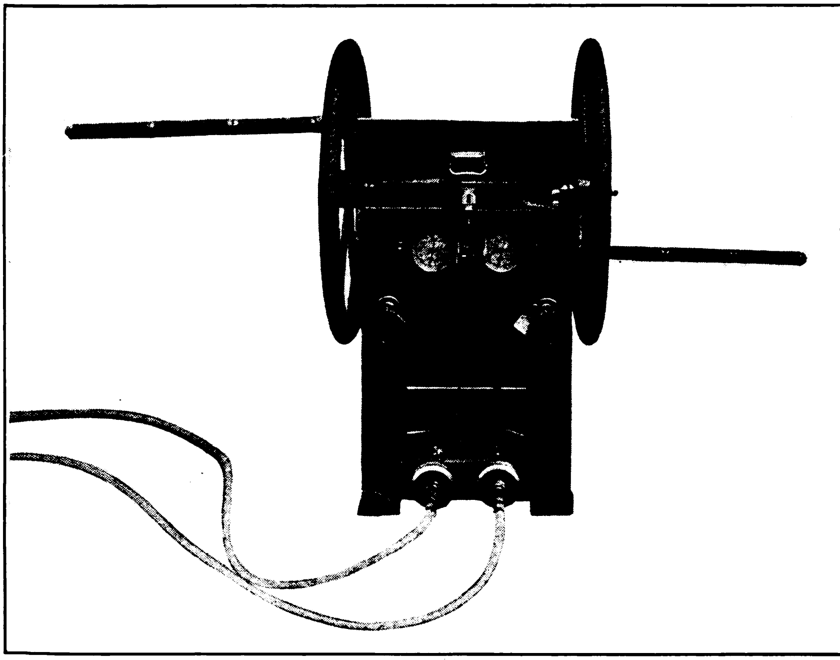
PORTABLE SECTION
DECOMPRESSION LADDER

PLATE XII.



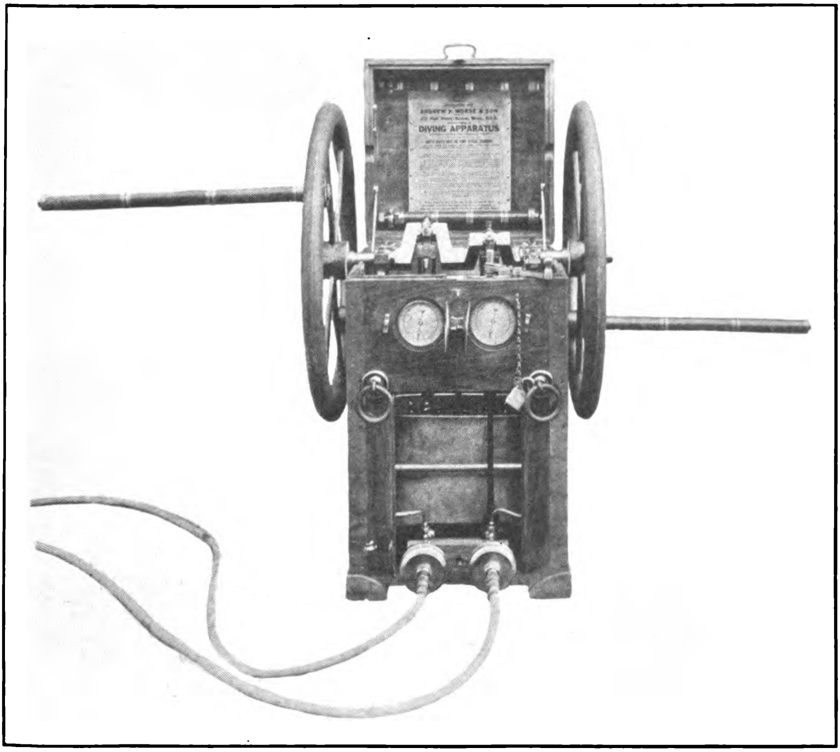
DIVING AIR PUMP, MARK III, REMOVED FROM CASE.

PLATE XIII.



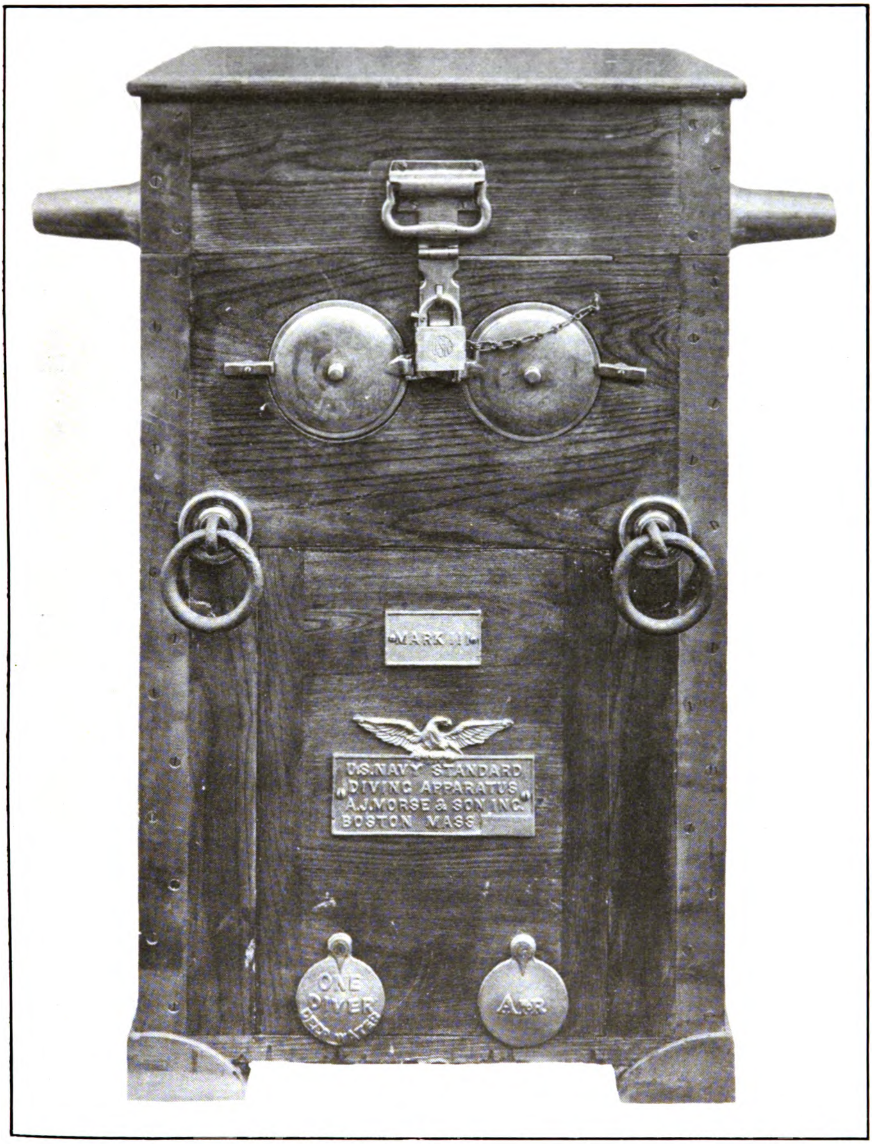
DIVING AIR PUMP, MARK III.

PLATE XIV.



DIVING AIR PUMP, MARK III, ARRANGED TO SUPPLY AIR FOR TWO DIVERS.

DIVING AIR PUMP MARK III, BACK VIEW.



DIVING AIR PUMP, MARK III, FRONT VIEW.

DIVING AIR PUMPS.

There are several different kinds of diving air pumps in service, including several different types of each kind, including single-cylinder, double-acting pumps: three-cylinder, single-acting pumps; and two-cylinder double-acting pumps. The former is rapidly being eliminated and is now seldom met with. The three-cylinder, single-acting pumps are used principally at navy yards and stations where the water is, as a rule, quite shallow. However, a few of this type are still afloat. The latest type of two-cylinder, double-acting diving air pump has been adopted as standard on account of its greater capacity and efficiency, and this type will, eventually, displace all others.

The two-cylinder, double-acting diving air pumps in general use are designated, and the principal characteristics are as follows:

Mark I.—"Morse" type, 3⅞-inch diameter cylinders, 6-inch stroke, "Morse" valves, low water cistern, low front door.

Mark I, Mod. 1.—"Morse" type, 4-inch diameter cylinders, 6-inch stroke, "Morse" valves, low water cistern, low front door.

Mark I, Mod. 2.—"Morse" type, 4-inch diameter cylinders, 6-inch stroke, standard valves, raised water cistern, high front door.

Mark II.—"Schrader" type, 4-inch diameter cylinders, 6-inch stroke, "Schrader" valves, low water cistern, low front door.

Mark II, Mod. 1.—"Schrader" type, 4-inch diameter cylinders, 6-inch stroke, standard valves, raised water cistern, high front door.

Mark III.—Navy standard, 4¼-inch diameter cylinders, 7¼-inch stroke, standard throughout.

DIVING AIR PUMP, MARK III.

(Pls. XII, XIII, XIV, XV, XVI, and Pl. IX, p. 33.)

The diving air pump, Mark III, is a two-cylinder, double-acting, manually operated diving machine air pump.

The cylinders are 4¼ inches internal diameter; the stroke is 7¼ inches; the calculated or theoretical capacity is 405 cubic inches of free air per revolution; the efficiency of the pump, when new, is required to be 80 per cent, when operated against a pressure of 100 pounds per square inch, with corresponding increase of efficiency at lower pressures.

The pump is constructed in accordance with designs and specifications prepared by the Bureau of Construction and Repair.

The frame is of cast iron, without defects, of rigid design and construction, and the manufacturer's serial number of the pump is stamped in figures plainly visible on the upper center of the upper rail-rod support. The frame is strengthened by horizontal braces, supports the crank shaft and bedplate, and is firmly secured to the pump case by four brass holding-down bolts which pass through the foot lugs of the frame and the bottom of the case.

The bedplate, of gun metal, is bolted to the frame, and supports and forms a true base for the cylinders. Cast in one with the bedplate, and located on its under side, are two oblong boxes, or air reservoirs, fitted with cover plates bolted in place, and made air-tight by means of leather gaskets.

The cylinders, of gun metal, are bolted and sweated permanently to the bedplate, bored true and exactly parallel to each other, and finished dead smooth inside to exact dimensions.

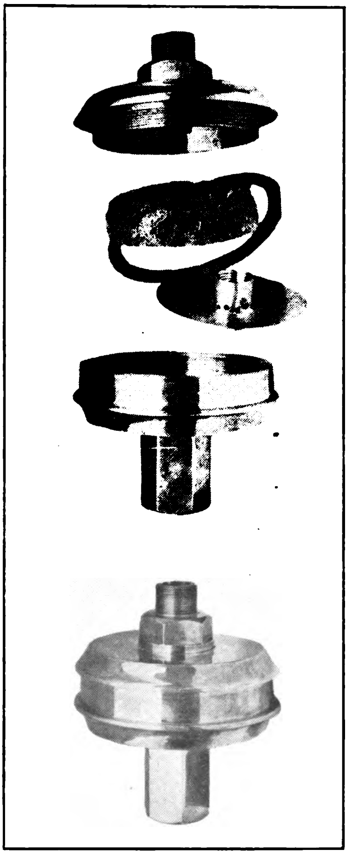
The cylinder covers, of gun metal, are interchangeable, bolted to the flanges on the cylinders, and fitted with inlet and outlet valves, cylinder oil cups, and piston-rod stuffing boxes. The inlet air openings, oil, cups, and stuffing-box glands are elevated above the water overflow outlet of the water cistern. The cylinder-cover joints are made air-tight by leather gaskets. Through a rib, cast on the front of each cylinder, air passages are drilled which connect the air spaces of the upper outlet valves with the air reservoir on the under side of the bedplate. Each air reservoir receiving air from its respective cylinder. The lower outlet valves are located, one each, inside the air reservoirs.

The air reservoirs are fitted with air-delivery nozzles to each of which an oil separator is screwed on when the pump is to be used to furnish air to divers; the diver's air hose being coupled to the male submarine threaded portion of the oil separators. (See Pl. XVII.) The delivery nozzles are cross connected, and a two-way transfer valve, with valve rod, and shifting handle, is fitted in the cross connection and so arranged that the air from each cylinder may be directed out its respective delivery nozzle or all the air from both cylinders may be directed out the left-hand nozzle. Therefore, it is possible to supply air independently to two divers, working in shallow depths (30 to 40 feet) at the same time, or to one diver working in moderately deep water (60 to 80 feet), while running the pump at ordinary speed.

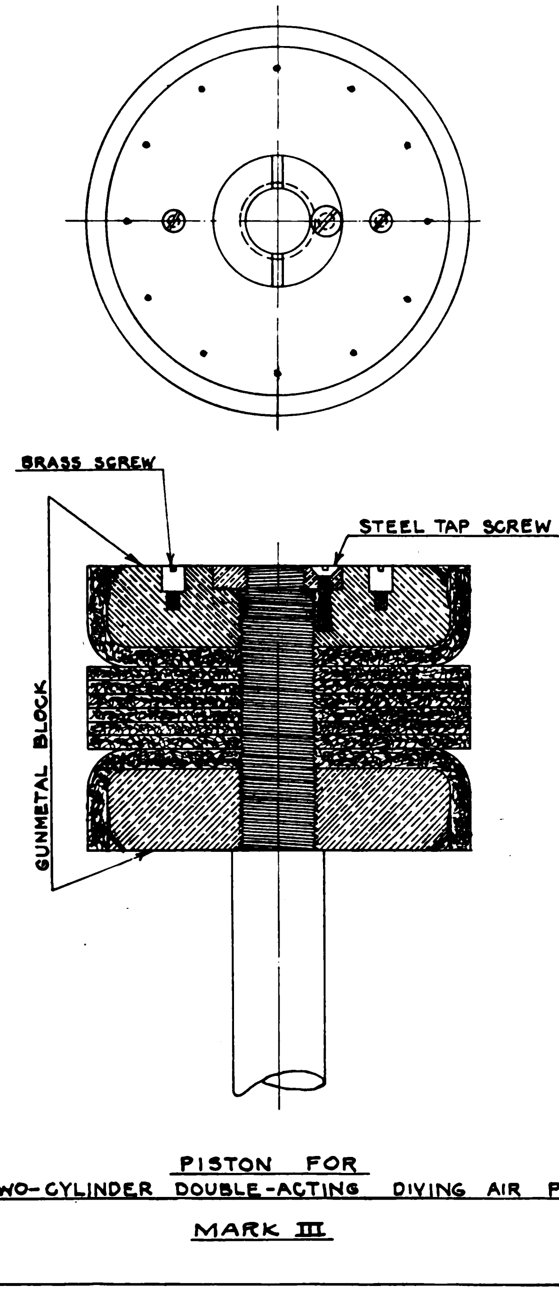
The pistons (Pl. K) are composed of inverted cup leathers, and leather disks, held together by metal blocks screwed, left-handed, on to their respective piston rods; and are prevented from backing off by lock nuts and set screws, right-hand threaded. In operation, the air holes, shown in the illustration, admit air to the grooves cut around the periphery of each block, and, thus, when the pressure is developed, the air forces the leathers against the walls of the cylinders and prevents leakage of air past the pistons. The piston clearances are adjusted as close as practicable so that, on each stroke, practically all the air compressed in the cylinders is forced out.

The valves are of universal pattern, interchangeable, made of gun metal, and faced with leather on either side. The valves are held on their seats by spiral brass springs under light initial tension; the valve stems moving in guides formed in the valve casings or valve bodies. The valve bodies are each made in two parts: one part of each being permanently secured over a valve opening into a cylinder,

PLATE XVII.



OIL SEPARATOR FOR DIVING AIR PUMPS.



PISTON FOR
TWO-CYLINDER DOUBLE-ACTING DIVING AIR PUMP.
MARK III

thus forming an integral part of the combined cylinders and bed-plate. The removal part of a valve body is termed a valve-body cap. The arrangement is simple, efficient, and provides easy access to the valves.

The transfer valve is of the plug cock type with a "T" opening. The valve stem is made short, and square in setion. A long valve connecting rod is fitted at its upper end with a valve-operating handle, and at the lower end with a square female socket which ships over the short valve stem. The transfer valve and its connecting rod are housed inside the pump case; the valve-operating lever being located to the front and at the pump case cover joint, at which point a direction plate is also located which indicates the position of the valve ports.

The piston rods pass through the cylinder-cover stuffing boxes, and the piston-rod guides located in separate guide supports fastened to the angle braces of the pump frame. To the square sections on the rods, connecting slings are pivoted, which, in turn are connected to brass bearing blocks on the crank shaft.

The crank shaft of forged steel revolves in the journal bearings on the pump frame. The cranks are set at about 90 degrees from each other, and the ends of the shaft project from the pump case on either side sufficient to provide room for the flywheels.

Brass oil drip cups, packed with wisps of hair felt, are fitted to each upper bearing brass of the crank shaft, and the ends of the shaft are threaded and fitted with turned brass nuts for holding the flywheels in place.

The flywheels are of cast iron, with wrought iron spokes, and provision is made to secure either long or short hand handles directly into the wheel rims. The wheels weigh 150 pounds each, and have a square hole machined through the hub which fits a corresponding square section, slightly trapered to facilitate removal, on the ends of the crank shaft. The wheels are interchangeable.

A water cistern, of sheet copper, heavily tinned inside and out, surrounds the pump cylinders, and is secured to the bed plate. The cistern is of such height as to permit the contained cooling water to flood the tops of the cylinders as well as the sides. The necessary water connections are provided for water filling, overflow, and drain, and these open at the back of the pump case. Whenever the pump is in use during warm weather the water cistern must be filled with cold water and this changed whenever it gets warm, or the air being supplied to the diver or diver's will be heated to such an extent as to endanger their physical well being.

The pump case is made of high-grade, well-seasoned, fine-grained white ash; the sides are dovetailed together at the corners; the corners bound with angle brass, and the bottom edges are protected by brass shoes. The cover is hinged at the back, and held in the open positions by cover supports. A large removable door is fitted in the front of the case, through which access may be had to the interior of the pump not convenient from the top. Provision is made on the inside of the cover for stowing the set of short wheel handles, and the long handles are secured in brackets in the front corners of the case. The pump gauges are located on inside of the case, and the gauge dials are visible through circular openings in the front part of the case; the dials are protected by brass covers hinged on the outside and front of the case. When not in use brass protecting caps bolted to the pump case protect the ends of the crank shaft; these should never be used for lifting the pump about.

Wrought-iron lifting rings are secured on the front and back of the case for the above purpose; and the bolts for these pass through the woodwork and are fastened into a stiffening iron running round the inside of the case.

In the upper part of the case, at the back, a wooden till is provided for holding the tools and spare parts for the pump.

The opening at the bottom is closed by a brass cover, held in place by a number of wing nuts. The plate is dished so that the dripping oil or water will be drained toward the center, at which point a drain plug is located.

WEIGHTED DIVING SHOES.

(Pl. IV, fig. 6, see p. 30.)

The latest type weighted diving shoes are made with wooden inner soles and lead outer soles, fitted with brass toe caps, straps, and buckles, and brass eyelets for lacings.

DIVING LAMP.

(Pl. XVIII.)

The diving lamp consists of a length of double-conductor portable wire; a water-tight fitting for a 100-watt lamp, with metal guard; a heavy glass cylindrical globe; a lamp holder; and rubber gaskets and washers for making the assembly water-tight. The surface end of the portable wire is fitted with a standard water-tight plug.

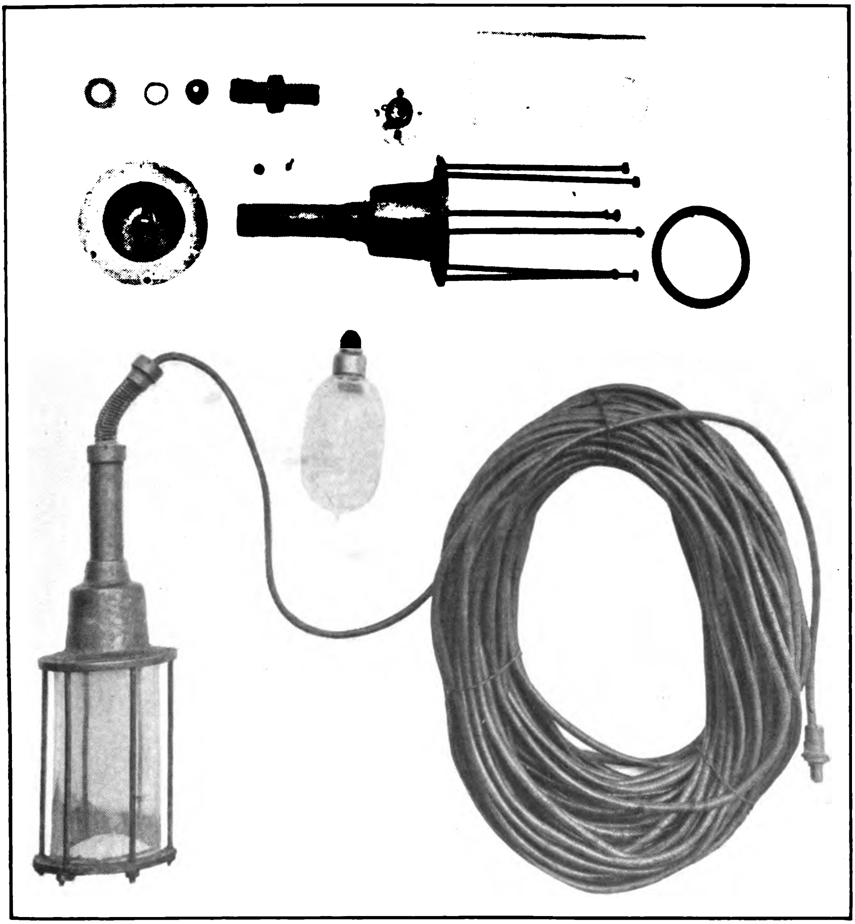
DIVING TELEPHONE.

(Pls. XIX and L.)

The diving telephone consists of the following principal parts:

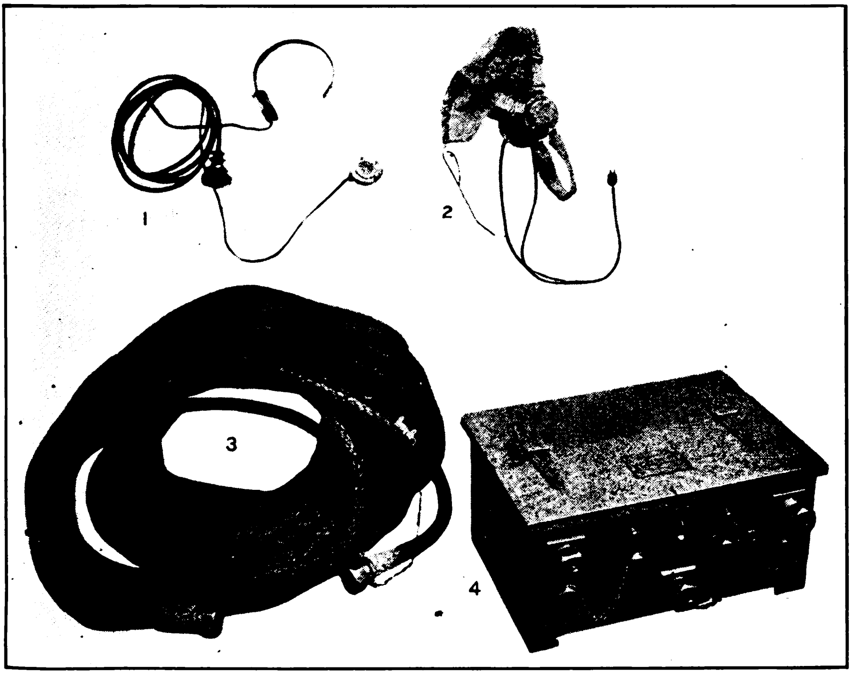
(*a*) Battery box.
(*b*) Diver's head set.
(*c*) Diver's transmitter.
(*d*) Attendant's outfit.
(*e*) Telephone cable.

PLATE XVIII.



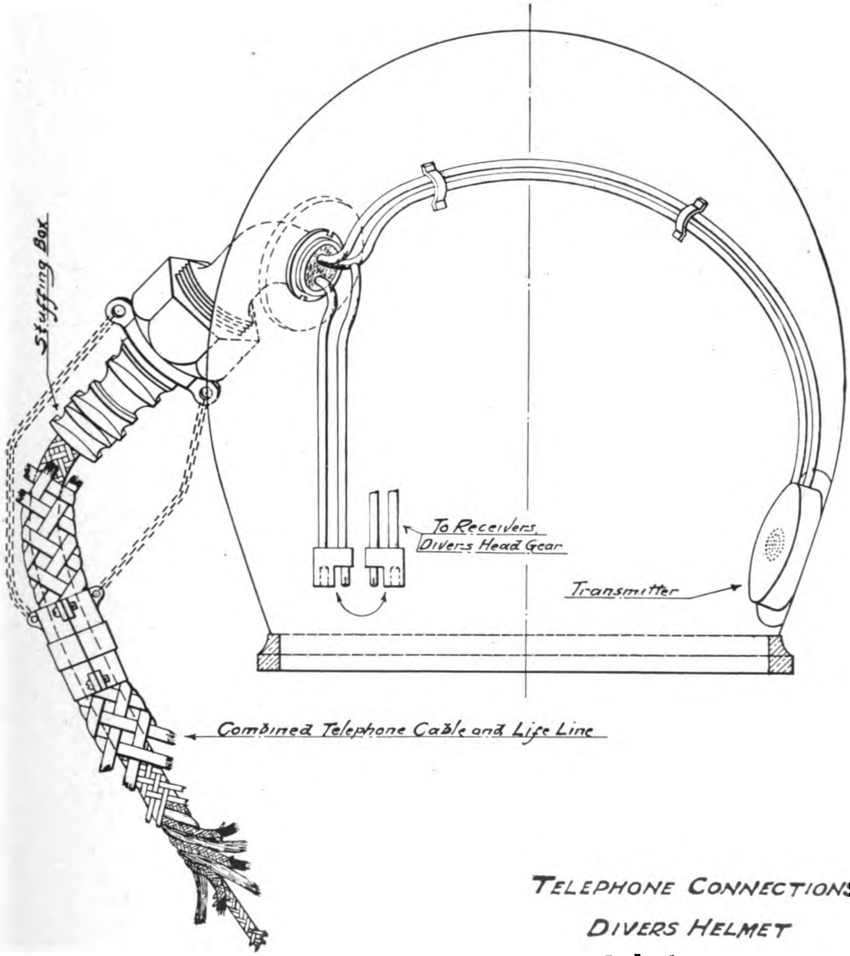
DIVING LANTERN AND PARTS.

PLATE XIX.



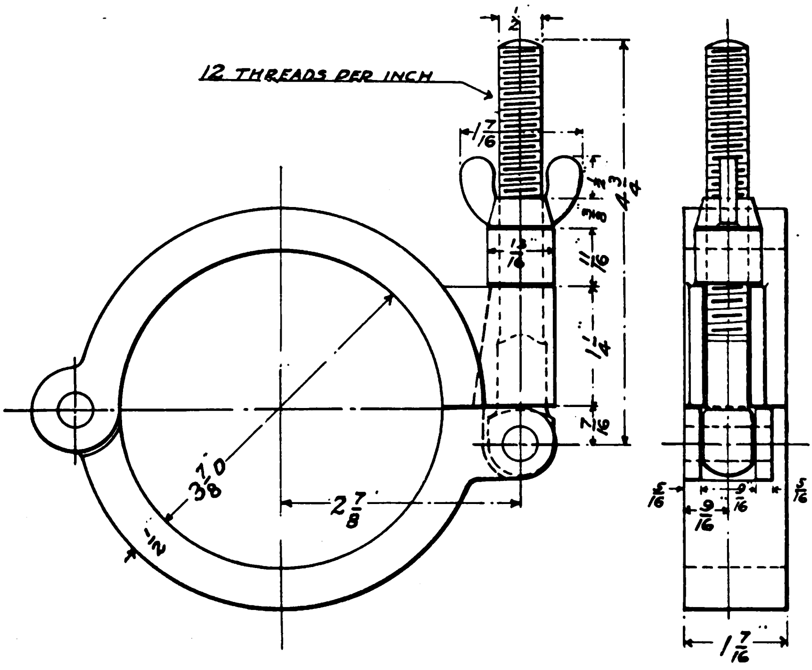
THE DIVING TELEPHONE.

PLATE L.



TELEPHONE CONNECTIONS
DIVERS HELMET
Scale: 6" = One Foot

PLATE M.



TOOL FOR ASSEMBLING PISTONS OF DIVING PUMPS.

The battery box, Plate XIX, contains the battery of six dry cells, connected, as shown in the wiring diagram, to the terminals of a double-pole, single-throw switch. The connections for the attendant's and the diver's telephone cables are located on the front of the box, the male couplings being on the box and the female couplings on the cables.

The diver's head set consists of canvas cap, to which the telephone receivers are suspended. The cap is made adjustable as to size, and is held firmly on the diver's head by means of a chin strap.

The receivers are connected in parallel by a special telephone cord, and are fitted with rubber ear pieces. The receiver cord is fitted on one end with a special jack plug which fits in a corresponding plug receptacle located permanently inside the helmet, the connection being made or broken by reaching in through the faceplate when the helmet is in place on the diver. The diver's transmitter is located in a recessed box in the helmet to the left and a little above the faceplate; the wiring is held close to the wall of the helmet by metal hangers, and the leads from the transmitter are connected to the proper points in the fitting of the helmet telephone connection or gooseneck.

The helmet telephone connection is male threaded and takes either female coupling of the telephone cable.

The attendant's outfit consists of a single receiver fitted to a spring headband; a transmitter; the attendant's telephone cord; and a coupling with which attachment is made to the proper outlet on battery box.

When not in use, the attendant's outfit and the diver's head set are stowed in the vacant compartment of the battery box.

The telephone cable is a combined telephone cable and life line, the three conductors forming the heart of the cable and the remaining construction serving as a life line and a protection to the conductors. The couplings are of the design and are fitted as shown in the illustrations.

The whole arrangement is a simple combination of two simple telephone circuits, a transmitter and a receiver being in each circuit, and the two circuits having separate batteries but a common return.

ASSEMBLING TOOL FOR PISTONS.

(Pl. M.)

The assembling tool for use in entering the pistons in the cylinders of diving pumps is made of gun metal in two parts hinged together and fitted with a clamping screw and wing nut. The assembled pistons, when new, fit the cylinders very neatly and the use of this tool is necessary to avoid injury to the edges of the lower cup leathers. When the pistons are difficult to enter it is also necessary to provide a length of pipe to fit over the piston rod, upon which pressure may be applied without injuring the rod; the pipe should be longer than the rod and its lower end should rest upon the metal part of the piston.

OVERALL TROUSERS.

(Pl. XX.)

The overall trousers are made of light canvas, with adjustable straps fitted with brass buckles and eyelets, two pockets, reinforced with patches over the knees, and provided with flaps and lacings for lacing up the legs. These are worn to protect the diving dress during rough work.

AIR-CONTROL VALVE.

(Pl. VII, fig. 1, see p. 31.)

The air-control valve is a needle valve designed for use in controlling the inlet of air to the helmet when diving is to be undertaken by the the compressed-air method. The couplings are expanded on, and the retaining yoke prevents the stuffing-box gland nut from backing off. The valve is attached to the diver's apparatus by means of the link connection which is placed under the wing nut of the stud at the lower left-hand side of the breastplate, and the air hose is coupled to the valve as shown in the illustration, Plate I, page 3.

URINALS.

(Pl. IV, fig. 1, see p. 30.)

The urinals are made of rubber, fitted with a nonreturn valve at the constricted part and a drain plug at the bottom.

CAST-IRON WEIGHTS.

Three sizes of cast-iron weights, 25 pounds, 50 pounds, and 100 pounds, respectively, are furnished for use with the diving apparatus. These are of the mushroom pattern, fitted with eye pads and painted black. The 25-pound weights are for use as anchors for the cork-marker buoys, the 50-pound weights are for use with the decompression ladders, and the 100-pound weights are the descending line weights.

OIL SEPARATORS.

(Pl. XVII, see p. 38.)

The oil separators are furnished to protect the diving hose from any oil which the air may carry over from the cylinders of the diving pumps. The separator consists of two brass cups screwed together against a leather gasket, a lufer sponge which collects the oil, and a baffle plate which changes the direction of the air current, and prevents oil being blown through the sponge into the air hose.

OVERALL TROUSERS, STANDARD PATTERN.

CHAPTER VI.

THE CARE AND PRESERVATION OF DIVING APPARATUS.

GENERAL INSTRUCTIONS.

Every effort shall be made to preserve the fine appearance of diving apparatus, to keep it in good repair, and ready for immediate use at all times. With this end in view, the following general instructions shall be carried out in detial:

(*a*) The outfit, helmet, and air-pump chests for diving apparatus, furnished to all vessels of the first and second rates, shall be kept clean inside and out, finished in the natural color of the wood, and coated with clear spar varnish: all exterior brass work to be kept clean and polished; all exterior ironwork to be kept free of rust, and black enameled.

(*b*) On board vessels other than those of the first and second rates, to which diving apparatus is furnished, the outfit, helmet, and air-pump chests may be painted to match the color of the surrounding paint work of the parts of the ship in which they are stowed.

(*c*) All chests of diving apparatus shall, when sufficient space is available, be kept habitually stowed under cover, away from steam pipes and excessive heat. When it is necessary to keep them in the open, and exposed to the weather, suitable canvas covers shall be provided, and used to protect the apparatus.

(*d*) Diving apparatus which may be required for immediate use shall not be stowed in compartments below the water line or in places difficult of access in time of an emergency.

(*e*) On vessels where suitable lockers are provided for stowing the diving apparatus, and the hardwood chests ordinarily supplied are not required for their original purpose, they shall be turned into store.

(*f*) All outfits of diving apparatus furnished to a vessel shall be kept ready for immediate use.

(*g*) Spare parts of diving apparatus not required for probable immediate use shall be kept in a suitable storeroom, and when drawn for use shall be replaced by new ones at the earliest practicable opportunity.

PERIODICAL INSPECTIONS.

Monthly inspections.—All diving apparatus on board ship shall be critically inspected once each month. At this inspection the efficiency of the diving air pumps shall be proved and recorded in the ship's diving log book; the telephones shall be tested, by connecting the cables to the battery boxes and helmets, and talking over them; each outfit shall be inspected as to its completeness and serviceable condition, and the condition and quantity of the spare parts shall be looked after.

Weekly inspections.—All diving apparatus, except spare parts, shall be inspected once each week for cleanliness, conditions of stowage, etc. At this inspection, the diving air pumps shall be hove round several times; helmet valves, faceplates, and fittings looked after; telephone batteries tested; diving dresses inspected for dampness, and aired; dirty woolens washed and dried; oil separators cleaned, if necessary, and the lufer filters washed in hot water and dried; diving knives and their cases, all tools and metal fittings cleaned and lightly oiled; diving shoes, belts, etc., attended to; lengths of air hose that have been coupled together a long time shall be parted, the coupling threads lightly oiled, and the washers looked after; the interior of all chests cleaned of any oil, grease, or dirt, and, if the apparatus has been in use, the contents of each shall be checked over to see that they are complete.

Commanding officer's inspection.—When it is known that the commanding officer is about to inspect the parts of the ship in which diving apparatus is stowed, the apparatus shall be conveniently arranged for his inspection; all chests shall be unlocked, the covers opened, and men standing by to exhibit the contents as he may require.

DETAILED INSTRUCTIONS FOR THE CARE OF DIVING APPARATUS.

Helmets.—The helmets shall be kept habitually screwed on to their respective breastplates, the metal clamps shipped in place, and the wing nuts lightly screwed on to the studs to prevent damage to the threads.

When in the diving boat, and not actually in use, the helmets should be placed right side up on a helmet rack to keep them from being knocked around and to protect the telephone transmitters from dampness.

Before being stowed away in their chests or in the diving apparatus room, the helmets should be wiped over inside and out with a dry cloth to prevent an accumulation of moisture from rusting the diaphragms of the telephone transmitters. Neglect of this precaution soon renders a diving telephone useless.

If, as a result of wear, a helmet when screwed on its breastplate will go so far round to the right that the safety locking catch at the back is past its recess, and the faceplate is not directly in front of the diver's face, one or more paper washers should be cut and inserted under the large leather gasket on the breastplate or a spare gasket should be fitted.

The helmet valves and fittings must frequently be overhauled and the parts of valves lightly oiled. The proper functioning of the safety valve is most important, and these shall always be carefully tested before a diver is permitted to descend. To test a safety valve, screw it on to the end of an air hose, in the reverse manner, attach the length of hose to a diving pump, pump air into the hose at considerable pressure, immerse the valve in water, and note if any bubbles of air issue from the valve. If none appear the valve is tight; if not tight, a new valve leather, spring, or both, should be renewed and the test repeated. When screwed in place on the air connection of the helmet, the valve should be tried to see that it works freely and seats smartly upon release of pressure; verdigris sometimes causes the valve to be sluggish in its action; the spring may be weak or the follower nut not screwed all the way down. If these precautions are carefully observed, the safety valve can be absolutely depended upon in an emergency; however, if neglected, and the safety valve were to fail at a critical time, the result would be disastrous.

Especial care should be exercised to see that the metal clamps of the breastplate do not become bent or injured, thus saving an endless amount of trouble in making a tight joint at the junction of the diving dress and breastplate.

Dresses.—After use, the diving dresses shall be cleared of mud, etc., and, if wet, turned inside out, and hung up in the shade to dry; if used in salt water they should be washed off in fresh water. When dry they should be turned right side out and hung up in the locker or diving room. On no account must they ever be packed away in a damp state; they must be thoroughly dried inside and out, otherwise they will mildew and become rotten.

The following is an easy and efficient mode of drying the diving dress:

Take two wooden battens about 8 feet long, secure them together in the form of St. Andrew's cross, place them inside the dress, and pass another through the arms to keep them distended. The dress can then be leaned at a slight angle until it is dry.

In case a diver urinates in a dress it should be turned inside out, washed with clean water, and then allowed to dry.

When diving dresses are to be worn for rough work, the canvas overalls shall be worn over them as a protection against chafe and wear. Repair cloth is provided for patching diving dresses when necessary. To patch a diving dress, the defective portions to be cemented must be thoroughly dry and free from dirt or grease; lift the surface cloth by loosening with benzine; then roughen the under rubber surface of the dress with sand or emery paper; coat the exposed roughened rubber surface with three coats of rubber cement, allowing each coat to dry 45 minutes. Prepare the patch by cutting a piece of the repair cloth about 1 inch larger on all sides than the exposed rubber surface on the dress to be patched; remove sheeting wrapping protection cloth from the patch; loosening, if tightly adhered, with benzine; then swab exposed surface with benzine, and apply one thin coat of rubber cement, allowing same to dry for 45 minutes. Next lay the edge of the patch on the exposed rubber cemented surface of the dress, then gradually work the patch down onto the dress, using the fingers so as to remove all wrinkles and air bubbles. Next subject the repaired part to pressure either by the use of a hand roller, rolling tool, or flatiron. If any part of the edge of the patch does not appear to be thoroughly adhered and is inclined to curl, trim the loose part with sharp scissors.

New rubber cuffs are attached in the same manner that a patch is applied, except that the edges are recemented, if necessary, and a thin strip of repair cloth is cemented on over the joint formed at the end of the sleeve and the edge of the cuff.

New rubber collars are sewn onto the inside layer of cloth in addition to being cemented in place.

If a bolt hole should be torn in the collar, the tear should be sewn together with herringbone stitches, the needle holes filled with rubber cement and allowed to dry, when a patch should be cemented around the injured hole on either side of the collar.

A common mistake made by most divers is to wear a diving dress that is too small for them; this restricts their freedom of movement and strains the dress; it is better to have a dress too large rather than too small.

To fit a diving dress, with blank collar, onto a diving helmet, proceed as follows:

Remove the helmet from the breastplate and take off the four metal clamps. Set a pair of dividers to fifteen-sixteenths inch and with them draw a line on the rubber collar seven-eighths inch from the upper edge all the way around. Obtain the place of the first hole by marking a cross on the line drawn round the rubber collar exactly opposite the seam on the front of the dress. Punch this hole with a punch making a seven-eighths-inch hole. Put the dress on the breastplate, putting the front center stud through the hole. Bring the line on the collar over the center stud in the back, mark the place for the back center stud, being careful that the dress is evenly divided on either side, remove the breastplate, and punch the hole. Replace the dress on breastplate, putting the center studs at the front and back through their respective holes. Using the line on the rubber collar as a guide, even up the collar over the remaining studs, and mark the place of the center shoulder holes, remove the breastplate, and punch them. Continue the procedure until all the remaining holes have been punched. During the operation of punching the collar of a diving dress to fit a helmet, if it should be found that there is going to be some slack in the collar, it should be evenly distributed between the holes. Usually the collar, if punched according to these directions, will lie flat on the breastplate, the holes being exactly on the line drawn with the dividers seven-eighths inch from the edge; however, with an odd-sized collar it may be necessary to punch the back and shoulder holes a little off the line to make the collar lie flat.

Telephones.—If handled with care and intelligence, the standard telephone gear will last a whole commission and be of the greatest use in connection with diving operations. The essential thing is to keep water or moisture out of the instruments and thus prevent them from rusting. Like everything else, they must be thoroughly dry before being packed away. Always keep the battery box closed if it is raining, and if a helmet is in the boat but not in use, do not let the rain or spray get inside it, but close the faceplate and stand it right side up.

Continuity of the circuit may fail through the wires breaking a few inches from either end of the combination life line and telephone cable; care must be taken to prevent the line getting a sharp nip or bend at these points. In case this happens the only remedy is to cut off the injured end and replace the couplings.

Trouble occurs through trying to force the spills into the wrong holes when connecting the cable to the helmet or battery box, or through violently shaking at the cable when trying to disconnect it. Good contact must be got by keeping the spills and connections bright and clean (not oiled). It is of no avail to use two hands on the telephone spanner and try to obtain contact by brute force.

After a day's diving, if the telephone has got out of order, it should be sent to the electrical gunner for repair at once, and never stowed away unless it is in thorough working order. The telephone cables deteriorate rapidly if stowed away in a damp state, and special care shall be taken to preserve them.

Air pumps.—Before putting a pump away it should be tested, and repaired if necessary, the water cistern drained and cleaned of any excess oil or grease. The wheels should be unshipped, and the shaft-protecting caps bolted in place.

A common error is the use of an excessive amount of oil in the cylinders of diving pumps; this causes oil to be carried over into the air hose, and oil or grease causes rapid deterioration of any rubber material with which it comes in contact.

On each cylinder cover of a diving air pump is a small oil cup for lubricating the pistons, which is done as follows:

A piston is brought to the top of its cylinder, the oil cup filled with neat's-foot oil (nonodorous), and the cup is then opened. The crank is revolved until the piston is forced to the bottom of the cylinder, sucking in the oil as it descends. The oil cock is then closed; if the cock were left open the cylinder would deliver no air on the upstroke. When the pump is in use, one such oiling for each cylinder per day is ample; when laid up, once a month will suffice. During the operation of a diving air pump a few drops of lubricating oil should be placed in each of the crank-shaft bearing oil cups. The piston rods should also be lightly oiled; however, nothing but neat's-foot oil or a mixture of neat s-foot and olive oils in equal parts should be used for this purpose, lest an injurious oil work its way into the cylinders, contaminate the air, and affect the divers. Once a month, and oftener if they have been used much, the air reservoir cover plates of diving pumps should be removed, the air reservoirs thoroughly cleaned of excess oil or grease, and the bottom outlet valves looked after.

The diver s air hose should not be connected direct to the delivery nozzles of a diving pump but to the oil separators, as shown in the illustration, Plate XVII, see page 38.

Diving air pumps are designed to deliver a specified volume of free air per cylinder per revolution of the flywheel; however, when the volume of air delivered by an air pump is measured, the actual capacity of the pump never equals the designed capacity. This is due to waste room in the pump, leakage, etc. The designed or calculative capacity is termed the theoretical capacity, and the difference between the theoretical capacity and its actual capacity is referred to as loss of efficiency.

Hence, if a diving air pump is rated as 80 per cent efficient when pumping air against a pressure of 100 pounds per square inch, its loss of efficiency would be 20 per cent of its theoretical capacity, measured under the same conditions. The efficiency of an air pump varies inversely as the pressure of the air being delivered, and conversely as the speed of operation, i. e., it will deliver a greater volume of air at low pressure and high speed than it will deliver at high pressure and low speed. At high pressures, when a greater volume of air must be taken in by the pumps to force the requisite volume down to the diver, and where the extra speed is usually required, the pump men are most likely to slow the speed and attain to the worst conditions of air-pump operation; this on account of the greater manual labor required to heave round the pumps at the high pressure. For these reasons, when a diver is working in moderately deep water and the labor of pumping becomes severe, the attendants must frequently check the speed of the pump or pumps in order that the pump men may be cautioned and the diver not subjected to bad effects due to a short air supply. It is readily apparent that, although a greater number of pump men would be required, it is more practical to run two pumps at 18 revolutions per minute against 45 pounds excess pressure per square inch than it would be to run one pump at 36 revolutions per minute against that pressure, etc.

In the first case it would be easily possible to speed up the two pumps in case of an emergency, while in the second it would be practically impossible.

A certain amount of waste room in all diving air pumps, as the piston clearances, etc., are unavoidable; however, air leaks, due to faulty pistons, worn valve leathers, poor connections, etc., can be remedied. If not remedied, the leakage of air will rapidly become worse and in time bring down the efficiency of the pump to zero when it is operated against pressure.

The percentage efficiency of a diving air pump can be practically and approximately determined by pumping air into a reservoir or air tank of known capacity, noting the number of revolutions required for the different pressures, and then making a mathematical comparison of the results thus obtained, with the theoretical capacity of the pump at the test pressures.

When:

T=Theoretical capacity of pump in cubic inches per revolution.
P=Test pressure in pounds per square inch by gauge.
C=Capacity of test tank, air hose, and air space in pump connections.
14.7=Pressure in pounds per square inch of 1 atmosphere.
R=Theoretical number of revolutions required to charge test tank to P.
X=The number of revolutions actually required to charge test tank to P.

1. $\frac{\frac{CP}{14.7}}{T}=R.$

2. $100\frac{R}{X}$=per cent efficiency.

3. 100 minus per cent efficiency=per cent loss efficiency.

The theoretical capacity of the various two-cylinder, double-acting, diving air pumps in service are as follows:

Mark I: (3¾-inch diameter cylinders, 6-inch stroke), 277.7 cubic inches.
Mark I, Model 1..
Mark I, Model 2..
Mark II..........
Mark II, Model 1 } (4-inch diameter cylinders, 6-inch stroke), 296.3 cubic inches.
Mark III: (4½-inch diameter cylinders, 7½-inch stroke), 405 cubic inches.

NOTE.—The capacities of air spaces contained in the air connections (capacity of branch pipe, gauge pipes, air reservoirs, etc.) of the Mark I; Mark I, Model 1; Mark I, Model 2; and Mark III diving air pumps are approximately 83 cubic inches each. Those for the Mark II and Mark II, Model 1, are approximately 43 cubic inches each.

The capacity of a 50-foot length of standard diving air hose (½-inch interna diameter) is 117 cubic inches.

For proving the efficiency of diving air pumps in accordance with the foregoing method, a test tank of 1 cubic foot capacity is furnished with all new outfits of diving apparatus.

In using the test tank as a reservoir for measuring the volume of air furnished by a diving pump, the capacity of the air-hose connection, between the tank and the pump, and the capacity of the air connections of the pump must be taken into consideration when computing the capacity of the testing reservoir.

For convenient reference, the following table has been compiled and shows the losses of efficiency at different percentages on different revolutions of the two-cylinder, double-acting, diving air pumps in service, when tested in the manner prescribed to 100 pounds pressure per square inch, using a test tank of 1 cubic foot capacity and a 50-foot length of air hose between the tank and a pump.

Table of revolutions, with corresponding percentages of loss of efficiency for two-cylinder, double-acting, diving air pumps, when tested at 100 pounds gauge pressure.

Revolutions.				Per cent loss of efficiency.
Mark I.	Mark I, Model 1; Mark I, Model 2.	Mark II; Mark II, Model 1.	Mark III.	
47.2	44.6	43.7	32.4	0
49.7	46.9	46.0	34.1	5
52.4	49.6	48.6	36.0	10
55.5	52.5	51.4	38.1	15
59.0	55.8	54.6	40.5	20
62.9	59.5	58.3	43.2	25
67.4	63.7	62.4	46.3	30
72.6	68.6	67.2	49.9	35
78.7	74.3	72.8	54.0	40
85.8	81.1	79.5	58.9	45
94.4	89.2	87.4	64.8	50
104.9	99.1	97.1	72.0	55
118.0	111.5	109.3	81.0	60
134.9	127.4	124.9	92.6	65
157.3	148.7	145.7	108.0	70

NOTE.—When testing air pumps for efficiency according to this method and when using a test tank of 1 cubic foot capacity, errors are easily made in recording the exact number of revolutions required for a given pressure; therefore each test should be repeated two or three times and the average results thus obtained should be taken as the true result. On account ot the heat generated when compressing air, and the consequent increase in volume due to expansion on account of the heat, cooling water should always be used in the water cistern in diving air pumps when they are being operated against pressure.

The specifications for new diving air pumps require that prior to acceptance they shall prove at least 80 per cent efficient, when tested in accordance with the foregoing method, against 100 pounds pressure per square inch by gauge, immediately after having been tested for endurance against a pressure of 100 pounds by gauge for a period of one hour.

If, after testing a diving air pump, it is found to have decreased in efficiency, more than a reasonable percentage from the above requirements, the pump should be carefully examined for air leaks, and if, after examining the valves and air connections, these are found to be tight, the cause of the additional loss of efficiency may be ascribed to the pistons, which most likely are in need of new leathers.

Fitting new piston leathers: Spare piston leathers for diving air pumps are sometimes a trifle large and when assembled on the piston can not be entered in the cylinders. In this case the piston assembled on its rod should be centered on a lathe and a light cut taken off the leathers to make the diameter of the piston equal the internal diameter of its cylinder. This operation must be done very carefully; a sharp tool must be used to turn down the piston. Also a piston must fit very neatly in the cylinder and the length of the piston must be such as to leave only a very small clearance in the cylinder, with the piston on the downstroke. If the piston is found too short, leather, paper, or thin metal disks must be added, as necessary, and if too long, some of these should be removed as necessary.

The illustration, Plate N, shows the assembly of different types of diving air-pump pistons and should be referred to, if necessary, when the pistons are to be overhauled.

Attention is particularly directed to the construction of piston shown in the illustration (Mark III), Plate N.

The diving air-pump valves, particularly the bottom outlet valves, are sometimes found to leak, due to injury of the valve leathers, dirt or grit on the valve seats, or to injury of the valve seats. These troubles are readily apparent upon inspection. An air leak around the transfer valve can be detected by the following method: Connect the testing tank to an air supply (another diving pump); place a nonreturn valve (helmet safety valve) in the air-supply line to the test tank; connect the outlet nipple of test tank to the right-hand air-delivery nozzle (opposite the transfer valve to be tested); pump air into the test tank until the gauge records considerable pressure. If all the connections are tight, the nonreturn valve does not leak, and the pressure in the tank, as indicated by the gauge, decreases steadily, it is proof that the transfer valve leaks.

A leaky transfer valve is a difficult thing to repair, and in this case the services of a skilled mechanic should be obtained.

It has been remarked that the labor of operating a hand-driven diving air pump increases much faster than the increase in pressure of air being delivered, hence if a pump is found not difficult to operate against pressure, that pump is in need of immediate repair; however, on the other hand, any one or a combination of the following conditions will unnecessarily add to the labor of pumping:

(*a*) Crank-shaft bearings, brasses set up too tight.
(*b*) A bent crank shaft.
(*c*) Stuffing-box gland nuts set up too tight.
(*d*) A bent piston rod.
(*e*) Lack of proper lubrication.
(*f*) Grit or dirt in bearings.
(*g*) Transfer valve improperly assembled.
(*h*) Pump-wheel handles too short.
(*i*) Pistons striking on down strokes.
(*j*) Pump improperly secured.

While the remedies suggest themselves, the following hints may be of value:

(*a*) Crank-shaft bearings should be set up carefully; just tight enough to prevent end play of the shaft or to eliminate knocking. If reference marks are lightly scribed across boltheads and onto a permanent part, they can be returned to their original setting without difficulty.

(*b*) If it is suspected that a crank shaft is bent, this can be determined by centering the shaft in a lathe and checking its alignment between bearings.

(*c*) To adjust the setting of stuffing-box gland nuts, slack up the nuts, blank off air-delivery nozzles, pour a little neatsfoot oil around the piston rods, revolve flywheels on pump, and watch for air leaks around the rods; air leaks will be indicated by oil bubbles. Set up on the gland nuts, a little at a time, until the leaks disappear. Occasionally the piston-rod glands should be repacked.

(*d*) See directions under (*b*).

(*e*) See paragraph on lubrication.

(*f*) Protect diving gear with canvas covers when coal is being taken aboard. Use no emery or gritty cleaning materials.

(*g*) The transfer valve may be assembled in any one of four posi tions, only one of which is the correct one. If it is incorrectly assembled, it may allow all the air from the right-hand cylinder to exhaust into the atmosphere, or, in a different position, it may blank off the right-hand cylinder entirely. It should always be tested after assembly, by moving the transfer valve-rod handle to different positions and noting if the air delivery corresponds to the markings on the direction plate under the valve-rod handle.

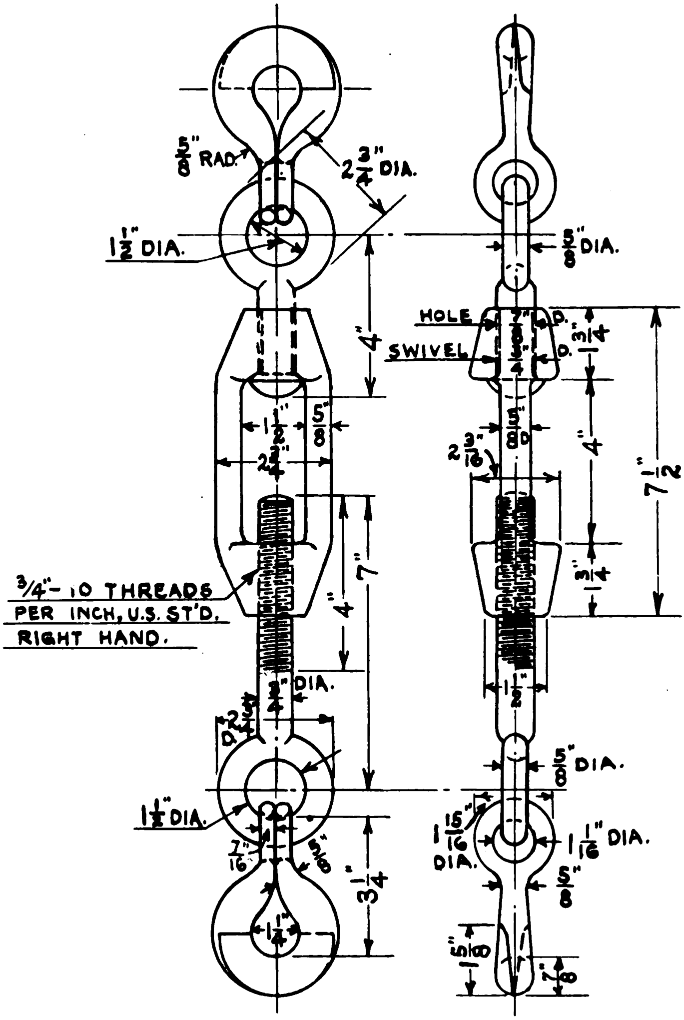
(*h*) The pump-wheel handles should accommodate two men each, at least; and, preferably, three men each. Old type or short handles can be altered by the ship's force.

(*i*) Refer to paragraph relating to instructions for fitting pump wheels.

(*j*) For testing diving air pumps, they can be secured to a wooden deck by nailing a wooden cleat to the deck on each side of and against the pump case. For the approved method of securing air pump in a diving launch, see Plates O and P.

When rigging a diving air pump preparatory to the commencement of diving operations, the nuts for pump wheels and handles should be tightened with a wrench; and if, while a diver is under water, they should become loosened, the diver should be ordered to ascend.

If there is room in the diving boat, it is always a good plan to have two pumps rigged ready for use and connected to the manifold, so



TURNBUCKLE FOR SECURING DIVING PUMPS
IN SAILING LAUNCH.
WROT IRON (GALV).

that in case of a breakdown with one pump the other may immediately be started without affecting the diver.

The following accidents have been known to happen to a diving pump while the diver was under water:

(*a*) Pump capsized during a sudden squall; not properly secured.

(*b*) Pump handle securing nut worked loose and fell off.

(*c*) Pump wheel securing nut worked off its thread.

(*d*) Piston backed off end of rod far enough to stop pump.

(*e*) Pump cover slammed shut, spilling oil can and wrench, that had negligently been left in cover; wrench jammed and stopped pump.

(*f*) Gasket under cylinder blew out and caused pump to leak badly (diving air pump, Mark II).

(*g*) Water leaked out of water cistern, due to faulty gasket; air to diver became hot, and diver forced to ascend; diver much distressed.

(*h*) Air hose improperly connected to pump; coupling unscrewed by turns in air hose straightening out, causing three divers in succession to be asphyxiated before trouble was discovered and remedied.

(*i*) Transfer valve assembled wrong, causing distress to diver.

(*j*) Valve broken in pump, causing increased loss of efficiency.

(*k*) Wrong kind of oil used in cylinders of pump, causing divers to become nauseated.

(*l*) Excessive piston leakage; divers brought to surface unconscious.

(*m*) Air reservoir cover gaskets defective, causing loss of air and distress to diver.

Accidents such as these can only occur as the result of culpable negligence, and are inexcusable.

Testing the gauges: It is most important to know the errors of the gauges on the diving pumps, especially when testing the pumps, and when decompressing a diver. The gauges should be tested once a quarter, and oftener if error is suspected, by the following method:

Connect two or more lengths of air hose together; join end of the coupled lengths to a delivery nozzle of a diving air pump; commencing at the free end, mark the hose at every 10 feet, if not already marked; attach a weight to the free end and with pump heaving round, lower the end of the hose under water until the first 10-foot mark is awash. Then stop the pump, tap the gauge; take its reading and record it. Heave round the pump again; lower the hose an additional 10 feet, take and record the gauge reading; continue process, etc.

The air hose must, of course, hang up and down in the water, so the test should be done at slack water or, if a boat is to be used, it may be allowed to drift with the tide.

The results are to be tabulated, as per the following example, and a table of the errors pasted on the inside of the cover of the pump chest, where they can readily be referred to.

Result of test of left gauge.

[Carried out Jan. 16, 1916.]

True depth.	Gauge shows.
Feet.	*Feet.*
10	15
20	24
30	33
40	43
50	52
60	62
70	71

NOTE.—The gauges on a driving air pump can be changed over so as to bring the more accurate one to the left-hand side; it is the left-hand gauge that is most used.

Air hose.—Diving air hose will deteriorate rapidly if stowed in a hot place. Special care must be exercised to protect air hose from mechanical injuries or from contact with oil or grease. It should always be tested to a pressure considerably higher than that to which the diver is to be subjected. If a long length of air hose has been in use, moisture is sure to have accumulated in it; the lengths should be separated and triced up to drain. Heavy weights should never be stowed on top of air hose. When coupling lengths of air hose together, a leather washer should always be placed in each female coupling. Air hose should not be coupled directly to the delivery nozzles of air pumps, but to the oil separator as shown in the illustration, Plate XVII, see page 38. Whenever special couplings are to be used they should be placed in the line of air hose so that they will not be under water; special couplings are intended for use in making surface connections.

In case of an injury to a length of air hose, the defective portions may be cut out and the ends recoupled.

Rubber goods.—All rubber goods should be carefully protected from excessive heat, and should not be kept folded more than necessary.

Rubber materials when folded acquire a permanent set at the bends, and, latter, when used are apt to crack open or break at these points.

On account of the fact that oil or grease is specially destructive to rubber, parts of diving apparatus composed of rubber must be protected from oil or grease in any form whatsoever. Diving dresses, and other parts consisting of rubber with cloth coverings or cloth insertions, must never be put away while damp or wet.

The instructions for making repairs to diving dresses also apply to other rubber or rubberized materials.

Leather goods.—Unless properly cared for, leather articles used in water will soon become dry and hard and liable to crack. Finished leather contains a certain amount of oil or grease, and, when this is washed out, the leather loses its flexible quality and will soon show signs of deterioration.

Occasionally the leather parts of diving apparatus should be given a coat of neat's-foot oil well rubbed in, so that the articles will not be disagreeable to handle.

Metal parts.—All metal parts of diving apparatus should be kept free of rust or verdigris, in efficient working order, and protected from injury. Special precautions are to be taken with valves, valve seats, and like parts. Parts not kept painted, polished, or galvanized should be kept lightly coated with sperm oil.

Cottons and woolens.—All cotton and woolen goods should be kept clean and dry and in repair. Dirty woolens should be washed with soap and tepid fresh water, thoroughly rinsed of soap, and carefully dried.

CHAPTER VII.

PREPARATIONS AND ARRANGEMENTS FOR DIVING, SIGNALS, ETC.

THE DIVING APPARATUS.

Soon after the commissioning of a vessel, the diving apparatus shall be carefully inspected, tested, and made ready for immediate use in every detail. It shall, thereafter, be maintained in the best possible state of efficiency.

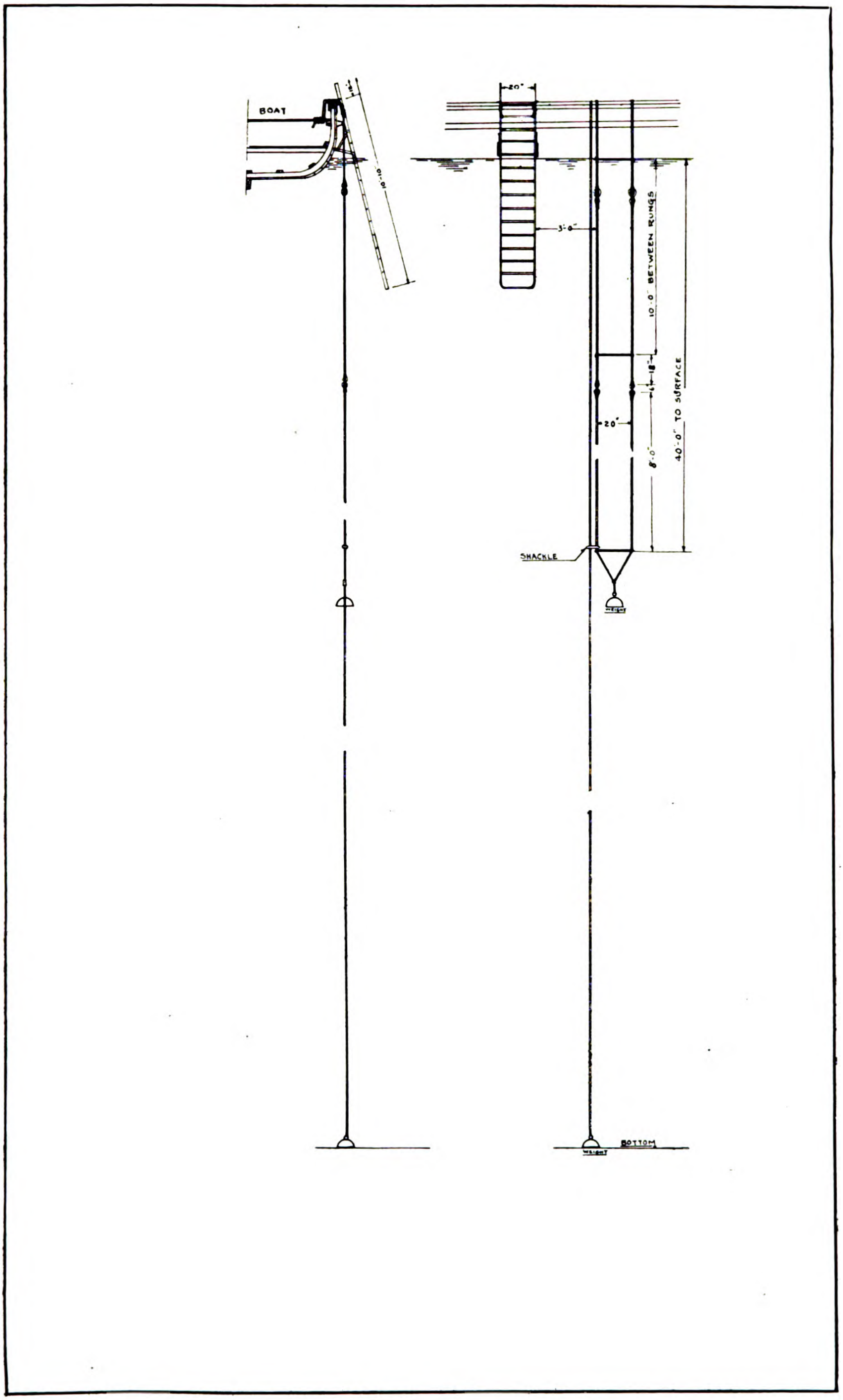
SPECIAL GEAR.

The following special gear shall be prepared and kept ready for instant use:

Two descending lines, complete.
Sling for hoisting out diving gear.
Means for securing diving air pumps in diving boats. (For method see Pl. P, p. 52.)
White line stops for securing life line and air hose to breast plate.
Lashings for ladders.
List of corrections for each gauge of diving air pumps.
Four fearnaught or canvas jumpers for use with diving gear at a fire.
Rough diving log book and pencils.
Two large shackles and some small line for sliding a slate or rope down the diver's life line.
Marker buoys, lines, and anchors.
Two red flags for use in diving boats.
Two slates, with pencils stopped on them, for use of divers.
Length of rope for sending down to diver.

DIVING LAUNCH.

Except for special diving work, a sailing launch, preferably a motor sailing launch, if practicable, shall always be used for diving. All sailing launches in service are to be fitted with eye pads, see Plate P, page 52 for hooking in the hook ends of the turnbuckles for securing the diving air pumps in position for operating them. In cases where these eye pads are not already fitted, they should be installed by the ship's force. The eye pads must be placed so that the diving air pump may be secured so as to leave room for the pumping crew to operate the pump, to be out of the way of the diver, the men attending him, and so the latter may have a clear view of the pump gauges.



ARRANGEMENT OF DIVING LADDERS.

PLATE R.

LE & HOSE,
IVER.

RS TELEPHONES

If practicable, the necessary fittings, chocks, etc., should also be provided so that four torpedo air flasks may be neatly stowed under the thwarts for use, in lieu of the diving pump, for supplying air to divers. The necessary high-pressure copper air tubing, connections, etc., must be fitted for connecting the torpedo air flasks to the testing tank, as indicated by the arrangement shown in the accompanying illustration, Plate R.

The method of rigging the descending line, jacob's ladder, and diving ladder over the side of a diving launch is shown in the illustration, Plate Q.

TORPEDO AIR FLASKS.

Whenever the requisite number of torpedo air flasks are obtainable it is preferable to dive with air furnished from them, and they shall be so used when deep diving is to be undertaken. The exercise heads, afterbodies, and delicate parts of the torpedo mechanism should be removed from the flasks; outlets not needed should be blanked off, etc.

Prior to being used for diving, the air flasks should be thoroughly cleaned inside of any rust, dirt, oil, or grease which would be apt to contaminate the air contained in them.

DIVING FROM VESSELS.

When diving operations are to be conducted from on board any vessel (using the vessel itself as a diving platform) the necessary air connections for the divers may be made direct to either the high or low pressure air installation on board. In any case, when diving is to be conducted in this manner, the diving hose shall be connected direct to the outlet nipple on the testing (or expansion) tank, and the inlet connection shall be of piping. High-pressure piping only shall be used when high-pressure air is to be utilized, and in every case a suitable pressure-indicating gauge shall be so installed (temporary if necessary) that it will indicate the pressure in the air supply pipe line, and be visible to the diver's attendants. The actual air pressure in the diver's air hose will be indicated by the low-pressure gauge on the testing tank.

CONTROL OF COMPRESSED AIR.

When diving with compressed air from torpedo air flasks (Pl. R) the torpedo stop valves on the flask from which air is to be used by the divers shall be opened and left open during the time the diver's helmet is being worn. The diver's air supply shall be drawn directly from the testing tank, in which the air shall be very carefully maintained at the pressure prescribed by the officer in charge.

The same general procedure shall be followed when diving is undertaken with compressed air furnished from other air reservoirs. The piping to the testing tank shall always be so arranged that, in the case of the failure of one valve the high pressure air may be controlled by a duplicate valve. In no case shall a reducing or automatic valve of any kind be placed in the air line between the diver and the air reservoir containing his air supply. On torpedo vessels a convenient air reservoir can be obtained by connecting three or more torpedo air flasks to the regular torpedo charging line, opening the stop valves on these flasks, and permitting the air to back through the line of pipe. This arrangement provides an air reservoir of the capacity of the flasks so connected together. The diving air line should then be connected to the charging line in the most convenient manner, care being taken to duplicate the controlling feature previously mentioned. As these flasks would also be directly connected to the compressor, it is evident the pressure of air in the flasks can be raised by operating the compressor.

ADVANTAGES OF DIVING WITH AIR FURNISHED BY POWER-DRIVEN COMPRESSORS.

The employment of compressed air is a marked improvement in the development of diving. The possibility is offered to supply divers at all depths with a constant and a sufficient volume of air. The diver's work is made much easier and far more safe, as he is provided with the means for instant control of his air supply, thus avoiding the complication of air regulation by signaling to a second party who must do the controlling. The labor of pumping is dispensed with and fewer men are required in the diving party, thus providing more room in the diving launch. It is the only practical method of deep diving. It is simple and easy to learn and is much to be preferred over the manually operated pump method.

NECESSARY PRECAUTIONS WITH COMPRESSED AIR.

The air supplied must be clean and pure, i. e., free of any noxious or injurious fumes, disagreeable odors, etc.

The supply of air must be ample, the instructions in Chapter III must be religiously followed in every detail, at least 25 pounds more pressure must be maintained in the testing tank than at the diver's special air-control valve in order to produce a sufficient circulation of air through the diver's helmet, and the air hose must be in good condition. In any case, whether by the compressed-air or pump method, should the diver's air supply fail him, he will suffer no immediate ill effects, providing he does not waste the air in his dress, immediately starts and continues to ascend slowly.

Divers inexperienced with the compressed-air method of diving should, before attempting serious work, first be practiced in shallow water to accustom them to the necessary valve regulations.

METHOD OF PROCEDURE.

When diving work is to be undertaken, the commanding officer shall be informed. A general plan of procedure shall be decided upon, the necessary officers and men detailed, and an effort made to conduct the operations with dispatch and efficiency. A specially qualified officer shall be placed in charge of the diving launch and divers. If he requires it, a special boat, properly manned and equipped, shall be placed at his disposal. A dinghy or other small boat properly manned and equipped shall always be assigned as a tender to each diving launch.

Sufficient men shall be detailed to manage the diving launch while the diver is under water, independent of the men required to man the diving pump and for attendants to the diver.

The following equipment must be in the diving launch before it is permitted to leave the immediate vicinity of the ship:

The requisite number of torpedo air flasks, and all necessary connections and special tools, or, if a diving air pump is to be used, it must be complete, in working order and properly secured.
Complete apparatus for two divers.
Sufficient air hose for two divers.
Two life lines.
Two telephone outfits (if supplied).
Tool box w th air-hose spanners, wing nuts, etc.
Spare washer for air hose.
Spare rubber wrist rings.
Fitted descending line and distance line.
A length of rope for sending down to diver.
Diving ladder.
Jacob's ladder for decompression.
Slate with pencil attached.
Red diving flag on staff.
Lead line.
Stadimeter.
Boat's diving anchor gear.
Boat's compass.
Hand flags for signaling.
Boat box.
Boat medical outfit.
Binoculars.
A watch for timing divers.
Long heaving line.
Large shackle.
A coil of small stuff for lashings.
A luff tackle.
Drinking water.
Other special gear as necessary.

If deep diving is to be undertaken, a medical officer should be available in case his services may be required.

If a diving pump is to be used, it should be properly lubricated, and the water cistern filled; the water in this should be changed whenever it gets warm.

The officer in charge shall see that the diver is properly dressed, the air hose and all air connections properly made, the oil cocks on pump cylinders closed, and all gear properly stowed or placed in the boat.

He shall, at all times, be responsible for the adequacy of the air supply for the divers.

He shall see that the red flag is prominently displayed when the diver is under water.

He must explain to the diver exactly what has to be done and see that he understands the routine to be followed in ascending.

He shall see that all diving times are to be taken by watch and recorded, that all changes of depth are noted, and that the gauges are read and logged every few minutes.

The following sample page from a gunner's diving note book shows the proper way of logging a dive, everything being of course written in at the time it happens, and not from memory:

Date..................................

Diver, name .... Rate..................................

Purpose of dive..

Depth.............................. REMARKS.

Left surface..........................

On bottom.............................

Called up.............................

Left bottom...........................

Reached....feet.......................

Left....feet..........................

Etc.................................. {Local conditions, speed of tide, condition of bottom, etc.

Reached surface.......................

Diver's condition.....................

Diver reported that...

....

....

When diving work is to be done about a ship's bottom, propellers, etc., the officer in charge shall superintend the rigging of all lines, or ladders that may be required for the work, and shall be responsible for their security. He is also responsible that the engine room department is notified whenever a diver is going down to the vicinity of the propellers or valves, and that the torpedo-room force is notified when the diver is working near a torpedo tube. He shall take every possible precaution to prevent a diver from falling. An efficient telephone is absolutely necessary.

When a diver is working in a place where there is danger of fouling, a second diver shall always be ready to go to his assistance. When a diver is sent under water to examine damage to a vessel, or to perform work of similar nature, have him make a sketch on a slate, of the outlines of the injury and the lines of the plating around it, with the positions of any valves or outlets in the neighborhood, and, whenever possible, actual measurements should be taken. Such a sketch, however rough, will greatly enhance the value of the diver's report, and may be of the utmost assistance to the responsible authorities who have to decide on the steps to be taken.

If working on a wreck, it is of the utmost importance to moor the diving launch so it cannot swing away from the wreck. A good plan is to start operations by mooring the wreck bow and stern with large buoy ropes, which will assist in mooring the diving boat. The great danger in diving on wrecks is that the diver may get foul, and after the tide has begun to run strongly there is not much chance of his getting clear until the next slack water. To avoid this, diving should not be attempted until there is enough light on the bottom for the diver to see well all round him. Artificial light may be necessary. Diving must be stopped directly before a change of tide; the air hose and life line must be seized together and the attendants must never allow their attention to wander. An efficient telephone is absoutely necessary.

SIGNALS BETWEEN DIVERS AND ATTENDANTS.

The following reserve code of line signals shall be carefully memorized by all divers and attendants and used in lieu of the telephone when the latter may be temporarily out of order and in cases where an apparatus is not fitted with the improved diving telephone:

FROM DIVER.

On life line:

- 1 pull means.................."I am all right."
- 2 pulls mean.................."Slack away, lower."
- 3 pulls mean.................."I am coming up."
- 4 pulls mean.................."Haul me up."
- 5 pulls mean.................."Send me a rope."
- 2–1 pulls mean................"I understand."
- 1–2–3 pulls mean.............."Send me the square mark."
- 2–1–2 pulls mean.............."Send me a slate."

On air hose:

- 1 pull means.................."More air."
- 2 pulls mean.................."Less air."
- 3 pulls mean.................."Take up slack of life line and air hose."
- 4 pulls mean.................."Haul me up ("Emergency signal")."

FROM ATTENDANT.

On life line:

- 1 pull means.................."Are you all right?"
- 2 pulls mean.................."You have come up too far; go down slowly until we stop you."
- 3 pulls mean.................."Stand by to come up."
- 4 pulls mean.................."Come up."
- 2–1 pulls mean................"I understand you."
- 2–1–2 pulls mean.............."I am sending you a slate."

On air hose:

- 1 pull means.................."Search (or remain) where you are."
- 2 pulls mean.................."Go straight ahead."
- 3 pulls mean.................."Go to the right."
- 4 pulls mean.................."Go to the left."

SPECIAL SIGNALS.

Other signals will of course be arranged to suit the exigencies of the particular work in hand. However, care must be taken not to confuse the regular code. Where the telephone is in use, all signals by hose and life line may be dispensed with.

FOUL SIGNALS.

Foul signals shall be made on either the air hose or life line. Two pulls repeated several times quickly shall mean that the diver is foul and requires the assistance of another diver; on receiving such a signal, answer it as received, but make no attempt to haul the diver up. Send the relief diver under water as soon as possible. Three pulls repeated several times in quick succession shall mean that the diver is foul, but can clear himself if left alone.

NOTES ON SIGNALS.

All signals made and received, and all sudden movements of the diver, or anything that seems to indicate that he is in difficulties, shall be reported to the officer in charge. The person receiving a signal shall repeat it as received, to show that he has understood it. A signal should never be repeated unless what is meant is clearly understood; if a wrong answer is received, the signal should be repeated until it is correctly understood. In case the diver does not answer a signal after two or more trials at frequent intervals, ask him if he is all right; if he does not now answer, haul him up to the first stop or stage of decompression and try again; if he still does not answer, there is nothing for it but to bring him to the surface. When a diver makes a signal and his attendant does not answer, it may be because there is too much line out and the signal is not received; in this case the diver should gather in the slack and repeat the signal.

The attendant must ask the diver from time to time if he is all right, and if no reply is obtained the diver must be hauled up under the direction of the officer in charge.

If the life line and air hose get turned around the descending line, it may become impossible to send or receive signals, and the turns must be taken out as soon as they are noticed. One pull on the descending line, repeated several times in quick succession, will indicate that the life line and hose are foul, and after a trial, if they can not be cleared, the diver should be hauled up. It frequently becomes necessary to pull the diver up, descending weight and all, together; in this event if the weight is heavy the diver might try to cut it adrift; time should be given him for this purpose. On account of the possibility of his lines becoming fouled around another line a diver should never be permitted to descend on a line he can not cut, thus avoiding the unnecessary chance of fouling.

Signals should not be made on a slack rope; a foot or two should be pulled up till the diver can be felt, and then the signals should be made gently but distinctly. A sudden jerk may cause harm.

It should be remembered that a diver at work may sometimes be in such a position that he can not answer a signal for several seconds; a reasonable time should be allowed him before it is repeated.

HOLDING THE LIFE LINE AND AIR HOSE.

In attending the life line and air hose the diver should be given 2 or 3 feet of slack when he is on the bottom, but not so much that he can not be felt from time to time so as to make sure that there is not too much slack out.

It is embarrassing for a diver to find his lines too taut, so that he is being continually pulled away from his work. As it is difficult for him (without the telephone) to make his attendants understand that they are holding him too tight, special care must be taken that this does not happen.

INTERPRETING SIGNALS.

Judgment must be used in interpreting signals, and the attendant must consider what they are most likely to refer to. For instance, suppose a diver is going down and you are his attendant. You should know from the gauge and the marks on the hose when he gets close to the bottom, and if you get one pull on the life line about that time it means of course that he has reached the bottom, but if you were to get one pull while the gauge and the marks on the hose should show that the diver has not yet reached the bottom, the meaning would be to "Hold on"; the diver has probably let go the descending line, or for some reason wants to be held by the life line and air hose. When the diver is on the bottom and near the descending line, also watch the latter for signals, as the diver may want it lowered or the slack taken up. If at any time there is anything seriously wrong, the diver should ask to be hauled up, by signaling four pulls on the air hose; in any other circumstances, and he wanted to be hauled up, he would make the signal on the life line. Four pulls on the air hose is the emergency signal, and the diver must never use it unless something serious has happened. There must be no delay in obeying it.

2–1 pulls on the life line is the telephone signal.

In case either the diver or attendant fails to get an answer over the telephone, he should make the telephone signal, which would indicate to the other that he is trying to talk over the telephone. He should wait a few seconds and then talk. If now no answer is received, he knows his own transmitter is out of order and it is of no further use for him to try to use it, and that he must resort to the reserve code of signals. If, on the other hand, after answering a telephone message, the same message is repeated several times, and no attention is paid to the answer, the person receiving the message should acknowledge that he understands it by making the telephone signal (2–1).

In deep water, when a strong tide is running, signaling by ordinary methods is very difficult, and, therefore, diving under these conditions should not be attempted without a telephone in good working order. Under these circumstances, if while the diver is on the bottom and the telephone should suddenly fail, the diver should ascend.

INDICATIONS OF DIVER'S AIR BUBBLES.

The air bubbles rising to the surface from the diver's helmet must be constantly kept track of. If they entirely disappear for more than a minute or two, ask the diver if he is all right and repeat the question frequently until the bubbles reappear. If the mass of bubbles appearing on the surface are moving around, there need be no fear as to the diver's physical well-being, for if he can maneuver around on the bottom he is not very sick; also the same holds good when he can be felt moving around or working by the life line; however, if he remains perfectly quiet, i. e., his bubbles remain in one spot, and he can not be felt moving by the life line, he should frequently be asked if he is all right. If a diver were working on a stage under a ship, and it were suddenly noted that the bubbles were moving rapidly in a straight line, it would indicate that he had fallen; therefore, grip all lines tightly and gather in the slack quickly; if air is being furnished by hand pumps, give the diver "more air" quickly, and then ask him if he is all right. If an affirmative reply is received, reduce the air supply to normal and await developments. In every case where there is danger of a fall to a diver, keep a tight hold on his lines and do not give out any more slack than necessary.

SIGNALING WHEN AIR HOSE AND LIFE LINE ARE SEIZED TOGETHER.

The life line and air hose are sometimes made into one line (by seizings) to lessen the danger of fouling when diving in close quarters, as in a sunken vessel. Under ordinary circumstances the following special code may be employed in lieu of the telephone, or when the latter is out of order.

FROM DIVER.

1 pulls means.................."I am all right."
2 pulls mean..................."Lower."
3 pulls mean..................."I am coming up."
4 pulls mean..................."Haul me up."
5 pulls mean..................."Send me a rope."
2–1 pulls mean................."I understand."
3–2 pulls mean................."More air."
4–3 pulls mean................."Less air."

FROM ATTENDANT.

1 pull means....................	"Are you all right?" (When diver is ascending, 1 pull means "Stop.")
2 pulls mean....................	"You have come up too far. Go down until we stop you."
3 pulls mean....................	"Stand by to come up."
4 pulls mean....................	"Come up."
2–1 pulls mean..................	"I understand you."

Foul signals to be made in the regular manner.

Four pulls repeated several times in quick succession would mean the emergency signal.

THE USE OF THE SLATE.

A slate may be used to advantage by divers for sending messages other than the usual code, or for making sketches under water, etc.

SENDING DOWN A ROPE, SLATE, OR TOOLS.

In shallow water where there is danger of the diver getting foul, the procedure in sending down a slate to a diver is as follows: On receiving signal (2–1–2) from the diver, the attendant, under the direction of the officer in charge, will stop on a slate, with pencil attached, to the life line. When all is ready the attendant will make the signal (2–1–2); when the diver will gather down the slack of the life line he will make the signal (4), followed by (1) when sufficient slack has been taken up. When the diver wishes to send an article to the surface without taking it up himself, he will make the signal (1–2–3). The attendant will secure a square mark, as a piece of bunting stopped securely in place, on the life line about 10 feet above the water. When ready he will make (2–1–2), and send the square mark to diver in the same manner as a slate would be lowered; the diver attaching the article to the life line above the square mark and sending the slack up again by the signal (4).

Before sending a rope to a diver it should be first lowered overboard and allowed to take in extra turns as it shrinks. To send it down, the same routine as for sending down a slate is followed, except that after bending it to the life line the rope is taken well forward or aft in the boat to prevent turns getting around the latter; when the diver gets the rope, he must be careful not to dip it between the life line and air hose; this he can easily prevent if the lines are fairly taut and the rope tends off at an angle.

In deep water or in a strong tideway the above method is dangerous and must not be used; instead a heavy shackle is to be shipped so as to slide down the life line, or if the air hose and life line are seized together, a shackle large enough to travel easily down the two of them must be used. If a slate or tool is being sent down it is stopped to the shackle, which is lowered by a light line. A small rope to be sent down can be bent directly to the shackle but in the case of a large rope or wire, a heaving line can be sent down by the shackle and the diver uses the heaving line to haul down the larger rope.

Also, in deep water, if a (1–2–3) signal is received from a diver, a small line will be sent down by the aid of the shackle.

It sometimes happens that when attempting to slide a shackle to the diver it does not reach him on account of the life line being turned around another line, when, after repeated attempts, if unsuccessful, the diver will of course have to ascend, and if he has been down about the limit of time allowable, another diver will have to be sent down or the diving operation delayed a sufficient length of time to make an additional descent by the same diver a safe procedure.

CHAPTER VIII.

DRESSING THE DIVER—SENDING HIM DOWN.

PRELIMINARY PREPARATIONS.

Having everything necessary in the diving launch and ready to commence diving operations, arrange the apparatus neatly and conveniently. Secure the diving ladder in position over the side to leeward. Put over the descending line abaft the ladder and leave room for the Jacob's ladder. Take a sounding and determine how many sections of Jacob's ladder are necessary. Couple them together, seize the sister hooks, place ladder in position, and shackle to descending line. The arrangement of ladders and lines is shown in the illustration, Plate P. (See page 57.) If the tide is strong, the descending line weight must be heavy enough to remain firmly on the bottom.

If a pump is used it must be placed forward in the boat and out of the way of the diver and the men attending him. The gauges shall face aft so that the diver's attendants may have a clear view of them. The pump must always be rigidly secured in place to prevent it from capsizing in case of a sudden wash, as from a passing vessel or an unexpected change in the weather. (See Chapter VII.)

The air hose, telephone cables, etc., should be neatly coiled down and clear for running; the telephone box placed in the stern of the boat and the red flag hoisted in the bow.

While the diver is dressing, the helmet should be examined, valves tested, telephone tested, decompression tables looked up, and calculations made as to the probable duration of the dive, adequacy of air supply, etc. The necessary lengths of air hose should be carefully coupled together, taking care that a washer is in place in each female coupling. Air should then be blown through to clear it of any rubber dust which it may contain, and the hose should then be tested to a pressure a little higher than that in which the diver is going to work. If leaks or defects are discovered in the air hose, the faulty section should be marked for survey and replaced by a good one.

Air pumps should always be worked in their chests and the securing nuts for wheels and handles firmly set up with a wrench. The hinged flaps covering the gauges opened, the screw cap on the overflow nozzle removed, the cistern filled with water, and the pump tested.

If air flasks are to be used, see that they are secure from rolling, that all connections are properly made, that all valves, including stop valves, are free to operate, and that the proper tools are at hand to relieve a stop valve in case it should stick in the closed position. Note the pressure in each flask, see that valves on the manifold are properly turned, and that the outlet nipples not in use are blanked off. Examine the air-control valve carefully and see that it functions properly.

DRESSING THE DIVER.

The diver first puts on the woolen shirt, drawers, and socks supplied. In cold weather he should put on additional woolens, woolen gloves, and the underjacket, to which the rubber gloves are attached. (See illustration, Pl. XIII, see page 32.)

The diver then gets into the dress with the help of the attendants; next he puts his arms into the sleeves, an assistant opening the cuffs by inserting the first and second fingers of each hand, taking care to keep his fingers straight. The diver, by pushing, forces his hand through the cuff (cuff expanders are also provided for this operation). Soapsuds rubbed on the inside of the cuffs, or dipping the cuffs and hands in fresh water, makes this operation easy and is especially necessary when the hands are covered with gloves. Next the canvas overalls are put on, then the weighted shoes. The shoulder pad is put on, then the breastplate, great care being taken that the rubber collar is not torn in putting it over the projecting studs. The bib is drawn well up, and the collar is placed over the front studs, working it over the studs in succession toward the back and alternately pulling up on the bib. Elevating the diver's arms will assist in getting the collar over the shoulder studs. In taking the collar off the studs the reverse procedure shall be followed. There is no excuse for tearing the collars and cuffs of diving dresses. The four jointing straps of the breastplate band are then put over the studs and down on the rubber collar; the wing nuts are then run onto the studs; before tightening up on the nuts the shoulder holes of the collar of the dress must be borne close up to the studs on the breastplate, and the wing nuts next on each side of those joints screwed down first, the diver holding his arms well up to assist; the wing nuts at the joints are the last to be screwed down; the overall dress is then adjusted and the diver permitted to sit down.

If wrist rings, Plate IV, figure 3, page 30, are required they are put on over the edges of the cuffs. The shoes are laced up, the lanyards well secured around the ankles, and the straps pulled tight and buckled; buckles should be outward. The telephone headgear is next put on; then the helmet, with front glass open, is screwed in place; the stop (lock pin) at back being turned down into its recess. The telephone cable, or life line, and the air hose are brought up under the right and left arm, respectively, and secured to the eyelets on the front of the breastplate by lanyards, rolling hitches being employed in making them fast.

If diving with air from torpedo air flasks, the short length of air hose, Plate IV, figure 5, page 30, and the control valve shall be in place. Air is then turned on the manifold or the pump started, as the case may be, and air admitted to the helmet so that the diver can tell that the connections are properly made by hearing the rush of air into the helmet. The telephone should now be tested by the diver.

The diver then gets on the ladder, an attendant keeping the life line and air hose well in hand, lest the diver slip and fall overboard. The weighted belt and diving knife are then put on, the belt being adjusted so that it will hang comfortably around the waist. The jock strap should be tightened, taking care that the diver can bend freely.

SENDING THE DIVER DOWN.

When the officer in charge is satisfied that all is correct and that the diver understands the signals and what he is to do, he orders the air started, the faceplate closed, and prescribes the speed of the pump or the pressure on the testing gauge.

This done, the diver descends just under water, assures himself that everything is functioning as it should, reports the fact by telephone or signal, and gets onto the descending line; the attendants assisting him and being careful to prevent a fall.

The diver grips the descending line between his legs, holding onto it with one hand, adjusting his air supply or the inflation of his dress with the other, and starts on down rapidly toward the bottom. During the descent he must be prepared to check himself as may be necessary. The diver may have to stop his descent on account of insufficient air supply, pains in the ears, or by having to approach the bottom cautiously, as, for instance, when entering a wreck.

Pain in the ears is a warning that must not be neglected, as rupture of the eardrums are threatened. The remedy is for the diver to stop his descent and to go through the motions of yawning and swallowing, or to press his nose against the wall of the helmet, thus blocking his nostrils, and make a strong effort at expiration. Relief is usually felt in a few moments, and, after which, the descent may be continued until the diver is again brought up by pain caused by an increase in pressure and the blocking of the eustachian tubes. With practice this trouble soon disappears.

It is apparent that with an insufficient air supply the diver will be subjected to a squeeze and forced to stop. This may be caused by a too rapid exhaust, or by the diver going down too fast, i. e., fast enough so that the water pressure increases faster than the increase in air pressure.

During the descent and at all times while under water there should be a lively exchange of air going on in the helmet, the diver should feel comfortable, and the inflation of the dress should be such that the helmet and attached weights are just lifted off the diver's shoulders.

To hang about on the distance line when going down wastes time and, by increasing the time under water, adds to the danger on coming up; therefore, the sooner the diver can reach his work and get through with it the better.

As the diver descends care must be taken that air is supplied to him in the correct volume and at the pressure corresponding to his increase in depth.

ADJUSTMENTS.

On arriving at the bottom the diver should hold onto the descending line for a minute or two and adjust his apparatus, the reason being that in descending the pressure of air is accelerating and when the diver comes to rest the air supply is, as a rule, either too little or too much. Generally the former condition prevails.

In either case, as previously explained, it is absolutely necessary to the diver that the inflation of his dress be exactly right. This is obtained when the helmet is just lifting the weight of the apparatus off the diver's shoulders.

Next, he must notice the ventilation of the helmet. While he is thus standing in a position of rest, his physical condition should be normal and the diver should feel comfortable. If his breathing is rapid, if he is panting for breath, perspiring unnaturally, experiencing an undue sensation of warmth or dizziness, if his eyesight is not clear, or if the helmet windows become cloudy from collected vapor, there is bound to be an accumulation of CO_2 in the helmet, and the remedy is "more air." Therefore, the diver should increase the rapidity of circulation of air through his helmet, but at the same time maintain the correct inflation of his dress.

Having adjusted his apparatus and air supply, the diver now should, with the least delay, clear his distance line and proceed to his work.

Before leaving the descending line he should note the bearing of the brightest light, the direction of the current, etc. If he can see well and is sure of his direction, he has merely to survey the field within the range of his vision, noting the formation and condition of the bottom, the trend of his lines, etc. If not, and the light is poor, he can determine its direction by facing it squarely and then turning slowly around to either side. If he turns to the right, the view out of the right side window will be dark and the view out of the left side window will be brighter. Continuing to turn, the light will be on the back of the helmet and all windows will be dark, etc. When he faces the light, all windows will be nearly evenly illuminated. Now, by remembering the direction of his work with reference to the direction of the sun while he was on the surface, it should be an easy matter for the diver to proceed in the direction desired. If, for instance, the sun shone in the left helmet window as he faced his work before starting down, the greatest amount of light should still shine in the left window. If there is no light, or the foregoing suggestions do not answer, the diver will have to depend upon the direction of the current for his guide. The slightest general movement of the body of water can always be detected by him; however, the current does not always flow in the same direction on the bottom as it dces on the surface, and consequently, should the diver start off in a wrong direction he should be warned by signal or preferably by telephone. For the purpose of guiding the diver in the right direction, a special set of signals are arranged. The direction signals refer to the diver when he is facing his descending line. For example, a signal for him to go to the right or left means that he should first face his descending line and then obey the signal.

MOVING AROUND ON THE BOTTOM.

As the diver starts along the bottom, the exertion of walking will cause him to breathe more often and deeply; hence he will have to increase his air supply to meet his increased air requirement. This applies to any kind of muscular activity, and the greater the exercise the greater the volume of air required.

In slack water the diver can travel along with ease, but as the tide or current becomes stronger an advance against it may become a difficult matter. In this case the diver will lessen the area of his body exposed to the sweep of the current if he stoops over or assumes a crawling position. The latter is the easiest one for a diver under water; however, each time he assumes a new position he shall have to look out for the regulation of the inflation of his dress.

When working in awkward positions both hands are usually employed, and at these times the use of the button on the regulating valve stem on the inside of the helmet becomes of special benefit. The diver can open the valve wide by merely pressing his chin or his head, according to the style of the helmet, against the button. The supplementary relief valve or "spit cock" is also valuable for letting out excess amounts of air which may accumulate from time to time, especially when the diver is lying on his back.

The tendency for an untrained diver is to permit too much air to flow through the helmet, and thus he wastes a great quantity, which becomes of importance when furnishing air by hand pumps. It also renders communication by telephone more difficult.

It is always a safe rule for the novice to go slow and cautiously for the purpose of conserving his strength. When he feels the slightest symptoms of distress he should stop still, rest, and think the situation over carefully.

Inexpert divers have been known to actually worry themselves to death over very simple circumstances. Such a state of mind is both needless and useless. A diver should never make the foolish mistake of running away from his air supply, and consequently from safety, i. e., to become panic stricken and make violent exertions to escape from a tangle, when the proper course is to go slow and deliberately. When in trouble he should slow down his exertions and, if relief is not immediate, rest awhile. No matter how serious the situation appears, a diver should remember that there was a way into his predicament, hence there is also a way out of it, and if he can not solve the problem himself that the relief diver and his friends on the surface will.

CHAPTER IX.

PROCEDURE ON THE BOTTOM, METHODS OF DOING WORK, ETC.

SEARCHING FOR LOST ARTICLES.

The diver should explore the whole of the ground within the sweep of his distance line as thoroughly and expeditiously as possible. To do this, he should take up the distance line and go to leeward of the descending line weight as far as he can see clearly, then, coiling the distance line in one hand and keeping it taut with the other, sweep around in a circle. When he comes back to the place he started from (which must be judged by some object on the ground, his own footprints, the direction of the tide, a line stretched along the bottom for the purpose, etc.), he fleets out a short distance along the distance line, and makes a fresh circle *in the opposite direction*, thus avoiding the twisting of his air hose and life line around the descending line. It is generally more advantageous to crawl on the bottom when searching, though in exceptionally clear water a better field of vision may be obtained by walking. The diver should not fleet out too much, but should let each new circle just overlap the preceding one.

When a diver has explored the whole of the ground in this way without finding the object sought for, he may be certain that it is not within the reach of the distance line, and the next step would be to move the diving launch so that a new area may be searched.

Each time before the diving launch is moved its position should be marked by a buoy, so that the search may be systematic. When a number of buoys have been thus planted over a considerable area, the unimportant ones may be removed by the dinghy's crew; the important ones marking the boundary of the explored area to remain until the search is completed.

Crawling about the bottom at random, in any direction, on the chance of stumbling upon the object sought for, is *not* the proper method of searching; however long the process is continued, there can be no certainty that the object of the search is not lying within the area that has been so carelessly searched. Some systematic method and well-thought-out plan should always be followed, and will save labor and time in the end.

The diver may not be able to make a complete circle if there is much tide or current, and in this case it may be necessary for him to simply work back and forth across the tide as far as he can reach, each time fleeting out a little farther along the distance line, until he reaches the end, and then having the boat shifted.

On good bottoms it is sometimes advantageous to let the diver trail along behind the diving launch as it drifts with the tide. In this method the anchor should be lifted just clear of the bottom and kept ready for letting go; the distance line weight should be trailed along on the bottom if the tide is strong, or else just clear of the bottom; the diver should be held to a short scope of lines, and on the alert to clear any obstruction on the bottom or to telephone the instant he sights the object sought for. A buoy should be kept ready to mark the spot in case the object is located. On receiving the signal from the diver to stop, the distance line and the diver's life line and air hose should be paid out so that he may remain as close to the object as possible; a buoy should be immediately dropped, but clear of the diver, to mark the location; the anchor should be lowered to the bottom to stop the boat, and when the headway has been overcome, the anchor line should be paid out and the boat hauled over the diver by the descending line.

Also, divers can sometimes be towed successfully along the bottom on a sled, but this method is somewhat dangerous to the diver unless he has a telephone and provision is made to stop the boat the moment the diver signals to do so, it being apparent that in unknown waters there is always a chance of running into some obstruction and fouling the diver.

An efficient method of stopping the headway of a boat is by the use of oars and at the same time dragging a weight.

Still another method of searching is to plant two large buoys a long distance apart. A surface line of 21-thread manila rope is stretched between the two buoys, and the diving launch, with diver on bottom, is then ferried along, the surface line being taken over the bow and stern rollers of the launch, the boat being given headway by pulling on the line, or stopped by holding on to it, according to signal from the diver. The advantage of this method is that the speed of the boat is always under exact control. In places where there is no tide or current, a diving launch may be maneuvered very satisfactorily under oars or by kedging.

On finding the thing sought for, the diver should immediately fasten his distance line to it if possible, after which he may signal for a rope and have it hauled up, or go up and make his report, as circumstances may require. The object can always be found again by the distance line.

DISTANCE LINE LOST.

Should the distance line be lost in the dark, the diver should feel carefully all round himself before moving. He should not waste time by searching about for it, but should signal that he is coming up, and when ready, ask to be hauled up. If there is a telephone, he should ask the attendant to keep his hose and telephone cable close to the descending line. As the attendants haul him up, he will most likely meet the descending line, when he can signal "Hold on" and "Lower," and then go back to his work.

GETTING FOULED.

If the diver finds that he is foul, he shouldn't get excited, but should think the matter over and try to remember how he got foul before he starts dipping his lines, etc. He should clear himself without hurry; violent exercise will daze him and make things worse. The distance line is a safe guide and will generally show the way out of a tangle. He should not let it go if he can help it. If signals can be got through, it is usually well for the diver to get the attendants to take up the slack of the air hose and life line. An air hose should never be subjected to a heavy strain, lest it be parted. If it is found that the air hose is clear there is never any real danger, for all other lines can be severed; either by the diver or relief divers. If the diver can not get clear, he should take a rest and await developments. The last resource is to send a relief diver down with a spare life line and air hose. The relief diver should first hand the fouled diver the new life line, or fasten it around him; next he should see that the nearest hose coupling is clear, and, after closing the helmet exhaust, uncouple the fouled air hose and couple on the new one. A fouled diver will, of course, assist the relief diver as much as possible. Clearing a fouled diver is simply a case of seamanship and there are few possible cases of divers becoming fouled under water when they can not be cleared easily, providing good judgment is used.

GOING TO THE ASSISTANCE OF A FOULED DIVER.

The first essential thing is to get a clear line around the fouled diver. Afterwards his life line and air hose may be underrun and an effort made to clear them. The relief diver must be careful not to complicate matters by getting his own lines turned around those of the fouled diver.

LEAK STOPPING, ETC.

Collision mats, patent leak stoppers, mattresses, canvas, swabs, cotton waste, caulking, wooden wedges, cofferdams, etc., have all been used successfully in making emergency repairs to the injured hulls of vessels. For stopping small leaks caused by shot holes, damaged valve inlets, scuttles, or openings in the hull or deck of a wreck being salved, the appliances described below are valuable. An iron plate large enough to cover the damage, a soft grommet to act as caulking, and three or four hook bolts with nuts to hold the contrivance in place will answer the purpose for closing a medium sized hole.

If the ship's plates around the hole are badly dented, a very soft grommet must be used, and it may be necessary to insert additional caulking after the cover plate has been screwed down.

A good way to make the grommet is to use tow and tallow well kneaded and worked together and then parcelled round with cloth or bandages. Where the ship's plating round a hole is quite flat, a rubber gasket may be used instead of a grommet. The number of hook bolts to be used depends on the area of the hole to be stopped, and it is well to have five or six holes drilled in the plate; those not required are easily plugged with wooden bungs. The hook bolts must be of the best material, so that they shall not give way when the heavy strain of screwing down water-tight comes on them. The hook itself must be fairly large as a holdfast may not be obtainable close to the edge of a hole.

Large holes are patched by the use of planking, held in place by hook bolts at the ends of each plank. Large iron washers are used under the heads of the bolts to prevent the planks from splitting. After one layer of planks has been secured in place over the opening, a second layer of planks, nailed to the one underneath, crossing the hole in the opposite direction, may be placed in position, and a covering of canvas spread over the wooden work. A patch of this kind should be additionally secured in place by binding turns of a wire cable completely round the outside of the vessel, heaving each turn very taut with the aid of deck winches, tackles, etc.

WORKING ON SHIPS' BOTTOMS.

For divers to accomplish work on a ship's bottom, a good deal depends on the proper rigging of lines, ladders, stages, etc. Two or more jacob's ladders lashed together side by side and weighted at the lower ends form a convenient arrangement to enable divers to work over the side of a vessel. If the ladder is hung from the ends of spars secured on deck and projected about 2 feet clear of the ship's side, the ladder is hauled under the bottom by hogging lines, the divers will have room to work, be able to move around freely, and be protected from falling, they of course being on the inboard side of the ladder. For working beneath the bilge keels of large vessels where the bottom is usually flat, a good plan is to lace a net between two jacob's ladders. The two ladders are separated by spars lashed in place so as to stretch the net, and the whole is passed under the keel by the aid of hogging and tricing lines. The diver can then lie back in the net and work on the bottom above him with comparative ease. When a diver is working under a ship, all lines, etc., must be carefully attended.

Another method of rigging a stage which is very quickly made and has been found very suitable for the use of divers working on a ship's bottom is as follows:

Two long spars, 20 to 25 feet long, are suspended from each other about 4 feet apart by means of two long ropes. The bights being clove hitched around the end of each spar, the upper ends forming the tricing lines, and the lower ends the hogging lines. The tricing lines are to take the weight of the stage, and the hogging lines are for holding it down and binding it in to the ship's side. A third spar about 16 feet long is hung to the lower of the two long spars by means of a slung weight, so as to keep it in a horizontal position about 3 feet below the lower long spar; sufficient weight being hung to the stage to overcome its buoyancy. To prevent the stage being bound too close to the ship's side, crosses of wood can be used, made from any rough pieces about 3½ feet long, and secured in the form of a cross. One of these crosses is secured at each end of the upper spar; a small cleat nailed on the spar prevents the crosses from slipping inwards, and the clove hitches of the stage ropes prevent them from slipping outwards. This stage is suitable for two divers, and the stage can be raised or lowered bodily, the diver at each end making his own signals. When it is desired to fleet the stage the divers should come to the surface.

CLEARING PROPELLERS AND VALVES.

Propellers usually get fouled by rope or wire hawsers, and at times are most difficult to clear. A stage should be rigged near the foul part (an iron grating will answer the purpose) to enable the diver to work in comfort.

First, the fouling should be thoroughly examined to see if it is possible to clear an end; if so, and if the turns are jammed, ropes ends or tackles from the surface must be got down and put on to break them out. Back turns can be taken, or the propeller turned by the jacking engine to insure the lead of the tackle being at its best, the diver and stage being out of the way when the propeller is being turned. If no end can be exposed, then the hawser must be cut with a sharp chisel or saw. This, however, is a tedious job with a steel wire. The engineer officer on duty must always be informed whenever a diver is working about the propellers.

Valves, as a rule, can be easily cleared from the outside by means of a wire brush and a pricker to clear the holes. If barnacles have gathered inside the perforated covering, the grating must be taken off to destroy them. The position of the grating should be marked before removal to facilitate its replacement. In case of the removal of a valve, after the securing plate has been taken off, the hole plugged up, and the plug cut off flush with the ship's side, the outside should be covered with wood, lined with greased fearnaught to prevent any leakage inboard. If the valve is only to be kept out a short time, this covering need only be temporarily fastened, as the pressure of the water on the outside keeps it in place.

RECOVERY OF AN ANCHOR OR HEAVY WEIGHT.

If going down to recover an anchor, the buoy of which is still watching, the buoy rope should be hauled up and down and the descending line weight dropped close alongside it.

The diver can then go down his descending line, keeping the buoy rope in hand as he descends. This will prevent him taking turns around the buoy rope.

If a wire hawser has to be shackled onto an anchor, the task may be accomplished in the following manner:

Prepare the wire by fitting a large shackle to the eye and by stopping another shackle with its crown against the wire a short distance above the eye. The pins of both shackles should be fitted with lanyards to prevent their loss under water. Shackle the wire to the descending line or to the anchor buoy rope (if watching) by the upper shackle, which will act as a traveler, leaving the end of the wire free for the diver to handle. When the diver has found the anchor, he should signal for the wire, which should be carefully lowered to him, great care being taken to prevent the wire being dropped on the diver or too much being paid out, since large flakes on the bottom render it difficult to find the end and may foul the diver. After shackling on, the diver must come up before any attempt is made to weigh the anchor.

If the anchor is any distance from the descending line, or the buoy is not watching, the diver should bend his descending line on, or get another rope bent on, so that the lifting wire may come down exactly where it is needed. The same applies for raising other heavy weights, such as guns, torpedo tubes, etc., from a wreck.

DIVING ABOUT MOORINGS.

When working about moorings, a diver should be especially careful not to get foul. He should not dip under chains, etc., without having a distance line to show him the way back. Old moorings are often covered with sharp barnacles, and gloves should be worn to protect the hands. A diver should never descend on a chain or wire if it is possible to do otherwise. Never permit a chain, wire, or other line or weight to be veered, lifted, or moved until the diver is clear of them.

When a diver is required to work with several lines, it is a good plan to have each one of a different size or material so that he may know one from the other and what each one is for. He should never cut a line until he has made certain what he is cutting. Before sending a line to a diver it should first be lowered in the water by means of a weight attached to its end and allowed to remain a considerable length of time before it is sent to the diver. When rope is lowered under water it shrinks and takes several new turns in it, due to the manner of its construction. If lowered alongside another line without taking this precaution it is sure to become foul. For underwater work cable-laid rope is the safest and most useful.

THE DIVER IN A TIDEWAY.

It should be remembered that there may be much less tide on the bottom than at the surface; therefore it is generally worth while to make an attempt at diving although the tide seems very strong. When going up or down the descending line in a tideway the diver should keep his back to the tide, so that he will be pressed up to the descending line and not away from it. It is not difficult for him to maintain this position if he watches which way the tide tends to swing him around and pushes the descending line over to one side or the other so as to check the movement. In strong tides it may be impossible to cling on to a descending line, much less climb up if he keeps on the wrong side. The best plan is for him to ask the attendants to pull him up if he finds it is a struggle to ascend. On the bottom, in a tideway, a diver should hang on to the distance line at all costs, crouch close to the ground so as to offer as little surface as possible, and maintain as much negative buoyancy as reasonable comfort and breathing will allow.

GUARDING AGAINST FALLS.

Whenever a diver is working clear of the bottom, as on a ship's bottom, he should never run the risk of falling off, but should always have something substantial to hold on to and make the attendants keep the life line and air hose well in hand. He should never go under the keel of a ship and up the other side; if it is necessary to work on the other side, he should ask to have the boat shifted. It is dangerous for a diver to hold on to something overhead and climb around in that manner if he is far from the ground; all the air in the dress may escape out the cuffs, and in that case he may become so heavy as to precipitate a fall.

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THE DIVER ON A MUDDY BOTTOM.

If a diver finds himself on a muddy bottom, he should not flounder around and stir up the silt; a cloud of mud will prevent him from seeing anything. For the same reason he should keep the lee side of his work if there is any current. If the bottom is very soft, he should spread himself out over it and not try to stand. He should make himself light by keeping plenty of air in the dress. By opening a cuff or elevating an arm and permitting excess air to escape, he may rid himself of excess buoyancy. If he sinks deeply in the mud, it is because of negative buoyancy; positive buoyancy will take him out; however, he should operate very slowly and cautiously. He should wiggle out of the mud as gradually as he can; otherwise, as he breaks loose, he is apt to be "blown up." When it is found that the mud is very soft, a good plan is to have a wooden grating under the diver, weighted so that it will have slight negative buoyancy. The action of the grating in this case is analogous to that of a snowshoe.

Divers have been known to work under many feet of mud and silt for long periods without discomfort. There is nothing to fear about mud, quicksand, and the like. On account of being in a substance of greater consistency than water, movements must, necessarily, be more deliberate, and, by the absence of light, all work must be accomplished by the sense of touch. In some localities, such as around piers and dockyards, much débris falls overboard, and there are apt to be old tin cans, bottles, etc., in the mud. These, of course, should be looked out for, and it may be necessary to protect the hands by a pair of ordinary leather gloves. These should fit well, so as not to lessen or restrict the use of the fingers.

THE DIVER ON A ROCKY BOTTOM.

On a rocky bottom the diver should be careful not to fall off a ledge of rock into deeper water, nor get his arm or leg caught in a crevice. If he should fall, he should open wide the air-control valve, or telephone the attendant to "Hold on," at the same time closing off the exhaust from the helmet. This rule, of course, also applies to a fall under any other circumstances. If the rocks are sharp, as coral usually is, the diver should wear gloves. He should watch his air hose, so that it will not catch a turn around a rock, and should caution the attendant about keeping the slack well in hand. If the diver's lines get fouled, he should gather them up and retrace his steps by following the lead of the air hose and life line. If they happen to become fouled in opposite directions, he should ask the attendant to take in the slack on one of them; then the other. It is almost sure one will be clear. In the event they are both actually fouled and there is no other resource left, he should cut the telephone cable or life line, then follow up the air hose and clear it. Never permit too much strain to be put on a fouled air hose, lest it be parted.

A safe plan when working in places under water where there is danger of fouling is to seize the life line and air hose together with untarred marline stops about 3 feet apart. If the tide is very strong, it may be even necessary to replace the telephone cable by three strands of bell wire laid up into a cable and seized every 2 feet by sail-twine stops to a 12 or 15 thread manila line; the improvised cable being seized, every third foot, to the air hose.

SLIPPING THE WEIGHTED BELT.

The weighted belt can easily be slipped; the waist buckle and jock strap being let go first, and then the shoulder straps. The only occasion when a diver might need to do this would be when an accident had occurred to the air supply, which would prevent him getting enough air in the dress to ascend otherwise. The weighted belt must not be slipped except as a last resource, as a diver is helpleess without it.

WORKING AROUND CORNERS, ETC.

When a diver is required to drag a long length of life line and air hose after him, or when it is necessary for him to work around several corners, additional divers should be sent under water to lighten his lines along for him and to tend him. For instance, if his telephone should fail accidentally, he would send signals to the diver tending his lines, who, in turn, would transmit them to the surface over the first diver's lines, using his own lines only for signals affecting himself.

THE DIVING APPARATUS IN CASE OF FIRE.

The diving gear provides a good, safe smoke helmet for use in fires, or in bunkers, etc., where poisonous gases may have accumulated.

A jumper should be made, fitted at the neck to take over the studs of the breastplate, and at the bottom and cuffs it should be fitted with strings to tie the jumper close to the body and wrists. The jumper should be attached to the breastplate when the diving gear is not in use, and kept in its chest, near the air pump, with helmet and air hose screwed on. In case of fire, a diver could put on the jumper and proceed to the fire, other men following with the pump and placing it in position; the air hose from the helmet being screwed to the left air-delivery nozzle, when, with two men to heave round, the diver would get a plentiful supply of air.

The diver should, of course, wear ordinary shoes and his clothes should be wetted.

CHAPTER X.

THE MANAGEMENT OF THE ASCENT.

The cardinal essential point in connection with the ascent of a diver is a proper and efficient decompression, so managed as to eliminate the possibility of caisson disease. For diving, the most efficient practicable method of decompression is that known as stage decompression.

The following tables are constructed on this theory and have been proved safe. While they are not guaranteed to protect a diver from a moderate attack of "bends," a diver decompressed in accordance with them will be spared from any serious attack of caisson disease.

In all diving operations, *decompression*, i. e., ascent in accordance with these tables, *shall be strictly followed* and, except in special exigency, *no diver shall be brought to the surface faster than the time specified.*

Decompression Table No. 1.

Ordinary time limits in deep water and stoppages to be made during ascent.

Depth.	Time under water, i. e., from surface to beginning of ascent.	Stoppages at different depths (in minutes).									Total time for ascent.
		90 feet.	80 feet.	70 feet.	60 feet.	50 feet.	40 feet.	30 feet.	20 feet.	10 feet.	
Feet.											*Minutes.*
0–36	No limit										0–1
36–42	Up to 3 hours										1–1½
	Over 3 hours									5	6
42–48	Up to 1 hour										1½
	1 to 3 hours									5	6½
	Over 3 hours									10	11½
48–54	Up to ½ hour										2
	½ to 1½ hours									5	7
	1½ to 3 hours									10	12
	Over 3 hours									20	22
54–60	Up to 20 minutes										2
	20 minutes to ¾ hour									5	7
	¾ to 1½ hours									10	12
	1½ to 3 hours								5	15	22
	Over 3 hours								10	20	32
60–66	Up to 15 minutes										2
	¼ to ½ hour									5	7
	½ to 1 hour								3	10	15
	1 to 2 hours								5	15	22
	2 to 3 hours								10	20	32
66–72	Up to 15 minutes									2	4
	¼ to ½ hour								3	5	10
	½ to 1 hour								5	12	19
	1 to 2 hours								10	20	32
72–78	Up to 20 minutes									5	7
	20 to 45 minutes								5	15	22
	¾ to 1½ hours								10	20	32
78–84	Up to 20 minutes									5	7
	20 to 45 minutes								5	15	22
	¾ to 1½ hours								10	20	32
84–90	Up to 20 minutes								3	5	10
	20 to 40 minutes								5	15	22
	40 to 60 minutes							3	10	15	30
90–96	Up to 20 minutes								3	5	11
	20 to 35 minutes								5	15	22
	35 to 55 minutes							5	10	15	32
96–108	Up to 15 minutes								3	5	11
	15 to 30 minutes							3	7	10	23
	30 to 40 minutes							5	10	15	33
108–120	Up to 15 minutes							2	3	8	15
	15 to 25 minutes							5	5	10	23
	25 to 35 minutes							5	10	15	33
120–132	Up to 15 minutes							2	5	7	17
	15 to 30 minutes							5	10	15	33
132–144	Up to 12 minutes							3	5	5	16
	12 to 25 minutes						2	5	10	12	32
144–156	Up to 10 minutes							3	5	5	16
	10 to 20 minutes					2	3	5	8	10	31
156–168	Up to 10 minutes						2	3	5	5	18
	10 to 16 minutes					2	3	5	7	10	30
168–180	Up to 9 minutes						2	3	5	5	18
	9 to 14 minutes					2	3	5	7	10	30
180–192	Up to 13 minutes					2	3	5	7	10	30
192–204	Up to 12 minutes				2	2	3	5	7	10	32
204–225	Up to 10 minutes		2	2	3	5	7	10	10	15	58
225–250	Up to 10 minutes	2	2	3	5	7	10	10	15	15	73

Decompression Table No. 2.

Stoppages to be made during ascent after exceeding the ordinary limits of time on the bottom.

Depth.	Time from leaving surface to beginning of ascent.	Stoppages at different depths (in minutes).										Total time for ascent.
		100 feet.	90 feet.	80 feet.	70 feet.	60 feet.	50 feet.	40 feet.	30 feet.	20 feet.	10 feet.	
Feet.												*Minutes.*
66	Over 3 hours									10	30	42
72	2 to 3 hours									10	30	42
	Over 3 hours									20	30	52
78	1½ to 2½ hours									20	30	52
	Over 2½ hours									30	30	62
84	1½ to 2 hours									15	30	47
	2 to 3 hours								5	30	30	67
	Over 3 hours								10	30	35	77
90	1 to 1½ hours								5	15	25	47
	1½ to 2½ hours								5	30	30	67
	Over 2½ hours								20	35	35	92
96	55 minutes to 1½ hours								5	15	30	52
	1½ to 2½ hours								10	30	35	77
	Over 2½ hours								30	30	35	102
108	40 minutes to 1 hour								10	15	20	48
	1 to 2 hours							5	15	25	35	83
	Over 2 hours							15	30	35	40	122
120	35 minutes to 1 hour							5	10	15	25	57
	1 to 2 hours							10	20	30	35	97
	Over 2 hours							30	35	35	40	142
132	½ to ¾ hour							5	10	15	20	53
	¾ to 1½ hours						5	10	20	30	30	98
	Over 1½ hours						15	30	35	40	40	163
144	25 minutes to ¾ hour						3	5	10	15	25	61
	¾ to 1½ hours						10	10	20	30	35	108
	Over 1½ hours						30	30	35	40	40	178
156	20 to 35 minutes						3	5	10	20	20	61
	35 minutes to 1 hour						7	10	15	30	30	95
	Over 1 hour					20	25	30	35	40	40	193
168	16 to 30 minutes						3	5	10	15	20	56
	30 minutes to 1 hour					3	10	10	15	30	30	101
	Over 1 hour				5	25	25	30	35	40	40	203
180	14 to 20 minutes						3	3	7	10	15	41
	20 to 30 minutes					2	2	3	10	15	25	60
	30 minutes to 1 hour				3	3	7	10	20	30	35	111
	Over 1 hour				15	25	30	30	35	40	40	218
192	13 to 20 minutes						3	3	7	15	15	46
	20 to 30 minutes					3	3	5	10	15	25	64
	30 minutes to 1 hour				3	5	10	12	20	30	35	118
	Over 1 hour			5	20	25	30	30	35	40	40	228
204	12 to 20 minutes					3	3	5	7	10	20	51
	20 to 30 minutes				3	3	3	5	10	20	30	67
	30 minutes to 1 hour			3	3	5	10	15	20	30	35	124
	Over 1 hour			15	20	25	30	30	35	40	40	238
225	10 to 20 minutes			3	5	7	7	10	15	20	20	95
	20 to 30 minutes		2	3	5	7	10	15	20	25	30	121
	30 minutes to 1 hour		5	5	10	15	15	20	25	30	35	164
	Over 1 hour		10	15	20	25	30	30	35	40	40	249
250	10 to 20 minutes		2	3	5	7	10	10	15	20	30	106
	20 to 30 minutes	2	3	5	7	10	15	15	25	30	30	146
	30 minutes to 1 hour	5	5	10	15	15	20	30	30	35	40	209
	Over 1 hour	10	15	20	25	30	30	35	40	40	40	289

EXTRA PRECAUTIONS AFTER A SECOND DESCENT.

If a diver makes a second descent in deep water with an interval of less than three hours between the two dives, his body will be more highly saturated with nitrogen at the end of the second dive, and extra care will be needed in bringing him to the surface. A safe rule is to take the total combined time of the two dives and use a table for that exposure, at the pressure at which the diver was working. The extra time is, however, only needed for the second half of the stops indicated in the tables.

When a diver is ready to ascend he shall notify the attendant at the surface by telephone or signal. He shall not commence the ascent until he has received the answer from the surface, "All right, come up," by telephone or corresponding signal.

The decompression ladder shall be rigged with the bottom rung at a depth under water as shown by the decompression tables, page 138, for the depth of dive to be undertaken.

INSTRUCTION FOR ATTENDANTS.

During the ascent the attendant must at all times keep a tight hold on the diver's air hose and life line, and the slack well in hand. The attendant shall always keep himself informed as to the depth the diver is under water. This can be estimated by the length of hose out, and, in the case of the pumps, by the pressure registered on the diving gauges; the hose usually tends straight up and down, especially in the shallow depths, provided that the sweep of the current is not too great.

For the ease and comfort of the diver, a Jacob's ladder with rungs 10 feet apart is supplied for use as a decompression ladder. The ladder is shackled to the descending line so that it will be impossible for the diver to miss it on the ascent. For the method of rigging the decompression ladder, see Plates J and Q, see pages 36 and 57, respectively.

When the hose or gauge, as the case may be, indicates that the diver is approaching his decompression ladder, he shall be notified to stop, and then ascend slowly and watch out for his ladder. Special care in this respect is necessary so that the diver shall not exceed a safe limit of ascent.

As the diver ascends, care must be taken to see that the air supply is not too rapid. If pumps are used, one cylinder may be cut out for every 33 feet the diver ascends. If the compressed air is used, pressure may be allowed to fall in the low-pressure accumulator, 15 pounds for every 33 feet of the ascent; this is advisable for the following reasons:

(*a*) It lessens the danger of the diver overinflating his suit suddenly, and acquiring too much positive buoyancy, and tends to prevent "blowing up."

(*b*) Strain on the air hose is lessened and is advisable, especially if the diving is carried out in deep depths.

As soon as the diver reaches the decompression ladder and is on the bottom rung, he shall notify the surface attendants.

In selecting the decompression table for a certain dive (depth and time of exposure), the time of exposure shall include time of descent and time on bottom.

These times shall be carefully kept and recorded as per the following example:

	(a. m.)
Entered water	10.00
Started descent	10.05
On bottom	10.07
Started ascent	10.30
First stop, 50 feet	10.32
Second stop, 40 feet	10.37

This would be a 25-minute exposure, and the table calling for this exposure should be used. In deep depths the length of exposure shall be limited. This time limit shall be decided upon before the dive is made. The diver shall be given a few minutes' notice before the expiration of this limit, so that he can make the necessary preparation prior to his ascent, and not exceed his limit of stay on the bottom. Time on the bottom rung of the decompression ladder shall be noted, and as this time (stated in the decompression table) of stated depth expires, he shall be instructed to come up one rung, i. e., 10 feet; the diver notifying the surface when he is on the second rung, and the procedure followed in accordance with the tables, etc., the time on each rung being carefully recorded.

As soon as the diver reaches the surface and is on his descending ladder, the faceplate shall be opened and the air supply stopped. This must not be done, however, until the diver is secured and there is no danger of his falling back into the water.

If the diver has been working at deep depths or exposed for long periods in the shallower depths, the dress shall not be removed until a period of at least 20 minutes has elapsed. The reason for this is that if symptoms of caisson disease intervene, the diver can immediately be sent down to his first stop on the decompression ladder and again decompressed.

If a recompression chamber is at hand and ready for immediate use, the interval before removing the dress shall not be observed, but it shall be removed as rapidly as possible, and the diver kept by the recompression chamber so that in case of an onset of symptoms of caisson disease, recompression can be promptly applied within the chamber.

INSTRUCTIONS TO THE DIVER.

After receiving instructions from the surface to come up, the diver shall make preparation for his ascent at once, i. e., get over to the descending line, see that he is clear, and that there is nothing to interfere with the ascent. The next step is to throw one leg around the descending line, as in descending, so that he will be able to check himself instantly, should he suddenly attain a strong positive buoyancy by an overinflation of the dress. Then notify the surface, "All ready, coming up." In order to facilitate ascent, the diver should lighten himself by inflating the dress. This is done by screwing down on the regulating escape valve. When buoyancy is but slightly negative, the diver should come up hand over hand, not faster than a foot per second. It may be necessary to stop occasionally and let the excess air escape from the dress; buoyancy being too positive. This is done by adjustment of the regulating escape valve, and at the same time lessening the ingress of air. Excess air in the dress may be got rid of quickly by elevating an arm and letting air escape from the cuff.

Notice shall be given from the surface, when the diver approaches his safe limit of ascent, by the order "Stop, come slow, watch out for the decompression ladder." After receiving this notice, the diver shall ascend slowly and look out for the decompression ladder; the guide being the sliding shackle holding the descending line and the decompression ladder together. As soon as he finds the ladder, he shall get on the bottom rung. When he has done this, he shall notify the surface "All right, on the ladder." The diver must now make sure that he is on the bottom rung of the ladder, take exercise as best he can by moving his arms and legs, bending back and forth, etc. He shall not leave a rung until he has been instructed to do so. He shall move up only one rung at a time, and shall notify the surface as soon as he is on the rung specified, continuing his exercise, etc.

In ascending, the diver must be careful to take out all turns in his life line and air hose about the descending line; the attendants shall do all they can to help the diver in doing this.

While on the decompression ladder the diver should watch out for any untoward symptoms, as pain, dizziness, etc. These will not come on, if at all, until the diver is close to the surface. If he experiences any of these, he should notify the surface and then descend when instructed to the bottom rung of the ladder and come up one rung at a time after undergoing a second decompression time on each rung.

After the diver has reached the surface, he must be watched carefully for any symptoms of caisson disease. These may be apparent when the diver is brought up, but may not intervene for several hours. As a rule, they will appear within the first hour. Symptoms may be any of the following: Unconsciousness, vomiting, dizziness and staggers, inability to talk, weakness or paralysis of the arms or legs, asphyxia or difficult breathing. If none of these symptoms become manifest in an hour, one may feel quite sure that no serious attack will occur. If any deep work has been undertaken it is best to keep the man aboard where he can be observed by some one for at least 8 or 10 hours.

HAULING A DIVER TO THE SURFACE.

In case a diver loses his distance line and can not locate his descending line, he must not blow himself to the surface, especially if working at deep depths. If a diver finds himself in this predicament, it becomes necessary for his attendants to haul him to the surface. In this case the diver shall notify the attendant to pull him up, and not waste time searching for the descending line.

In hauling a diver to the surface, care must be taken not to bring him up too rapidly, as over inflation of the dress due to expanding air may cause him to be "blown up." Under this condition the diver should regulate the inflation of his dress so as to be heavy on the life line. The attendants should always keep the diver ascending very slowly until he reaches the decompression ladder, and cease hauling if it is found that he is becoming too light. Trouble in this respect may be experienced when a diver is unconscious or helpless. It rests entirely with the officer in charge as to the safe rate of ascent, the speed of ascent depending on the amount of air escaping from the helmet and the amount of air flowing into it. If necessary, the pumps may be stopped as the diver is hauled to the surface or extra cylinders cut out, as the case may be. *Flow of air through the helmet should never be stopped for more than four consecutive minutes at a maximum, unless the diver is ascending.*

The diver should not as a rule be brought up beyond his first stop, as indicated by the decompression tables. As the diver reaches this stage he may be worked over to the decompression ladder and, if he is sensible, no trouble will be experienced in landing him on it. In case the diver is helpless, decompression will necessarily have to be carried out at depths estimated by length of hose out or by pressure recorded on the pump gauges, with the pumps momentarily stopped in order to obtain a reading.

DEEP DIVING.

From a study of the decompression tables it will be seen that for deep depths and long exposures to high pressures, the tables are necessarily long. It is readily apparent that very deep diving is an exceptional undertaking. Where the local conditions of tide, weather, temperature of water, etc., are ideal it is not a hardship for the diver to remain for long periods upon the decompression ladder. However, where the local conditions are liable to sudden changes or where they are severe the long decompression in the water does become a hardship, and therefore it becomes absolutely necessary at times to manage the ascent of a diver from deep water as directed in the case of emergency ascents.

EMERGENCY ASCENTS.

In case of accident or special exigency it may be essential to get a diver to the surface as rapidly as possible, even if an attack of caisson disease is threatened. Under these conditions, the speed of the ascent will depend on:

(*a*) Nature of the accident or emergency.

(*b*) Depth and length of exposure at which the diver has been working.

(*c*) Whether or not means for treating or preventing an attack of caisson disease can be resorted to by sending the diver down again immediately or whether there is a recompression chamber ready for immediate use.

In any case where a diver fails to answer his telephone or signal, that diver shall be started toward the surface immediately. A pause should be made at the first stage of decompression, an attempt made at communication, then, depending on the nature of the accident or emergency, the remainder of the ascent must be according to the judgment of the officer in charge. The emergency may be serious enough to warrant immediate ascent.

If there is reason to suppose that the diver can be sent down again immediately, or a recompression chamber is ready for immediate use, a chance should be taken on a fairly rapid ascent for the remaining distance.

The record for apparent safe ascent with a recompression chamber ready for immediate use is 150 feet after a 30-minute exposure, recompression applied immediately to a pressure corresponding to 150 feet, and decompression carried out in accordance with the the tables without ill effects.

In the case of very deep diving (over 150 feet), when a recompression chamber is available and a rapid ascent becomes imperative, bring the diver at once to half the absolute pressure, keep him there for a period of 20 minutes, if at all possible, or if this be not possible, as long as practicable, then haul him to the surface, remove the helmet, life line, and air hose (cut them off the diver), place him in the recompression chamber, then proceed as directed under "Treatment of caisson disease," removing the diver's dress and equipment in the chamber.

FAILURE OF DIVER'S AIR SUPPLY.

An accident which, though remote, may happen to a diver is that of the failure of his air supply. This would be immediate cause for an ascent from any depth. It could happen from a break in the air line leading to the diver, an accident to a diving pump, or the exhaustion of the air in the air reservoir, etc.

An old air hose has been known to burst at high pressure (200 pounds); pistons, improperly secured to the rods, have been known to back off and stop the pump; but an air reservoir could only be allowed to become entirely empty due to negligence in bringing up a reserve supply of air.

In the case of injury to an air hose, the proper method of procedure is to immediately get an extra length of air hose ready to couple on in place of the injured one; start the diver toward the surface; and when the break is found, replace the injured length of hose by a good one. During this manoeuver, keep the diver ascending slowly. When the damage has been corrected, decompress the diver according to the tables.

If the diver's safety valve is in working order, there need be no fear about breaking the air hose joints, if managed quickly, as the nonreturn feature of the valve will prevent air escaping from the helmet except by way of the regulating escape valve, and the diver will have sufficient air, providing he is careful not to waste it, on account of the expansion due to diminished pressure.

In cases where the diver has been brought rapidly to the surface from deep water and a recompression chamber is not available, the safety of the diver will depend upon getting him under water and down to half the absolute pressure as quickly as possible; no matter what his physical condition may be. Under these conditions there is absolutely nothing that can be done for him under atmospheric pressure; prompt decision and rapidity of action are imperative.

THE MANAGEMENT OF THE RECOMPRESSION CHAMBER.

For the prevention and treatment of caisson disease, a recompression chamber may be had upon application. No diving operations in deep water should be carried out without one, except in case of special exigency.

The maximum safe working pressure of the portable chamber at the diving school is 120 pounds per square inch, but it is rarely necessary to subject a patient to a pressure greater than 60 pounds.

It is desirable that a medical officer or at least somebody with experience of caisson disease should go into the chamber with the patient. It is of utmost importance that there shall be no delay in getting the patient under pressure. For this reason the attendants should be trained to take pressure quickly. Dry clothing, blankets, medicines, etc., shall be kept in the chamber. In case of stoppered bottles, small openings through the corks should be made, so that pressure within and without the bottles may be equalized, and prevent them from breaking as the result of unequal pressures. No volatile or dangerous liquids shall be stored in the chamber.

An air lock is provided through which small articles may be passed in and out of the chamber.

PREVENTION OF CAISSON DISEASE.

In case a diver has made a rapid ascent from deep water, but shows no symptoms of caisson disease, he must be hurried into the chamber as soon as possible and pressure raised to 60 pounds or less, this pressure being at least half the absolute pressure at which the diver has been working. He must be kept at this pressure for at least five minutes, after which, if no symptoms have developed, he can be decompressed according to the tables, corresponding to the time and depth of the dive, with an extra five minutes added to the total diving time for time in selecting the table. Should symptoms of caisson disease develop during decompression, gradual decompression as outlined under "Treatment" should be resorted to.

TREATMENT OF CAISSON DISEASE.

If symptoms of caisson disease develop, the patient should be taken immediately into the recompression chamber and pressure run up to 45 pounds, with as little delay as possible. In most cases this will be sufficient to revive him. If, however, the patient does not show marked improvement, the pressure must be increased to 60 pounds. In one instance, 75 pounds was necessary after a 300-foot dive. The patient must be kept at this pressure until any symptoms of circulatory embarrassment or dyspnea have disappeared. Such symptoms disappear almost directly and if no other serious symptoms are present decompression may be begun at once.

If paralysis is present, and does not pass off in two hours, it is useless to wait longer at high pressures. It must be remembered that exposure in the chamber exceeding 30 pounds is likely to delay decompression very much.

Decompression should be started as soon as the patient is relieved, pressure being allowed to fall at the following rate:

When pressure in the chamber is—	Pressure may be allowed to fall at a rate not faster than—
Above 60 pounds	Rapidly.
Between 60 and 45 pounds	1 pound in 1 minute.
Between 45 and 30 pounds	1 pound in 3 minutes.
Between 30 and 15 pounds	1 pound in 5 minutes.
Below 15 pounds	1 pound in 10 minutes.

No hard and fast rule can be laid down for a decompression rate, which will depend on the condition of the patient, how he stands decompression, and also the pressure at which he was saturated. If the patient becomes ill again while the pressure is falling, decompression must be stopped, and, if necessary, the pressure raised; when the patient is better, pressure may be allowed to fall again, but at a slower rate. If after decompression the patient again develops symptoms, the process of recompression and subsequent decompression must be repeated.

CHAPTER XI.

PHYSICAL QUALIFICATION OF DIVERS, FIRST AID TO DIVERS, ETC.

A candidate to become eligible for detail to the school of training for divers must have served one enlistment in the Navy, be physically fit for duty, and of temperate habits.

In selecting divers, men of high physical standard only shall be chosen, i. e., men free from diseases of the ears, heart, lungs, and kidneys. They must possess normal blood vessels and be of good muscular development. There are two other elements to be considered in the selection of men for deep diving, viz:

1. Degree of fatness.
2. Age.

Moderately stout men and men of middle age are more disposed to caisson disease than young, slim, small, wiry men. The degree of fatness is the element most concerned. Nitrogen is absorbed by fat in much greater volume than by blood or muscle, and on decompression fat gives off its nitrogen more slowly than the other tissues. Consequently a stout person is more liable to caisson disease.

Men of middle age are more inclined to fatness, and, therefore, more predisposed to caisson disease. The respiratory exchange in middle-aged men is slower, and in moderately fat men the blood instead of being one-twentieth of the body weight is nearer to one-thirtieth, and hence elimination of nitrogen in solution of body tissue would be slower, i. e., a proportion of 20:30 in slim young men as compared to moderately fat men.

Arteriosclerosis is a dangerous factor and men with even moderate or slight arteriosclerosis must not be chosen for diving.

EAR DISEASE.

Ear disease is a bar to diving. This is especially true of any trouble that interferes with the patulousness of the Eustachian tubes, each of these tubes being a passage by which the pharynx communicates with the middle ear and through which the air pressure on each side of the drum is ordinarily equalized. Frequently men with even a slight cold are, owing to the congestion of these tubes, unable to clear their ears, i. e., make the pressure on the inner surface of the drum equal to the external pressure. The pain from unequal pressure on the drum is severe. Fortunately the hardest part of the dive, in this respect, is the first 30 feet. If a diver reaches 30 feet, the Eustachian tubes will be opened and he will not be seriously troubled for the remaining depth to which he may be required to descend. (See Chapter VIII.)

CONDITION OF THE LUNGS.

As air pressures exceeding three or four atmospheres tend to have an irritant effect on the lungs, it is evident that for diving the lungs must be sound and even free of tubercular tendencies.

The best type for diving work is the young (20 to 30 years), thin, wiry man of a phlegmatic temperament. The circulation is faster in his case, he desaturates more quickly, and he is less inclined to caisson disease.

PHYSICAL EXAMINATIONS.

The medical officer shall examine all candidates for the course of instruction at the diving school. They must come up to the standard physical requirements before they are considered eligible for instruction.

Qualified divers shall be examined physically periodically and special physical examination shall be made in the case of all men prior to all diving operations.

Divers second class are to be permitted to dive only in depths not exceeding 15 fathoms. Divers first class to be physically sound, of the type not predisposed to caisson disease, and not over 40 years of age.

In order to suit the diving apparatus, men under 5½ feet and much over 6 feet in height shall not be selected as divers.

A temporary physical defect shall not be considered a cause for disqualifying a diver but shall excuse him from being ordered to dive if, in the opinion of the medical officer, his condition warrants it. Men with permanent physical defects shall be disqualified as divers.

Men over 40 years of age shall be automatically disqualified from divers first class to divers second class. Divers first class who become unfit to dive in depths greater than 15 fathoms shall be disqualified from divers first class to divers second class.

ACCIDENTS AND FIRST AID TO DIVERS.

The accidents usually encountered in diving operations are as follows:

(*a*) Asphyxia.
(*b*) Squeeze.
(*c*) Caisson disease.
(*d*) Accidental blowing up.
(*e*) Fouling.
(*f*) Ear pains, (bleeding from the ears).
(*g*) Bleeding from the nose and lungs.
(*h*) Mechanical injuries from external violence.
(*i*) Exhaustion.
(*j*) Drowning.
(*k*) Oxygen poisoning.

NOTE.—In all accidents occurring in deep water it must be remembered that the diver can not, as a rule, be brought immediately to the surface on account of *the danger of a quick or fatal attack* of caisson disease, but may be brought immediately to the first stop or stage of decompression. On this account *coolness and judgment are essential*, as the effects of caisson disease may prove worse than the accident. If a recompression chamber is close by and ready for immediate use, the diver may be hauled to the surface with some rapidity, quickly placed in the chamber with an attendant, preferably a medical officer, and pressure applied to at least half the absolute pressure at which the diver was working. First aid or other treatment can then be given the diver within the chamber.

The record for apparently safe ascents, with a recompression chamber ready for immediate use was from 150 feet after a 30-minute exposure. Men were brought to the surface immediately as a routine, after an exposure of 30 minutes at 150 feet, quickly placed in a recompression chamber, pressure applied corresponding to the pressure of water at 150 feet, and then decompressed according to the tables without ill effects.

Asphyxia.—Asphyxia is usually the result of a deficient air supply, but, also, may result from supplying air containing a large per cent of CO_2, the result of flashing in air compressor cylinders of the lubricating oil, etc. It may also result from the diving dress not being properly inflated, thus interfering with the diver's respiration.

Its occurrence would be indicated by the diver ceasing to answer his telephone, or signal, after calling for more air.

In case of a short or bad air supply, the diver should remain perfectly quiet, operate his regulating escape valve, inflate his suit, and be prepared to ascend. Asphyxiation, except in case of a squeeze, is the result of CO_2 accumulation in the helmet.

The diver is always warned of the excess of CO_2 by his increased respiration; i. e., panting, an uncomfortable feeling of warmth and sweating, headache, and *clouding of the helmet windows* from the excess moisture from his breath.

Fortunately, a diver is cognizant of increasing CO_2 long before dangerous amounts are present, and it is of value to note that unconsciousness occurs from it long before death. Attendants should always be warned of a deficient circulation of air through the helmet by—

(*a*) Decrease in the amount of air bubbles rising to the surface.

(*b*) The decrease of the noise (caused by air escaping from the helmet through the regulating escape valve) audible over the telephone. This is an excellent guide, telephone attendants becoming so efficient that by this method they are able to estimate the amount of air a diver is using.

With these two guides alone, in conjunction with the diver's own sensations, except in case of accident, asphyxia from *insufficient air supply is inexcusable.* The danger of supplying air contaminated with CO_2 from flashing in the cylinders is very unlikely, especially if any precautions at all are observed in using a good oil of high flashing point in lubricating the compressors and the water cooling system is working efficiently.

Asphyxia from a slight squeeze; i. e., improper inflation of the dress, will only occur, as a rule, in case of an inexperienced diver. Divers learn to remedy this defect themselves long before they are allowed to attempt diving at any appreciable depths.

In cases where asphyxia is suspected, with the diver under water, he should be started immediately toward the surface. A pause should be made at the first decompression period, and another attempt should be made at communication. If there be no response from the diver he should be brought to the surface.

Once at the surface, in case of asphyxia, fresh air should be given the diver as quickly as possible, getting the face plate open, or cutting the diving dress.

The condition of a man suffering from asphyxia is as follows:

(*a*) Respiration entirely absent or as an occasional gasp.
(*b*) Muscles limp or rigidly contracted.
(*c*) Face blue or deep red.
(*d*) Eyes, as a rule, bloodshot.
(*e*) Pulse not palpable or as an occasional beat, or it may be full and strong.
(*f*) Body cold and clammy.

In a mild case of asphyxia, where a man is still breathing, a few breaths of fresh air immediately relieves the condition. In a case where the man is apparently dead or unconscious with feeble respiration, artificial respiration should be started immediately. Do not wait to remove the helmet and dress but get an ingress of fresh air into the helmet and start the Schaffer or prone method of artificial respiration as follows:

(*a*) Lay the diver on his belly with the arms extended as straight forward as possible and face to one side, so that the nose and mouth are free for breathing. A second attendant should see that the patient's mouth is held open and the tongue drawn forward, so that it will not be swallowed and block the windpipe.

(*b*) Kneel beside the diver's thighs and facing his head. Put the palms of your hands on the diver's loins (on the muscles of the small of the back) with the thumbs nearly touching each other, and with the fingers opened over the lowest ribs.

(*c*) With the arms held straight, swing forward slowly so that the weight of your body is gradually brought to bear on the diver. This operation should not take longer than four seconds and must not be violent, as internal organs may be injured. The lower part of the chest and abdomen are thus compressed and air is forced out of the lungs.

(*d*) Now immediately swing backwards so as to remove pressure, but leave the hands in place. Expansion of the chest and abdomen now results, and the lungs are supplied with fresh air.

(*e*) Thus, deliberately repeat, 16 to 18 times per minute, the double movement of compression and release; a complete respiration in three to four seconds. Do not interfere with the patient's own efforts at respiration. Remember, perseverance brings success.

(*f*) As soon as the patient is breathing properly cease the efforts. Get the suit off and get the patient wrapped up in blankets and keep him warm.

Squeeze.—In cases of slight squeeze, as caused by the regulating escape valve being wide open and a minimum air supply, extra pressure is exerted on the chest (suit flat), the air within the air passages is at a lower pressure than the pressure without, and the diver is forced to breathe against this extra pressure. Respiratory embarrassment results in a short while, and often a diver struggling up his descending line (buoyancy negative) under these conditions may bleed considerably from the lungs and nose. Hemorrhage, in this case, is usually due to the rupture of small lung capillaries.

Squeeze is usually the result of an accidental fall. This has already been explained under the "Physics of Diving." It may occur from other causes, however:

(*a*) A diver descending ahead of his air supply, i. e., descending before the pressure within the dress is equal to the water pressure without.

(*b*) Ruptured hose and a leaky safety valve.

(*c*) Ruptured cuff of the dress and the diver raising his arm as when trying to reach the escape valve.

(Squeeze in this case being slight, but enough to interfere with respiration.)

The injury from squeeze can cause death that is almost immediate. The injury *is usually serious*, and as such demands the immediate assistance of a medical officer. Get the diver to the surface as soon as deemed safe (see "Management of the ascent"); remove the apparatus as gently as possible; keep patient in the recumbent position; cover his body with blankets to keep it warm. The patient will usually be unconscious and bleeding profusely from the nose and mouth. Extreme cases have been known where the diver has been moulded into his helmet, so that it was practically impossible to remove it.

On account of the seriousness of this accident, *tenders must always observe the utmost caution to protect the diver from falling.* The life line and air hose should never be permitted to skip through the hands by the run. If for any reason the diver finds himself in danger of falling, he should signal for more air, or open wide his air control valve, throttle the regulating escape valve, and signal to the surface to "Hold on." The moment the danger is over, reregulate the air to prevent the counter accident of "blowing up."

NOTE.—The effects of squeeze are much more serious than those of "blowing up." Avoid both, but if it is a matter of two evils, choose the latter.

Caisson disease or compressed-air illness.—The cause of caisson disease has been explained. Its prevention consists of:

(*a*) Limiting time of exposure to high pressure.

(*b*) Proper stage decompression.

(*c*) Proper physical standard in the selection of divers.

An attack of caisson disease may be delayed as long as fifteen hours after the ascent. For this reason divers should always remain about the place where recompression can be applied until dismissed by the officer in charge. Symptoms vary from a slight attack of the "bends" to complete respiratory paralysis and death. If any untoward symptoms are noted, as pains in the joints, cramps, staggers, weakness or paralysis of the arms or legs, inability to talk, asphyxia, or difficult respiration, the diver should be immediately recompressed to at least half the absolute pressure at which he had been working and given a long decompression after all signs of the attack have subsided. (See "Management of the recompression chamber," p. 90.)

Accidental "blowing up."—Accidental "blowing up" may be injurious in various ways, as:

(*a*) From deep depths, an attack of caisson disease may result.

(*b*) From any depth, mechanical injury may result, from striking some object, as the ship's side, etc.

(*c*) From the possible fall back into deep water with resulting "squeeze."

Blowing up is caused by over-inflation of the dress, or by the drag of the tide on the diver's lines, etc., sweeping the diver to the surface.

In case of blowing up from depths beyond safe limits, the diver's valves should be regulated for him, as he will be unable to do so himself, and he should be sent down again as rapidly as possible (without subjecting him to a squeeze) to his first stage of decompression, at least, and decompression in accordance with the tables carried out. A diver who has been "blown up" should never exhaust air from his helmet or dress until he is certain that the attendants have secured hold of his lines, and he is protected from a fall.

Fouling.—Fouling is caused by the diver's lines and hose becoming entangled with some obstruction under water, a situation which prevents him from ascending. It usually requires the services of another diver to clear the one fouled.

Divers should be warned of the dangers from fouling. When a diver has become fouled and unable to ascend, death has resulted from shock and exhaustion. Also, prolonged exposure at deep depths may be followed by a fatal attack of pneumonia.

Ear pains.—Ear pains are due to inequalities of pressure on either side of the ear drum. They are experienced while descending underwater, and are usually the result of inexperience, the diver not knowing how to clear his ears, i. e., equalize the pressure in the Eustachian tubes and the outer side of the ear drums. Where the pressure on the outer side has been sufficient to rupture the drum, bleeding from the ear and nose usually occurs.

If a diver experiences severe ear pains, especially if there has been bleeding from the ears or nose, he shall report to the medical officer for examination.

Bleeding from the nose and lungs.—These conditions are caused by the effects of a squeeze, but may result from great respiratory efforts when the dress is unusually flat or the air supply is deficient. First aid is the same as for "squeeze."

Mechanical injuries from external violence.—There are many varieties and call for no special comment. The diver should be brought to the surface as soon as deemed safe, first aid supplied as indicated, and the medical officer notified.

Drowning.—There are two cases on record of drowning in the diving dress in which the helmet became detached from the breastplate. This accident can not happen if the safety catch at the back of a helmet is properly turned down. It is a common superstition among divers that if the dress is ruptured drowning will result. Such is not the case. Diving with helmets only has been accomplished in depths up to 140 feet as readily as with the complete apparatus. As long as the air pressure within the helmet is maintained and the diver remains in the erect position, water can not enter the helmet, and the diver will not drown. By simply closing the escape valve, air is forced down into the dress and will escape at the side of the vent. In case the dress becomes too full of water, it may be necessary to slip the weighted belt to facilitate ascent.

In case of apparent drowning artificial respiration as directed under "Asphyxia" should be supplied as soon as possible. The first step, however, should be to allow the water to drain from the mouth and trachea. This is accomplished by grasping the diver under the abdomen, lifting him up so that his head hangs downward (jack-knife fashion). Perseverance with the artificial respiration will often result in recovery. Men have been brought to life by this method even after submergence under water for a quarter of an hour.

Oxygen poisoning.—There is but one case known in the Navy and this may have been a complication of caisson disease which resulted after a long exposure to high air pressure; three hours of it at 120 pounds excess pressure. The diver developed a double broncho-pneumonia.

The prevention consists in limiting time of exposure at deep depths. First aid is the same as for "squeeze."

CHAPTER XII.

OXYGEN APPARATUS, ITS USE, CARE, ETC.

GENERAL STATEMENT.

The name of breathing apparatus has been given to devices that enable the wearer to work in places where the air is full of smoke or fumes or contains poisonous gases. These devices have many advantages, but they must be carefully adjusted and kept in o der and should be used only by men who have been trained in their use.

The use of such apparatus for rescue work has become an important factor in lessening loss of life or property from fires and explosions.

In exploring a compartment immediately after a fire or an explosion that has made the air poisonous or suffocating, some form of breathing apparatus is absolutely necessary. Breathing apparatus are made so that they can be worn hung from the shoulders like a knapsack. They can supply the wearer with good air for a period of from one-half hour to two hours, even if the air that surrounds him may be irrespirable.

Under ordinary conditions during respiration, the nitrogen in the air is not absorbed nor changed in the lungs, and may be breathed over and over again.

The types of breathing apparatus used in the Navy carry a supply of manufactured oxygen. Manufactured oxygen can be obtained from certain navy yards, or be bought at open purchase, that contains the following proportions of oxygen and nitrogen:

	Per cent.
Oxygen	95
Nitrogen	5
	100

The purpose of breathing apparatus is to supply the wearer with oxygen and to absorb the carbon dioxide and the moisture exhaled in his breath. To accomplish this purpose, the apparatus are so made as to permit the wearer to use the oxygen that is exhaled in his breath, and to permit him to breathe over and over again the nitrogen that is in his lungs and any that is inside the apparatus.

When breathing ordinary air at atmospheric pressure a man consumes from 10 to 35 per cent of the oxygen that passes into

PLATE XXI.

OXYGEN RESCUE APPARATUS.
PROTOTYPE, FRONT VIEW.

PLATE XXII.

OXYGEN RESCUE APPARATUS.
PROTOTYPE, BACK VIEW.

OXYGEN RESCUE APPARATUS. PROTOTYPE, RIGHT SIDE VIEW.

OXYGEN RESCUE APPARATUS.
PROTOTYPE, LEFT SIDE VIEW.

his lungs; the rest he exhales with the nitrogen he inhaled and the carbon dioxide produced in his lungs. Air that contains only 10 per cent of an atmosphere of oxygen is extremely dangerous, for it will quickly suffocate anyone breathing it. To accomplish useful work, the oxygen pressure must be maintained at 15 per cent of an atmosphere at least. The effects of pressure are mentioned in Chapters III and IV.

TYPES OF BREATHING APPARATUS.

There are a number of types of breathing apparatus in service. These are of European make, and include the following types:

Manufacturers and American agents of three types of breathing apparatus.

	Manufacturer.	American agent.
Fleuss	Seibe-Gorman & Co., 187 Westminster Bridge Road, London, S. E.	H. N. Elmer, 1140 Monadnock Building, Chicago, Ill.
Draeger	Heinr. and Bernh. Draeger, Draegerwerk, Lubeck, Germany.	The Draeger Oxygen Apparatus Co., Commercial Building, Pittsburgh, Pa.
Westfalia	Armaturen-und Maschinenfabrik "Westfalia," Gelsenkirchen, Germany.	Orio S. Knepper, 42 Broadway, New York, N. Y.

FLEUSS OR PROTO.

The Fleuss (or Proto) breathing apparatus, Plates XXI, XXII XXIII, and XXIV, consists of a steel cylinder or bottle, containing oxygen at a pressure of 120 atmospheres (1,764 pounds per square inch); a reducing valve equipped with a by-pass valve; a breathing and regenerating bag that contains, when ready for use, caustic soda in sticks, a saliva trap, a cooler, and a relief valve; and mouthpiece, nose clip, goggles, and skullcap. A face mask that covers the nose and mouth may be used instead of the mouthpiece.

The whole apparatus is supported upon a broad belt which is fastened around the body. A leather strap attached to the belt and passed through a pair of leather loops upon the body side of the breathing bag holds the bag in position when the wearer stoops or crawls. The breathing bag and cylinder may be hung from a pair of shoulder braces that can be adjusted by straps and buckles at the back to suit the height of the wearer.

Putting on the apparatus.—All that the wearer has to do is to put the equipment over his shoulders, fasten the belt, and take the plug out of the mouthpiece. The moment the mouthpiece is put into the mouth or the mask is adjusted, the main valve is opened not more than one turn, when the necessary supply of oxygen flows into the bag. At the start it is advisable to open the by-pass in order to partly inflate the breathing bag, but after the bag is inflated this valve should be screwed tight and should not be touched except in an emergency; that is, when the bag becomes deflated.

Should the reducing valve by any chance get out of order, the wearer should open the by-pass from time to time to give himself the necessary quantity of oxygen, but he should do this only when the breathing bag becomes deflated. The best guide as to the quantity of oxygen to admit by opening the by-pass is the fullness of the breathing bag. The working of the apparatus is most satisfactory when the bag is kept moderately full.

Care of the apparatus.—After the apparatus has been in use the caustic soda should be removed from the bag at once; but if it is not removed and becomes caked, it must be dissolved out with warm water before a fresh supply is put in. The caustic soda may be removed from the bag, washed, dried, and used again, or it may be removed, melted, and recast into sticks for future use. Caustic soda damages canvas and leather and will burn the skin if allowed to remain upon it.

If the apparatus is not to be used again for some time, the india-rubber breathing and regenerating bag should be washed out with warm water and dried inside with a cloth or towel before recharging; but if it is to be used at once, washing and drying are unnecessary. Before it is emptied or recharged the rubber bag must be removed from the canvas bag which incloses it.

The rubber mouthpiece (or mask, as the case may be) should be washed with soap and water after use. This not only cleans the india rubber, but helps to preserve it.

The small relief valve is to be opened (by pressing it with the finger) only when the bag becomes too full.

See that the inlet and outlet valves and the connections are screwed tight.

Heat helmet.—For the protection of the wearer in fighting a fire a heat helmet can be supplied. This helmet is made of rawhide and has a mica window in front, but it has nothing to do with breathing.

DRAEGER.

One type of the Draeger breathing apparatus has a knapsack, a pair of breathing bags, and either a helmet or a mouth-breathing device. The knapsack holds steel cylinders, or bottles, that are charged with oxygen to a pressure of 120 atmospheres (1,764 pounds per square inch); a pressure gauge (finimeter); a reducing valve; two regenerators containing caustic potash (ordinary lye), and a cooling cylinder.

The helmet incloses the wearer's face and the top of his head, and is made to fit closely about his face by means of a rubber tube that may be inflated by pressing a small rubber bulb. The front of the helmet is closed by a circular disk of mica, protected by a wire frame. An adjustable strap that passes around the head holds the helmet in position. From the helmet are suspended two breathing bags, protected by a leather apron. By a small sponge on the end of a stout wire the wearer of a helmet can wipe off any moisture that may collect on the inner side of the mica disk. The apparatus is so arranged that the mouth-breathing device may easily be substituted for the helmet

The circulation of the air and gases within the apparatus is controlled by an injector that keeps a pressure in the supply or inhalation tube and a vacuum in the return of exhalation tube equivalent to 10 centimeters (3.94 inches) of water column. The reducing valve is so regulated as to furnish 2 liters (122 cubic inches, or about 2 quarts) of oxygen per minute. The injector causes the air within the apparatus to pass through the supply and return tubes at the rate of 50 liters (1.77 cubic feet) per minute, so that the exhaled breath is quickly carried through the regenerator, where the carbon dioxide is absorbed, and then to the cooler and the supply tube.

This type of the Draeger apparatus has two mica valves in the circulating system to regulate the flow of air to and from the breathing bags. The breathing bags are connected by a short tube which permits the air to pass from one to the other and equalizes the pressure within the bags. A relief valve attached to the helmet allows air to escape when the breathing bags become too full.

WESTFALIA.

The Westfalia breathing apparatus (helmet and mouth-breathing types) has, like the Draeger, a knapsack that is suspended from the shoulders and rests on the back. This knapsack has a frame supporting two oxygen cylinders, a regenerator, a pressure gauge, a reducing valve, and an injector. Resting on the breast of the wearer are two breathing bags. One is connected to the oxygen-supply tube and the helmet, and the other to the exhalation tube and the regenerator. The helmet, like that of the Draeger apparatus, covers the front half and top of the head, and is held in place by a strap. A flexible rubber lining fits about the face and keeps out the external air. Ordinarily the lining makes a tight enough fit, but for greater safety a rubber tube around the edge of the lining may be inflated by an attached rubber bulb. The Westfalia apparatus is so arranged that the mouth-breathing device may easily be substituted for the helmet.

The reducing valve is adjusted to keep a pressure of 8 to 10 centimeters (3.15 to 3.95 inches) of water column on the oxygen circulation and to deliver 2 liters (122 cubic inches, or about 2 quarts) of oxygen per minute. The injector nozzle moves 50 liters (1.77 cubic feet) of air per minute.

GOGGLES AND NOSE CLIP.

Goggles.—Goggles are used with the mouth breathing in patterns of apparatus only when a man has to work in smoke or in gases that affect the eyes. The wearer should adjust the goggles beforehand so that they have an air-tight fit; wetting the rubber cushion with water helps to insure such a fit.

Before the goggles are put on, the glass should be wetted inside to prevent fogging.

Nose clip.—In the use of the mouth-breathing patterns of apparatus a clip is worn on the nose to close the nostrils. This clip has adhesive plasters, which make it fit the nose firmly. To keep the clip from being lost, it should be tied to the inhalation tube with a short stout string.

Every man who is to use the apparatus should have his own mask, or mouthpiece and nose clip, under his own care, not only for sanitary reasons, but also that he may shape and adjust the mask until it has a comfortable and air-tight fit. The masks have soft copper bands set in the rubber and can be shaped to an air-tight fit for any face.

HELMET VERSUS MOUTH-BREATHING TYPES.

Men who have had much experience with breathing apparatus have different opinions in regard to whether masks, helmets, or mouth-breathing devices are the best. The helmet is not necessary for safe and effective service in unbreathable gases, and it is a survival of the dress used in submarine diving. To become skillful in the safe use of a helmet the wearer should have much training in unbreathable gases.

Training in fresh air does not give confidence in the use of the helmet in poisonous gases, and such fresh-air training is a mere waste of the supplies needed for the upkeep of the apparatus.

In an atmosphere that contains smoke or fumes that irritate the eyes, nostrils, or throat the helmet may be worn with safety by one who has been thoroughly instructed and trained in its use, but in an unbreathable or poisonous atmosphere that contains no irritating fumes or gases a leak is not detected and the wearer may be overcome. The above disadvantage does not apply to the mouth-breathing form of apparatus, which should be used for rescue work in an atmosphere that will not support life and which does not contain irritating gases. In addition, the wearer of the mouth-breathing type can examine things overhead more easily than can the wearer of the helmet. Some men who have used both the helmets and mouth-breathing devices prefer the former, because they can breathe through the nose more easily than through the mouth. An objection to mouth-breathing devices is that they make it more difficult for men to talk to each other when working in a poisonous atmosphere, but audible signals may be used with success by men properly trained.

PRELIMINARY TESTS.

Before a breathing apparatus is used in unbreathable or poisonous gases it should be tested to ascertain its condition. The following are some of the important tests:

Quantity of oxygen and air circulated.—Attach a measuring bag to the inhalation tube leading to the helmet or mouthpiece, open the exhalation tube, turn on the oxygen, and note the time required to fill the bag. Compute the volume of air circulated. In the Draeger and the Westphalia apparatus the volume should be 50 liters (1.77 cubic feet) per minute.

Pressure in the intake tube and vacuum in the return tube.—Attach the inhalation tube to a water gauge. Do the same with the exhalation tube. In each instance the gauge should read about 10 centimeters (3.94 inches).

Connections and regenerators air-tight.—Disconnect the inhalation and exhalation tubes from the helmet or mouthpiece, place the thumb over the open end of the inhalation and put the open end of the exhalation tube in the mouth and blow hard. Any leakage will be evident.

Air-tight fit of the helmet.—Place the helmet on the head and inflate the facial tube till it feels snug; expel the air from the lungs; close the inhalation and exhalation connections; try to inhale. Inability to inhale means a close fit.

Reducing valves.—The types of apparatus described in this chapter have regulating valves which control the oxygen supply. These valves have levers, springs, disks, and adjusting devices that may, without apparent cause, get out of order and interrupt or stop the flow of oxygen. A piece of rust or dirt of less diameter than a sewing needle may clog the valve and partly or wholly shut off the oxygen. Hence, a by-pass valve is necessary for the safety of the wearer in unbreathable gases.

The reducing valves of the Draeger and Westphalia apparatus should be frequently tested to determine the pressure and vacuum produced by the oxygen nozzles. The test should always be made on each apparatus before using it in a compartment after an explosion or fire. Use the water gauge for testing. If the apparatus is in proper working order, the water gauge should read 8 to 10 centimeters (3.15 to 3.95 inches); the pressure and vacuum should both read the same for any one machine.

After a reducing valve has been used, caustic potash often collects in the chamber surrounding the oxygen nozzle or injector and obstructs the circulation of air and oxygen. When a reading of the water gauge indicates irregular operation of the valve, the nozzle (injector) should be examined and any potash found should be dissolved with warm water. The valve should be dried before using.

Do not take a reducing valve apart. Special machinery and tools are required to put it together. If a valve does not work properly and the trouble is not due to potash in the nozzle (injector) chamber, send the valve to a skilled mechanic for repair.

The reducing valve of the Fleuss (Proto) apparatus may be tested with a meter, or a measuring bag may be attached to the flexible tube leading from the valve to the breathing bag. If the valve is in proper working order, it should deliver 2 liters (122 cubic inches, or about 2 quarts) of air per minute.

CARE OF THE APPARATUS.

When the cylinders (bottles) of the breathing apparatus are being charged from a storage tank, the oxygen should first be drawn from the tank having the lowest pressure, and the pump should be used to make the pressure in the cylinder 50 atmospheres (735 pounds per square inch) higher than the pressure in the tank. Then oxygen should be drawn from the tank next higher in pressure and the pump used to raise the pressure in the cylinder to 50 atmospheres (735 pounds per square inch) above the pressure in that tank. This procedure should be followed until the cylinder is fully charged.

Oil should never be used to make any part of the apparatus slip easily. A mixture of water and glycerine, one-fourth glycerine and three-fourths water, should be used freely on the piston rods of the oxygen pump while the pump is in service.

The apparatus should always be ready for immediate use.

Keep regenerator cans ready for immediate use; for the Fleuss (Proto) apparatus, keep ready caustic soda in sticks.

Used regenerator charges should be immediately removed from the apparatus and so damaged as to leave no chance of their being placed in the apparatus the second time.

In the presence of dust keep the oxygen from circulating through the tubes while the exhalation tube is open to the atmosphere. Neglect of this precaution may cause some part of the circulating system to become clogged at a time when clogging will endanger the life of the wearer.

The apparatus should not be packed in excelsior or sawdust for shipment unless it is wrapped well with paper to prevent dust from getting into the circulating system.

When not in use the apparatus should be protected against dust, steam, and hot air. The helmets and rubber fittings should be kept in a ventilated cabinet, in which a pan of water is placed.

The apparatus should frequently be disinfected by placing it in formaldehyde fumes. After disinfection it should be wiped off with a weak solution of ammonia. Do not wash the rubber with hot solutions of soda nor with carbon bisulphide.

TROUBLES AND THEIR REMEDIES.

A man may at times find himself in trouble because the breathing bags are too full. The back pressure from the bags makes it difficult for him to exhale the air in his lungs, and he may get the idea that he can not inhale. Distress from this cause may be quickly relieved by pressing on the breathing bags and expelling part of the air through the relief valve.

Fear, nervousness, or lack of confidence, even though repressed, may lead to unnatural breathing and cause the breathing bags to become too full.

While climbing over falls or passing through narrow passages the wearer may compress the breathing bags, suddenly expel the oxygen within them through the relief valve, and deprive himself of a supply of air. In such an event it is difficult for an untrained man to avoid becoming excited; a trained man remains quiet until the bags become full.

Unions may work loose and cause a stoppage of the circulation. To be sure that unions are in proper adjustment, feel of them frequently.

The regenerator may not work properly, with the result that the air leaving it contains too much carbon dioxide; the wearer will then have headache and difficulty in breathing. The remedy is to expel part of the air in the breathing bags and rest a few minutes while getting a fresh supply of oxygen.

QUALIFICATIONS OF RESCUE MEN.

Divers 22 to 45 years old in good physical condition who are temperate in their habits and naturally calm and deliberate are best suited for rescue work.

Before a man undergoes training in the use of breathing apparatus he should be examined by a medical officer to ascertain his physical condition, especially the action of his heart and lungs and any defects of the nose or throat.

Rescue training should not be undertaken just after eating, nor less than two hours since the last meal. After having used the apparatus continuously for the limit of its capacity a man should rest for four hours before wearing it again. During work or travel in an irrespirable atmosphere the wearer should frequently rest by sitting.

RESCUE WORK AND EQUIPMENT OF RESCUE MEN.

A rescue party should have not less than two members. Only such persons should be allowed to join the party as have already been trained in the use of apparatus, are equipped with rescue apparatus in good order, and have agreed to follow the directions of the leader, who must have full charge. While working in unbreathable gases the men should keep close to one another and not separate under any condition.

To be efficient and successful a party must take every precaution for its own safety. If one person in a party faints or receives an injury he becomes a burden instead of a help, for the entire party must at once conduct him to fresh air. One or two stretchers should always be at hand.

A relief station or base of operations should be established at the end of the good air, and a relief crew with knapsacks should be stationed there ready to put on their apparatus and start at a moment's notice. A patrol of all doors leading up to the relief station should be maintained to protect the rescue crew from harm.

There should be at least four crews—each of at least two men—and these crews should have frequent practice.

While working in dense smoke the members of a crew should hold a rope which leads to fresh air.

In case the regenerator in a Draeger or Westfalia apparatus is punctured by a fall or by striking a pointed object, the wearer should get to fresh air as soon as possible, accompanied by the other members of the party.

In case of total failure of an apparatus to supply breathable air the wearer of the apparatus can throw away all parts but the oxygen cylinder and breathe from the cylinder through his mouth while endeavoring to reach fresh air with the rest of the crew.

Apparatus for giving oxygen to one who has been overcome with gases is an essential part of the equipment of a rescue party.

A record should be kept showing the work done by the men and the difficulties encountered. A record of each apparatus should be kept also. If an apparatus should fail to give proper service it should be subjected to the regular tests unless some injury is seen upon inspection.

GLOSSARY OF TERMS.

Alleviate........................To lighten or lessen physical or mental trouble.

Alveolar air....................The air contained in the somewhat enlarged terminal sections of the broncheoles whose walls are beset with air cells, through which the gaseous exchange in the air and blood take place (see Trachea).

Aphasia.........................Total or partial loss of the use of understanding of language, the vocal cords remaining intact. Any of the qualities or varieties of speech may be affected, both spoken and written. It results from injury or disease of the brain.

Arteriosclerosis..................Abnormal thickening and hardening of the walls of the arteries, especially of the intima (innermost coat), occurring mostly in old age.

Artificial respiration............Induced respiration by artificial means as with the Schaffer method or lungmotor, etc.

Asphyxia.......................Apparent death or suspended animation, in living organisms due to deficiency of oxygen or an excess of carbon dioxide in the blood, as interruption of respiration from suffocation or drowning, or from inhalation of irrespirable gases.

Buoyancy......................The property of floating on the surface of a liquid or in a fluid. Power of supporting a floating body. The upward pressure exerted on an immersed or floating body by a liquid.

Caisson.........................A water-tight box or chamber within which submarine construction is carried on under air pressure to keep out the water. The diving suit may be likened to a caisson.

Capillary........................A minute, thin-walled vessel, as the smallest lymphatic and biliary vessels; especially one of the minute blood vessels (the smallest barely permitting the passage of the blood corpuscles) which form networks in nearly all parts of the body. They are continuous with the minute branches of the arteries and with those of the veins, and are in most parts of the body the only communication between the arteries and veins. Capillaries consist of a single layer of endothelial cells. Through these walls the tissues absorb the nutriment and oxygen from the blood and discharge their waste into it.

Capacity.......................Power of receiving, containing, or absorbing; hence, extent of room or space; content; specific cubic content; volume; as capacity for moisture, thermal capacity, electric capacity; the capacity of a vessel is 5 quarts.

Central nervous system.........That part of the nervous system to which the sensory impulses are transmitted and from which the motor impulses pass out; in vertebrates, the spinal cord and brain.

Cerebral........................Of or pertaining to the cerebrum, or hemispheres of the brain.

Compress........................To press or squeeze together; to force into a narrower compass; to reduce the volume of by pressure; to compact; condense; as to compress air.

Compression.....................Subjection oi workmen to compressed air.

Concomitant.....................That which accompanies, or is collaterally connected with, another; an accompaniment.

Consolidate.....................To make solid; to harden or make dense.

Convert.........................To change or turn from one state to another; to alter in form, substance, or quality; to transform; transmute.

Decompression...................Release of excess air pressure from a workman in an air lock on returning to the outside air from a caisson under compressed air.

Dermatitis......................Inflammation of the derma or true skin.

Diminution......................Reduction in size, quantity, or degree; reduction.

Dyspnea.........................Difficult or painful breathing.

Eardrum.........................The tympanum or tympanic membrane of the ear.

Ecchymosis......................A livid or black and blue spot produced by the extravasations or effusion of blood into the alveolar tissue.

Elastic.........................Springy; of solids, capable of recovering size and shape after deformation; of gases, indefinitely expansive.

Embolism........................The occlusion of a blood vessel by an embolus. Embolism in the brain often produces sudden unconsciousness and paralysis.

Embolus.........................A plug brought by the blood current and lodged in a blood vessel so as to obstruct the circulation. It consists usually of a clot of fibrin, a shred of a morbid growth, a globule of fat, air bubbles, or a microorganism.

Epiphysis.......................A part or process of a bone which ossifies separately and subsequently becomes ankylosed to the main part of the bone. In the higher vertebrates the ends of the long bones of the limbs are formed in this way, and in man in some cases do not unite with the diaphysis, or shaft of the bone, until about the twentieth year.

Erythema........................Diffuse reddening or a livid or black and blue spot produced by the extravasation or effusion of blood into the alveolar tissue.

Exhaustion......................The state of being weary or tired out; to exhaust one's strength or patience.

Exigency........................Urgent or exacting want; pressing necessity; a case demanding immediate action.

Eustachian tube................A channel of communication between the tympanic cavity of the ear and the pharynx. In man the Eustachian tubes are about 1½ inches long, with walls of bone, cartilage, and fibrous tissue. They open into the upper back part of the pharynx, each side of the median line, and serve to equalize the air pressure on both sides of the tympanic membrane.

Extremity......................A limb of the body, as the arm or leg.

Exudate........................Exuded matter.

Exude..........................To discharge through pores or incisions, as moisture or other liquids; to give out.

Gastric........................Of or pertaining to the stomach.

Heat conduction................Heat may be conveyed by conduction as along an iron rod; by convection, as through the rooms of a house by air currents; or by radiation, as from the sun to the earth.

Hemiplegia.....................A palsy that affects one side only of the body.

Imbibe.........................To drink or drink in; to suck or take in or up; hence, to inhale; absorb; assimilate.

Inadequate.....................Not adequate; insufficient; deficient.

Inflate........................To swell or distend with air or gas.

Inert..........................Not having or manifesting active properties; not affecting other substances when in contact with them.

Inferior extremities...........Lower limbs, including thigh, leg, and foot.

Ingredient.....................That which enters into a compound or is a component part of any combination or mixture.

Inodorous......................Emitting no smell; scentless; odorless.

Irrespirable...................Unfit for respiration; not respirable (so as to sustain life).

Irritant.......................Any agent by which irritation or inflammation is produced, as a chemical or mechanical irritant.

Labyrinth......................The internal ear or its bony or membranous part, so called from its complex structure.

Larynx.........................The modified upper part of the trachea. In man it is the organ of voice. The framework of the human larynx consists of nine cartilages controlled by numerous muscles. The largest cartilage, the thyroid, is V-shaped in horizontal section, its point making the protuberance on the front of the neck, known as Adam's apple.

Laterally......................To or from the side; sidewise.

Lesion.........................A hurt; an injury; any morbid change in exercise of function or texture of organs.

Liberation.....................State of being liberated, i. e., to free; to disengage; to separate; to free from combination.

Liter..........................A measure of capacity in the metric system, being a cubic decimeter equal to 61.022 cubic inches, or 1.0567 U. S. liquid quarts.

Monoplegia.....................A paralysis affecting a single limb or part of the body.

Moribund.......................In a dying state; near death.

Motor........................Designating or pertaining to a nerve or nerve fibers, which passes from a ganglion or from the central nervous system to a muscle and by the impulse (motor impulse) which it transmits causes movement. The term is often loosely applied to an efferent nerve as opposed to a sensory or afferent nerve.

Noxious........................Hurtful; harmful; painful; destructive; unwholesome.

Paralysis........................Abolition of function, whether complete or partial; especially the loss of the power of voluntary motion or ot sensation in any part of the body; palsy.

Paraplegia........................Palsy in the lower half of the body on both sides. Usually due to disease ot the spinal cord.

Partial pressure of a gas........The pressure of any individual gas in a mixture of gases. It is the same as that which the gas would exert were it confined alone in the space occupied by the mixture; called also Dalton's law.

Patulousness..................State of being open.

Perverse........................Unfavorable.

Pharynx........................The part of the alimentary canal between the cavity of the mouth and the esophagus (gullet). In man it is a conical musculo membranous tube about 4½ inches long, continuous above with the mouth and nasal passages, communicating through the Eustachian tubes with the ears, extending downward past the opening in the larynx, where it is continuous with the esophagus.

Phlegmatic......................Sluggish; not easily excited; cool; calm; composed.

Physics........................That branch of science dealing with the material world; natural philosophy. With the growth of science various parts of this field, as biology, chemistry, astronomy, and geology, gradually were excluded. Now physics is usually held to comprise the closely related sciences of mechanics, heat, electricity, light, and sound, and to deal only with those phenomena of inanimate matters involving no changes in chemical composition. Motion is the most general and fundamental of all such phenomena, and physics is sometimes defined as the science of matter and motion.

Pneumonia......................Inflammation of the lungs. Lobar involvement of a lobe or lobes (large areas). Broncho or catarrhal involvement of lobules or small areas. General; involvement of both lungs in their entirety.

Ponderable......................Capable of being weighed; having appreciable weight.

Potassium hydrate..............A white deliquescent solid KOH, dissolving with much heat, in less than its weight of water, forming a strongly alkaline and caustic liquid; caustic potash. It absorbs carbon dioxide from the atmosphere.

Predisposed.....................To make liable; to dispose or incline beforehand; to give a predisposition, or a favorable susceptibility or bias to, to give a tendency to; debility predisposes the body to disease.

Prognosis........................Act or art of foretelling course and termination of a disease; also, the outlook afforded by this.

Prone............................Prostrate, flat, especially face downward.

Prostration......................State of being prostrate; great depression, lowness, as prostration of spirits or strength.

Pyelitis.........................Inflammation of the pelvis or the kidney.

Recompression....................To subject a workman to compression after being decompressed.

Recumbent........................Reclining, lying; as a recumbent posture.

Respiration......................Act or process of breathing; inspiration and expiration; the drawing of air into the lungs for oxygenating and purifying the blood, and its subsequent exhalation. The term designates both a single inspiration with the following expiration, and the continued repetition of these acts, which constitutes breathing. In ordinary inspiration the muscles chiefly used are the diaphragm, which enlarges the capacity of the chest by becoming flatter as it contracts and pressing down the abdominal viscera, and the external intercostals, levatores costarum, and others which raise the ribs. Expiration, unless forced, takes place chiefly by the return of the parts to their natural position of rest. But a small part of the total air in the lungs is replaced in an ordinary respiration.

Saturation.......................Act or process of saturation, or state of being saturated; complete saturation or impregnation.

Sensory..........................Of or pertaining to the sensorium or sensation, as sensory impulses; especially applied to nerves and nerve fibers carrying to a nerve center impulses resulting in sensation; also sometimes loosely used in the sense of afferent, to indicate nerve fibers conveying any impressions to a nerve center. Of the nature of sensation; pertaining to sense. (See motor.)

Solution.........................The act or process by which a substance, whether solid, liquid, or gaseous, is absorbed into and homogeneously mixed with another liquid substance; also, the resulting liquid product. Any homogeneous mixture (usually liquid), the composition of which can undergo continuous variation within certain limits; sometimes called physical mixture Also, the act or process by which such mixture is produced.

Specific gravity.................The ratio of the weight of any volume of a substance to the weight of an equal volume of some other substance taken as the standard unit; relative density; this standard is usually water for solids and liquids, and air for gases. Thus, 19, the specific gravity of gold, expresses that fact that, bulk for bulk, gold is nineteen times as heavy as water. In the case of gases, usually the weights of equal volumes at 0° and 760 mm. are compared.

Specific heat..................The ratio of the quantity of heat required to raise the temperature of a body one degree to that required to raise an equal mass of water to one degree. Also, the heat in calories required to raise the temperature of one gram of a substance one degree centigrade.

Staggers........................A cerebral and spinal disease, attended by reeling, unsteady gait, or sudden falling.

Subcutaneous..................Situated beneath the skin.

Symptom.....................Any affection which accompanies disease; a perceptible change in the body or its functions, either subjective or objective, which indicates disease or the kind of phrases of disease, as we study disease in the symptoms exhibited.

Tendon.........................A tough cord or band of dense, inelastic, white fibrous connective tissue uniting a muscle with some other part and transmitting the force which the muscle exerts; a sinew. Tendons, except in the largest, are very sparingly or not at all supplied with nerves or blood vessels, and are continuous with the connective tissue sheaths of the muscle and, when inserted into a bone, with the periosteum of the bone.

Tetanic.........................Having the character of tetanus. This condition of muscle, this fusion of a number of simple spasms into an apparent smooth continued effort is known as tetanus, or tetanic contraction.

Tissue..........................An aggregate of cells toegther with their intercellular substance, forming one of the structural materials out of which the body of a plant or an animal is built up.

Trachea........................Windpipe; in vertebrates, the main trunk of the system of tubes by which air passes to and from the lungs; in man it is about 4 inches long and somewhat less than an inch in diameter, and extends down the front of the neck from the larynx, bifurcating to form the bronchi. It has walls of fibrous and muscular tissue, stiffened by incomplete cartilaginous rings, which keep it from collapsing, and is lined with mucous membrane, whose epitheliumlis, composed of columnar ciliated and mucus-secreting cells. The bronchi divides into bronchioles, which continue to divide and subdivide.

Transparent...................Having the property of transmitting light, so that bodies can be distinctly seen through; pervious to light; diaphanous, pellucid.

Temperance...................Habitual moderation in the indulgence of the appetites or passions; moderation, as temperance in eating and drinking; temperance in any pleasures.

Tubercular....................Of or pertaining to tuberculosis; an infectious disease, the exciting cause of which is the tubercle bacillus and which is characterized by the production of tubercles; specifically, this disease, when seated in the lungs; pulmonary phthisis, or consumption.

Tympanites....................A distension of the abdomen; due to air or gas; accumulating in the intestinal tract or peritoneal cavity.

Vertigo..........................Dizziness, or swimming of the head; an affection of the head in which objects, though stationary, appear to move in various directions, and the person affected finds it difficult to maintain an erect posture. It results from changes in the blood supply to the brain and often precedes attacks of epilepsy or cerebral hemorrhage.

Vicious.........................Harmful.

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