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Siebe, Gorman & Co.

A DIVING MANUAL.

Davis, R. H

SUBMARINE APPLIANCES

AND THEIR USES,

DEEP SEA DIVING, &c., &c.

u. a. [ca. 1911]

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Price, 5/-

Diving Scientifically and Practically Considered.

BEING A

DIVING MANUAL

AND

Handbook of Submarine Appliances

COMPILED AND EDITED BY

R. H. DAVIS
(Managing Director of SIEBE, GORMAN & Co., Ltd.),

EMBODYING THE LATEST DEEP SEA PRACTICE ADOPTED BY THE

BRITISH ADMIRALTY,

AND INCLUDING CHAPTERS ON THE

PHYSICS AND PHYSIOLOGY OF DIVING

BY

The Admiralty Committee on Deep Diving,

ALSO AN ACCOUNT OF

THE EVOLUTION OF THE DIVING DRESS AND DIVING BELL,

AND

INSTRUCTIONS FOR DIVERS, etc.

PUBLISHED BY

Siebe, Gorman & Co., Ltd.,

SUBMARINE ENGINEERS,

WESTMINSTER BRIDGE ROAD,

LONDON, S.E.

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DIVERS OF THE BRITISH NAVY.

Copyright. **Photo No. 1.**
The Descent into the Sea.

Copyright. **Photo No. 2.**
"Hallo! are you there?" Telephoning to the Diver below.

INTRODUCTION.

OBJECT OF THIS BOOK.

THE chief purpose of this book is to ensure the safety of the diver and the caisson sinker who work at great depths. It is hoped, however, that the information given may also prove useful to the submarine worker whose duties are confined to the more ordinary depths, such as are met with in Harbour, Dock and Bridge building operations, etc.

ACKNOWLEDGMENTS.

Dr. Haldane and his Colleagues.

Much of the data given in the following pages is the result of original researches made on behalf of the British Admiralty by Professor J. S. Haldane, M.D., F.R.S., of Oxford University, to whom, and his colleagues Dr. A. E. Boycott, M.D., M.A., and Lieut. G. C. C. Damant, R.N., for their splendid work in connection with the preventive treatment of caisson disease, the gratitude of all engaged in deep diving and compressed air operations is due.

Dr. Hill's work.

We are also indebted to Professor Leonard Hill, M.B., F.R.S., of the London University Medical College, who has made many original and important researches into the effects of deep diving on the human system.

Admiralty.

For special permission to reproduce the chapter on "The Physics and Physiology of Diving," we are indebted to the Lords Commissioners of the Admiralty.

Dr. A. E. Boycott, M.D., M.A., and Lieut. G. C. C. Damant, R.N.

Our acknowledgments are also due to Dr. A. E. Boycott, M.D., M.A., and Lieut. G. C. C. Damant, R.N., from whose joint paper on "Influence of Fatness on Susceptibility to Caisson Disease" we have quoted.

THE GREATEST DEPTH SAFELY ATTAINED.

The greatest authenticated depth at which divers have done practical work in safety is 35 fathoms—210 feet; this was accomplished by Lieut. G. C. C. Damant, R.N., Inspector of Diving in the British Navy, and Mr. A. Y. Catto, Gunner, R.N., in August, 1906, the operations being carried out under the personal supervision of Professor Haldane on behalf of the Admiralty, who appointed a Deep Diving Committee consisting of Captain F. T. Hamilton, R.N., M.V.O., President; Professor J. S. Haldane, M.D., F.R.S.; Captain (now Admiral) Reginald H. S. Bacon, R.N., D.S.O., etc.; Captain Edgar Lees, R.N.; the Secretary being Staff-Surgeon Oswald Rees, M.D., R.N., whilst Lieut. G. C. C. Damant, R.N., and Mr. A. Y. Catto, R.N., were appointed for the experimental work. A summary of the Committee's conclusions and recommendations is given on page 7.

LATEST PRACTICE.

In conclusion, we would say that the reader may take it that the information given herein represents the very latest practice (similar to that adopted in the British Navy, whose divers are undoubtedly the most scientifically trained in the world), the result of the work of the eminent scientists and experts we have named, and of ourselves who have made a special study of the subject.

Amongst other matters included in this book are articles on :—

THE EVOLUTION OF THE DIVING DRESS, DIVING BELL, etc.

LIFE-SAVING DEVICES IN SUBMARINE BOATS.

SALVAGE OPERATIONS.

SELF-CONTAINED DIVING APPARATUS.

SUBMARINE MINES.

THE SAVING OF A CATHEDRAL BY DIVERS.

SUBMARINE SIGNALLING.

PEARL AND SPONGE DIVING.

etc., etc.

GENERAL DESCRIPTION OF THE CONSTRUCTION OF THE DIVING APPARATUS AND ITS USE.

A Set of the ordinary Diving Apparatus consists essentially of seven parts, *viz.* :—(*a*) A helmet with corselet. (*b*) A waterproof diving dress. (*c*) A length of flexible air tube with metal couplings. (*d*) Pair of weighted boots. (*e*) Pair of lead weights for breast and back. (*f*) A lifeline. (*g*) An air pump.

The **Helmet,** which is fully described on pages 26 to 29, and illustrated on page 28, is secured to the **Corselet** by segmental rings, the corselet being clamped water-tightly to the vulcanized rubber collar of the **Diving Dress,** which is a combination suit covering the whole body except the hands, which project through elastic cuffs (see page 32) which make a watertight joint at the wrists. Air is supplied to the diver through a non-return valve at the back of the helmet by means of a **Flexible Tube** connected with the **Air Pump.** The air escapes through a spring valve at the side of the helmet, this valve being adjustable by the diver. With this arrangement the pressure of the air in the helmet is always equal to, or slightly greater than, the water pressure at the outlet valve. It is absolutely necessary that the diver should breathe compressed air, otherwise his breathing would be instantly stopped and blood would flow from his nose and mouth. In order to enable him to sink and to stand firmly on the bottom, he carries a 40 lb. **Leaden Weight** on his chest and a similar weight on his back, and 16 lbs. of lead on each **Boot.** Altogether the weight of the equipment which he actually wears is about 175 lbs. (see pages 94 and 95 for particulars as to displacement, etc.). Besides the air pipe, the diver is usually connected with the surface by a signal, or **Life-line,** in which, in most cases, are embedded telephone wires. He usually descends by a rope (the "shot-rope") attached to a heavy weight which has been previously lowered to the bottom, and on reaching the bottom takes with him a line (the "distance-line") attached to this weight, so that he can always find the "shot-rope" again.

As a diver enters the water, the superfluous air in his dress is driven out through the outlet valve by the pressure of the water on his legs and body. The water seems to grip him all round. If the valve is freely open, he will feel his breathing rather laboured by the time he gets his valve just under water. The reason of this is that the pressure in his lungs is that of the water at the valve outlet, whereas the pressure on his chest and abdomen is greater by something like a foot of water. He is thus breathing against pressure, and if he has to breathe deeply, as during exertion, the effect becomes serious. One of the first things, therefore, that a diver has to learn is to avoid this adverse pressure by adjusting the pressure of the spring on the outlet valve, so that the breathing is always quite free. The spring on the valve at the same time regulates the amount of air in the dress, and therefore the buoyancy of the diver. A practised diver can thus slip easily, and without exertion, up or down the shot-rope. The breathing is, of course, easiest when the dress is full of air down to the level of the abdomen ; but, when this is so, the diver runs a risk of being "blown up." It will also be readily understood that a horizontal, or nearly horizontal, position is the easiest one for a diver's breathing, and many divers work crawling on the ground. In this position it may happen that too much air gets into the dress. If this air is allowed to get into the legs of the dress, the diver is capsized and blown helplessly to the surface, or he may be caught by a rope or other obstruction, and hung up in a helpless position with his legs upwards, the excess of air being unable to escape at the outlet valve since it is downwards. To avoid this risk, the arrangement for lacing up the legs, as shown in photo No. 5, page 13, is recommended. With the legs laced up, the head always comes uppermost if the diver tends to float upwards, hence the excess of air escapes by the valve.

BRITISH ADMIRALTY DEEP DIVING EXPERIMENTS.

The main conclusions arrived at by the Deep Water Diving Committee appointed by the British Admiralty may be summarised as follows:—

(*a*) Experiments carried out by Drs. Haldane and Boycott and Lieut. Damant, R.N., have shown that the dangers arising from the formation of bubbles of nitrogen in the blood and tissues on the ascent of a diver from very deep water can best be met (1) by limiting the time spent in deep water, and (2) by ascending most of the distance rapidly, and afterwards making the last part of the ascent in stages, with stoppages interposed. In order to limit the time spent in deep water, the descent, and most of the ascent, should be rapid. This new method, which, besides saving much time, is far safer, has been practically tested at sea up to 35 fathoms by the Committee, the depth named being the greatest hitherto definitely recorded as having been reached by divers. A table has been drawn up showing time limits on the bottom, and the corresponding precautions recommended in ascending, for different depths up to 35 fathoms. (See pages 47 to 49.)

(*b*) The respiratory distress which, under the old system of diving, usually prevented divers from working at depths exceeding about 20 fathoms, although a few men of exceptional skill and endurance have succeeded in working for short periods at as much as 30 fathoms, was solely due to pressure of carbonic acid gas in the air of the helmet, but such distress can be entirely obviated by increasing the supply of air in direct proportion to its increase in absolute pressure, and a diver can work as comfortably at 30 fathoms, or more, as in shallow water, apart from the hampering effects of tide and darkness. Tables have been drawn up showing the air supply necessary for the diver at different depths. (See page 97.)

(*c*) The risk of "blowing up" to the surface can be greatly diminished by lacing up the legs of the diving dress.

(*d*) In cases of accidental "blowing up," or too rapid ascent from deep water, the danger of air bubbles in the blood can be avoided by sending the diver down again, even after serious symptoms have already developed, or by placing him in a recompression chamber, carried on the deck of the diving vessel, and raising the air pressure. (See page 18.)

TRAINING DIVERS FOR THE BRITISH NAVY

AT WHALE ISLAND, H.M. DOCKYARD, PORTSMOUTH.

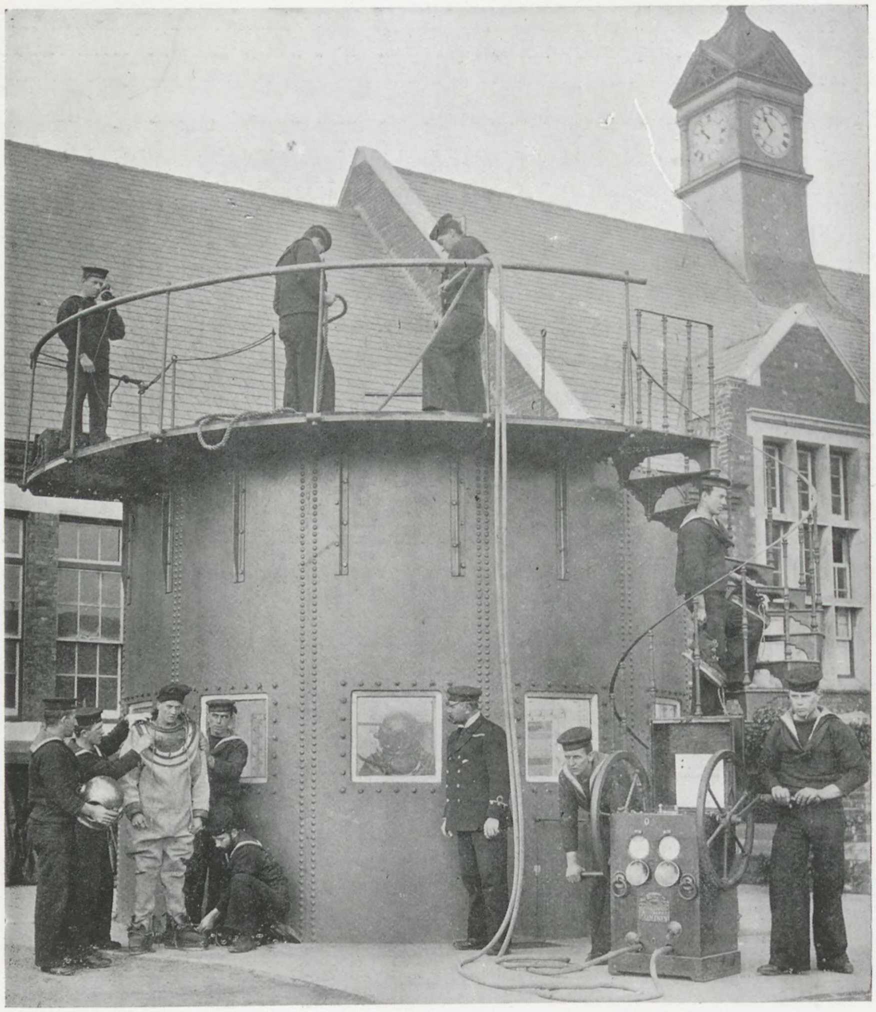

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Photo No. 3.

In this tank new recruits to the Diving Class receive their initial training before diving in open water.

THE PHYSICS AND PHYSIOLOGY OF DIVING.*

THE PHYSICS OF DIVING.

It is necessary before discussing the effects of deep diving on the human body to review very briefly a few of the physical properties of air and water.

Atmospheric Pressure.

If a pint measure be standing empty in the air, every square inch of its surface, inside as well as outside, is being pressed on by the air with a pressure of, roughly, 15 lbs.

This is the amount of pressure that the atmosphere all round us approximately maintains on everything near the surface of the earth. It is due to the weight of the miles of air overhead pressing down towards the surface of the earth.

This pressure of 15 lbs. on the square inch that the atmosphere exerts is called "atmospheric pressure," or the "pressure of one atmosphere."

Such pressure is not usually shown by a gauge, since gauges generally register a pressure in excess of that which is always present due to the atmosphere. There are, therefore, two ways in which pressure can be reckoned—first, that which includes the pressure exercised by the atmosphere, this is called "absolute pressure"; and secondly, that which does not take the pressure of the atmosphere into account; the latter is that generally shown by gauges, and is usually talked of as "pressure."

If now the pint measure be closed at the top, and another pint of air be forced into it, there will be a double quantity of air in the measure trying to force its way out in all directions; the original pressure will therefore be doubled, and there will be an absolute pressure of 30 lbs. on the square inch inside the measure on the top, bottom, and sides; but, of course, only 15 lbs. "pressure" above that of the atmosphere inside the measure.

The same result could have been obtained if an india-rubber ball containing a quart of air had been pressed on from the outside, and the ball squeezed in until its capacity had been reduced to one pint. A quart of air (that is, two pints of air) would then be held in one pint of space, and the pressure inside it therefore doubled. It is convenient to use the word "volume" to express the quantity of air in any receptacle at atmospheric pressure. The following simple rule can, therefore, be used, viz.: If one volume of air is present in a receptacle, the pressure is atmospheric pressure, or 15 lbs. absolute pressure. If two volumes are forced in, the pressure is doubled. If three volumes, the pressure is trebled, and so on. Further, if it is desired to obtain any given pressure of air in a receptacle, it is only necessary to force in a certain number of volumes of air to obtain it. For instance, if a pressure of 90 lbs. on the square inch *above* atmospheric pressure is required, we have merely to divide 90 by 15 to see how many volumes of air, in addition to the one already present due to the atmosphere, must be forced in. In this case six more volumes will produce a pressure of 90 lbs. on the square inch

* Reproduced by permission of the Admiralty.

above atmospheric pressure. These facts constitute what is called "Boyle's Law," which is that the volume of a gas varies inversely as the pressure, whilst the density varies directly as the pressure. It is not necessary for us to complicate this simple rule by dealing with the exact effect of changes in temperature of the air; but it is well to remember that if the temperature of confined air is raised the pressure will be increased, and if the temperature is lowered the pressure will be decreased.

When dealing with water totally different conditions arise; since water cannot be compressed, it is, of course, a practical impossibility to force a quart of water into a pint measure. Another important consideration is that water is very much heavier than air, and that, although when dealing with ordinary quantities of air we may neglect its weight, we cannot do so where water is concerned.

If a pint measure be full of air we can neglect the weight of the pint of air on the bottom of the measure, but if it be filled with water we cannot neglect the weight of water on the bottom. It is obvious that if a cubic box be filled with water the bottom of the box has to support the whole weight of the 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 box. It is also obvious that the higher we raise the sides of the box, still keeping it filled up, the greater the weight or pressure becomes on the bottom.

A column of water 33 feet in height presses on the bottom of the column with a pressure of about 15 lbs. on the square inch. This is the same pressure as is produced by one atmosphere of air, or a column of air the height of the atmosphere. Sixty-six feet of water would produce at its base a pressure of about 30 lb., or the same as two atmospheres, and so on. In other words, every one foot in height of salt water produces a pressure of a little under ½ lb. on the square inch.

Absolute Pressure.

It must be remembered that the atmosphere is also pressing down on top of the column of water, so that a column of water 66 feet in height would have at its base an *absolute* pressure of 30 lbs. due to its weight, plus 15 lbs. due to the atmosphere, or a total of 45 lbs. *absolute* pressure.

Air Pressure in the Helmet.

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 the body in the form of a squeeze. Of course, 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 water above the top of the body than above its bottom, and therefore in the case of the diver there is less pressure on his helmet than on his boots. If the diver be 6 feet high there will be about 3 lbs. less pressure on his helmet than on his boots, whatever depth of water he may happen to be in.

Helmet Valves and their action.

We are now in a position to see the connection between the pressure of the air inside a diving dress and of the water outside it. A diving dress has essentially two portions, a compressible dress and an incompressible helmet. As the diver descends the pressure increases, and tries to squeeze the air out of the dress into the helmet. If we wish to keep the upper part of the dress over the man's chest inflated, air must be pumped into the helmet and the upper part of the dress until the pressure of air in the dress is equal to that of the water at the level of his chest. As the man breathes, the air gradually becomes foul; fresh air must therefore be pumped in for him to breathe. If no escape is provided for the air from the dress, the pressure inside the dress would get higher and higher, and there would be more pressure inside the dress than outside it, which for several reasons would be very objectionable. An escape valve for this surplus air is therefore fitted. This escape valve works so that when the pressure inside the valve is greater than that of the water outside the valve, it is forced open and the extra air escapes. At first it seems as if the proper place for this valve would be at the same level as the man's chest, since it is the pressure at that level which is required in the dress; but many practical considerations lead to placing the valve at the back of the helmet. Since, when the man is standing upright, this spot has a pressure about ½ lb. less than exists at the man's chest, a spring is fitted to keep the valve shut until the pressure inside has risen about ½ lb. more than that of the water outside; by this means air is kept in the dress over the man's chest, although the valve itself is a little nearer the surface of the water. This valve can be adjusted by the diver to suit his convenience. This is very necessary, since a diver often lies down, when the relative depth of his chest and the valve is altered. Also, it makes a very great difference to the diver if the exactly right inflation of his dress is obtained. If the dress is too much inflated he becomes uncomfortably buoyant, and if too little inflated the weights bear heavily on his chest. It is, moreover, much less exertion when breathing inside a small space to have an elastic bag attached to it, like the inflated part of the dress, than to breathe inside such a space with rigid walls like the helmet alone, since the elastic part "gives" to each breath and keeps the pressure constant. The lungs also are only designed to work comfortably when the pressure inside and outside them is exactly the same; very little additional pressure outside them greatly increases the labour of breathing. As regards the remainder of the body, the pressure of the air at the mouth is instantly transmitted to the whole inside of the body. So that whatever depth the diver may be in, provided a proper air supply is maintained, the pressure outside the body can never be more than a pound or two over that inside the body. It must be remembered that air cannot be supplied to the inside of the dress by the pumps at more than a certain rate, hence, if for any reason a diver changes his depth at a greater rate than that at which the pumps can supply him with the proper pressure, he may be subjected to a very dangerous squeeze from the water.

Pressure effects.

The following illustration will emphasise this :—

Falls under water.

Suppose a diver at work on a stage cleaning the ship's bottom slips off the stage and falls 5 fathoms, owing to carelessness on his part, and culpable neglect on the part of his attendants to hold on to the life line and air pipe. At this depth the absolute pressure is twice as much as it is close to the surface, so by the descent the volume of the air in his dress is halved. He has an additional pressure of nearly 15 lbs. suddenly applied to every square inch of his body, or about 2,000 lbs. to every square foot. As the helmet is rigid, his body will be crushed into it with overwhelming force. He may be killed, he certainly will be severely injured, and there will be bleeding from the lungs, mouth, nose, etc. If, however, the diver is at 165 feet (27½ fathoms) and falls 5 fathoms, pressure has only increased in the proportion of seven to six, and the volume of air has only diminished by less than one-seventh of its volume, so that the effect will be proportionately less. From this it follows that the deeper a diver is the less serious is a fall.

"Blowing up." The danger in falling is due to the sudden diminution in the volume of the air; sudden ascents may be just as dangerous. A special danger of a sudden ascent is associated with the absorption of the air by the blood, and will be considered later. A diver in preparing to ascend tightens up the valve to increase his buoyancy and allows himself more or less to float up the shot rope. If the valve is closed more than will allow the excess of air to escape, his ascent will, at first, be gradual, but soon, with each foot of ascent, the volume of air in the dress expands and his speed is quickened. At first the limbs are more or less capable of movement, and the diver has a chance of holding on to the rope and adjusting his valve, but very soon the dress becomes so very much expanded that it is as hard as a board, and he cannot reach the valve: he is practically powerless. If the dress were to give way anywhere near the head under the strain, which fortunately is very unlikely, since the air always escapes through the cuffs, the diver might be in a still worse predicament, for if the attendant failed to haul in the slack of the life-line quickly enough he might sink like a stone, and be crushed by the pressure due to the depth he had fallen.

Pressure on the ears. One other effect we have to notice is the pressure on the ears. The ear may be compared with a cavalry drum, which has a parchment covering at one end only. If we were to place such a drum in a caisson or other air chamber, and pump in air, we should very soon find that the head of the drum was being forced in; but if we made a hole in the body of the drum there would be no change, since the pressure on the inside would always be equal to that on the outside. The condition of the ear is the same as that of the drum. The middle ear is the body of the drum, and across one end is stretched the "drum" of the ear; at the other end is a tube which leads into the nose and allows the air pressure on the inside of the ear to become equal to the pressure outside. But often, from a slight cold or other cause, the tube leading to the nose becomes blocked up, and we have pains in the ear until the passage is cleared. In the case of a diver this is best done by stopping in his descent for a moment and swallowing his saliva, as the action of swallowing opens the tube. If he cannot open the tube he must come up again. Usually, if the diver can reach five or six fathoms he will have little difficulty in attaining greater depths, where the relative differences in volume of the air become less and less.

Work on the Pump. The effect of the law of pressure on the work of the pump can be considered here. As the diver requires the same *volume* of air at whatever depth he may be, if the pumps are taking in one cubic foot a minute when the diver is near the surface, they must take in two cubic feet when the diver is at 33 feet, three cubic feet at 66, four cubic feet at 99, and so on. But not only have the pumps to take in and deliver a much larger quantity of air; they have also to deliver it against a rapidly increasing pressure, so that the work is greatly increased.

Effect of compressed air on the voice. We saw that the density of the air increased with the pressure; this leads to certain effects in connection with the voice, which at very great depths has a "Punch"-like quality, which is very distinctly noticed through the telephone. A diver cannot whistle when in deep water, as the density of the air hinders the vibration of the lips.

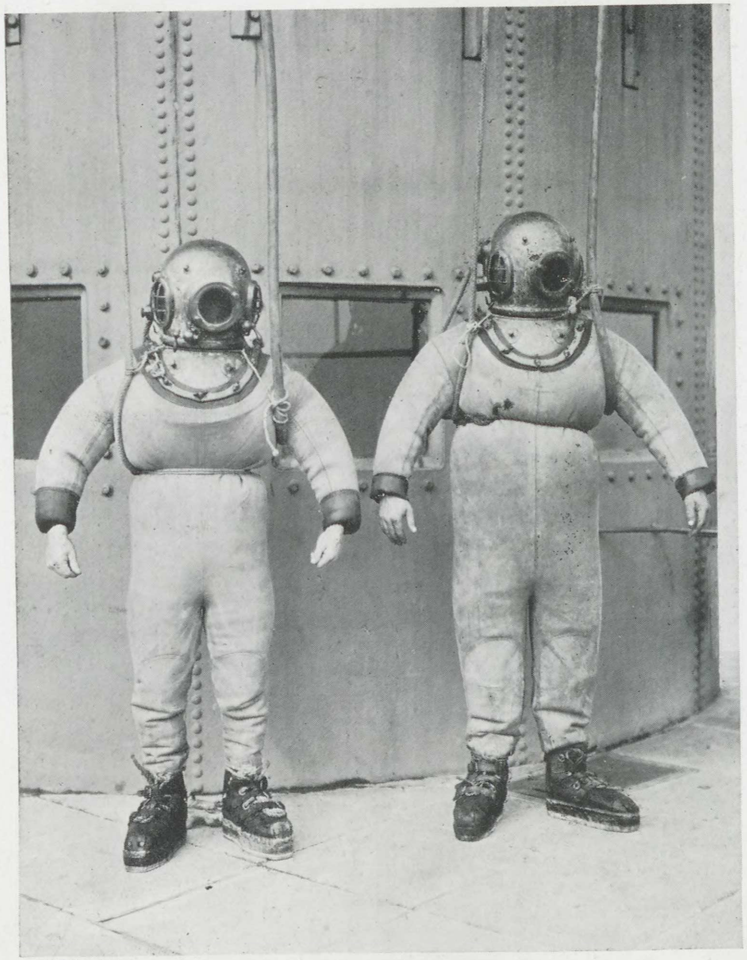

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Photo No. 4.

Diving Dresses fully inflated with air. The one to the left has laced-up legs, the other Dress is of the usual pattern.

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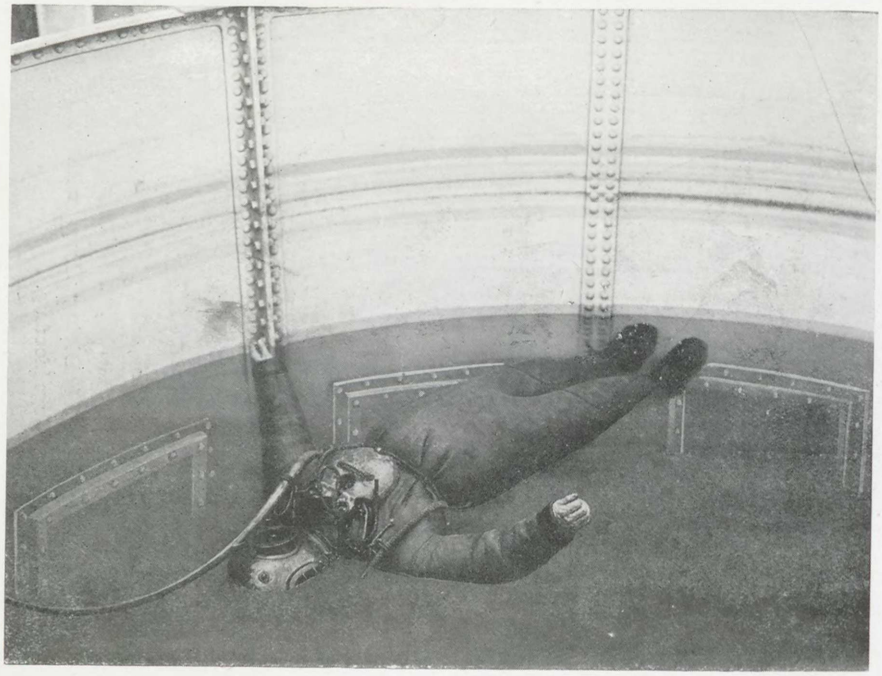
Photo No. 5.

Back view of Diving Dress with legs laced up.



This Diver has purposely blown himself up in the Ordinary Diving Dress. He is unable to move his arms, and the air cannot escape as his outlet valve is below the water.

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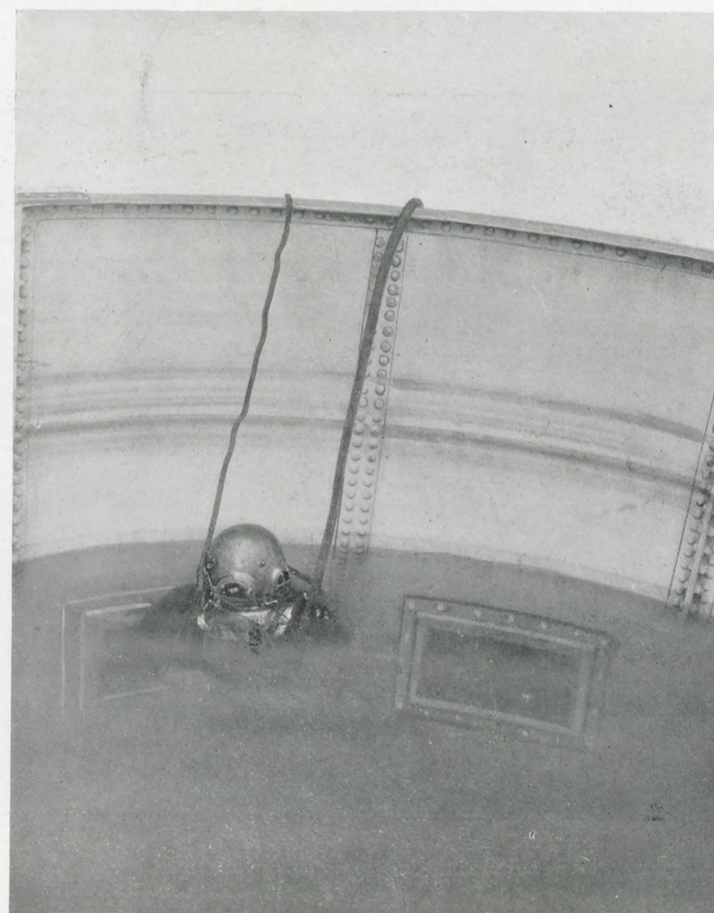
Photo No. 6.



This Diver has blown himself up in the New Pattern Diving Dress with laced legs. His head is upwards and his arms free.

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Photo No. 7.

THE PHYSIOLOGY OF DIVING.

The production of Carbonic Acid Gas in the body.

To produce energy we have to use up fuel in one form or another. In the steam engine we burn coal, in an internal combustion engine petrol or coal gas, and in the body certain constituents of the tissues. In each case oxygen is combined with the carbon of the fuel, and carbonic acid gas is formed, together with water vapour. Respiration is the process by which air is drawn into the lungs and, in turn, expelled. The blood in its passage through the lungs receives oxygen from the air, and gives up the carbonic acid gas and water. (Carbonic acid gas will be denoted in future by its formula CO_2.) The greater part of this exchange takes place in the minute recesses of the lungs. The amount of CO_2 given off by the lungs will depend on several factors, such as the amount of work that is being done, or the kind of food that has been eaten. If there is much CO_2 to be given off we shall require much air to wash out the lungs, also if there is much CO_2 in the air that we are breathing it is evident that we shall require a greater quantity of air to flush them out. This washing out of the lungs is best effected by increasing the depth of the respirations, and not by increasing their frequency. If, when a diver is in deep water, the rate of his respiration is counted, it will be found to be the same as when at the surface, provided the air supply is adequate.

Dangers of Carbonic Acid Gas at the surface.

The popular idea of the danger of CO_2 in the air is much exaggerated. In fresh air there is only .03 per cent. of CO_2, and if we are at ordinary atmospheric pressure, and provided we are at rest, it is not until we get this percentage increased a hundred times that we even begin to feel its effects in any way. Where this percentage (3 per cent.) is reached we find that we begin to breathe deeper than usual, and it has been found that this amount of CO_2 causes us to breathe about twice as deeply as we usually do. At 6 per cent. there is severe panting, at 10 per cent. there is extreme distress, and at a slightly higher percentage loss of consciousness occurs, which at 25 per cent. very gradually deepens into death.

Effects of Carbonic Acid Gas at different pressures.

Whilst the above is true for the effect of CO_2 at the normal pressure, it has been found that it does not hold true when the air is under pressure. In this case, to estimate the effect of the CO_2 the percentage present must be multiplied by the absolute pressure, when the effect on the human body will correspond with that produced by the new percentage at normal pressure. For instance, at 33 feet 1 per cent. of CO_2 has exactly the same effect as 2 per cent. has at the surface, or as 0.5 per cent. would have at 99 feet. In other words the deeper a diver descends the greater is the effect of a small percentage of CO_2 in the helmet.

Air supply required by Diver.

It will be seen that the danger from the accumulation of CO_2 in the dress is not an imminent one, and the pumps can usually be stopped for at least four minutes before the CO_2 would accumulate to a serious extent, and, if the diver is ascending at the time, for much longer. How much air does a diver need? We saw that when CO_2 reached 3 per cent. a man at rest at ordinary atmospheric pressure feels it. If he is working at the time 3 per cent. will cause him distinct discomfort. From a very large number of analyses of air issuing from the diver's helmet, we have found that he produces about .014 cubic feet of CO_2 (measured at atmospheric pressure) in one minute when at rest on the bottom at all depths, and about .045 cubic feet (measured at atmospheric pressure) when at work. From this it is a simple calculation how much air he will usually require to keep the CO_2 in his helmet from affecting him more than 3 per cent. would at the surface. Taking into consideration leakage* in the Navy pumps, this is found to be about 1.5 cubic feet per minute. This volume of air will be needed at all depths, so we can calculate the amount of air the pumps must take in at the surface to supply the diver with the requisite amount, and also the number of revolutions of the pump, which will give this amount. (*For table, see page* 97.)

The diver need never fear a want of oxygen, since the deeper he goes the more oxygen does he receive at each breath. In the very deep diving he might be affected by an excess of the oxygen pressure, but as he is unlikely at these depths to be exposed to its action for any very long time, we may disregard the danger altogether.

The absorption of gases by liquids.

When a gas is in contact with a liquid on which it has no chemical action, it is absorbed by the liquid in amounts which are proportional to the pressures under which the gas is at the time. In the lungs we have the blood practically in contact with the air. In the air we have three important gases—oxygen, nitrogen, and CO_2. Of these the nitrogen alone can remain and accumulate in the blood. It is not to be supposed that the oxygen and CO_2 are not absorbed by the blood under pressure, but the oxygen is used up by the tissues, and the breathing prevents the pressure of CO_2 from ever increasing, so that the only gas which accumulates in abnormal quantity in the blood when the diver is under pressure is the nitrogen.

When gas is forced into a soda water bottle under pressure, the water appears to be unchanged so long as the pressure is kept up, but the moment we reduce the pressure, by taking out the cork, we see the gas come bubbling off the liquid.

If we apply the analogy to diving, the diver is the soda water bottle, and his blood is the fluid in the bottle. As the diver descends, nitrogen under pressure is forced into contact with his blood. The blood takes up the nitrogen from the air. So long as he stays below under that pressure, his blood appears to be unaltered; when, however, he rises, the excess of nitrogen that the blood has taken up begins slowly to bubble off; if the blood were as fluid as water it would come off as rapidly as from the soda water. Fortunately for the diver the blood is a thickish, albuminous fluid, in which bubbles do not readily form, and, as far as we can see, it can retain about twice the amount in solution that water can keep at any given pressure. Every diver knows that it is quite safe to come up from a depth of from five to six fathoms to the surface as quickly as he likes; the reason for this will now be easily understood, since at such a depth the blood has only twice as much nitrogen in it as it has on the surface, and therefore bubbles are unlikely to form. *If, however, the diver has been for any considerable time at, say,* 30 *fathoms, and then comes up quickly,* it is almost certain that bubbles will form and cause serious symptoms.

Not only is the air taken up by the blood, but the tissues of the body also gradually get saturated with it. In the case of the blood the saturation is very quick; it is probable, indeed, that the blood leaving the lungs is always saturated

* Unavoidable loss due to clearance, heat of compression, and piston leakage.

to the existing pressure, but the tissues take up the gas at a much slower rate—a rate which depends on the blood supply. Where this is good, as in the brain and spinal cord, the saturation is quick, but in the fibrous tissues about joints, etc., saturation is very slow. Those tissues which are saturated quickly also give up their surplus nitrogen quickly, and those which saturate slowly also desaturate slowly.

It is of the utmost service that the tissues of the diver take so long to get saturated with the air, as it much reduces the dangers due to short stays under water. The Greek divers will come up from 30 fathoms as fast as they can, but they make very short stays under water; their time from surface to the bottom and return does not exceed 10 minutes, so that their tissues are not sufficiently saturated to cause danger unless they make successive dives at short intervals of time.

Dangers due to the Absorption of Nitrogen by the Blood.

We must shortly refer to the various dangers which result from the formation of bubbles in the blood and tissues. In the first place they may come off in the blood vessels themselves, filling the right side of the heart with air, and causing death in a few minutes. In less sudden cases the bubbles form in the brain or spinal cord, leading to paralysis of the legs (diver's palsy), whilst in less serious cases we may only have severe pains in the joints and muscles.

How to avoid the danger.

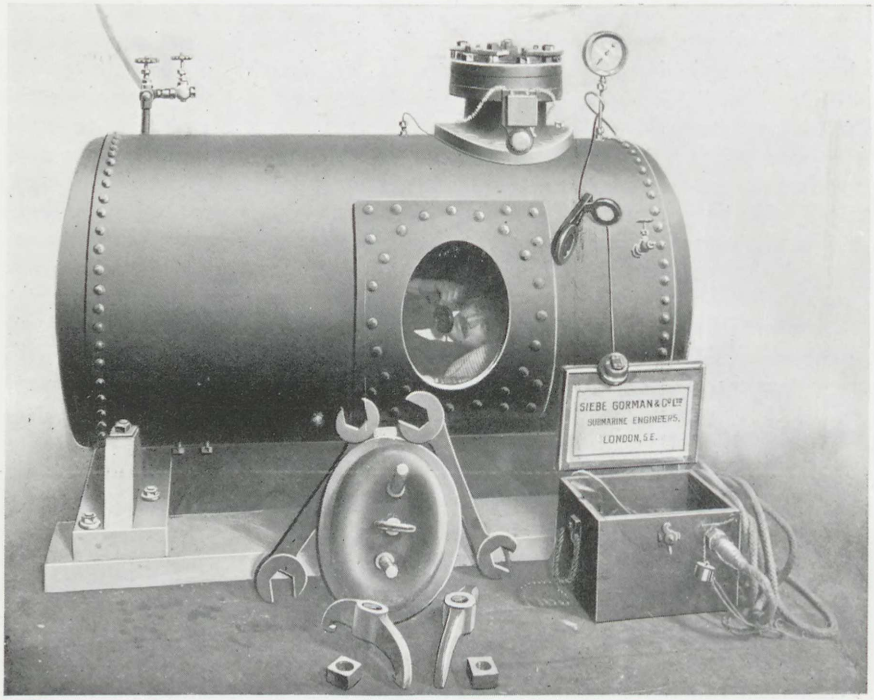
How are these dangers to be avoided? In the first place the diver must descend as quickly as he possibly can, *i.e.*, as quickly as his ears and air supply will let him. Every minute spent in descending is time lost, since the body is becoming saturated with nitrogen all the time. A scale of time to be allowed on the bottom has been drawn up, during which there is but little chance of the diver getting dangerously saturated. If the tissues are at all allowed to get fully saturated, the time required for safe desaturation is so great that it becomes very tedious for the diver to hang on to the shot rope. There is absolutely no danger in a quick descent, provided that the ears are well open, and that the air pumps can keep the pressure in the dress equal to that of the depth that the diver may be at. Of course, if the air pressure falls below that of the water, a quick descent would mean all the dangers of a fall, but this is not likely to happen, as the diver would very quickly feel the " nip " of the too short supply of air, and instinctively hold on to the ropes until the supply has caught him up again.

The stay at the bottom must be governed by the table appended when the depth is 9 fathoms or over. This table has been drawn so as to leave little chance of the tissues getting saturated.

In ascending, the diver is decompressing himself, and it is this gradual decompression that is the most important factor in the prevention of accidents from the formation of bubbles of nitrogen. The blood, we saw, could hold in solution about twice as much of the gas at any pressure as it would do if it behaved like water; we can therefore come up from 33 feet to the surface without fear of ill-effects. This relative amount of 2—1 of absolute pressures holds good up to high pressures, so that the diver at 7 atmospheres (198 feet or 33 fathoms) can come quickly up to $3\frac{1}{2}$ atmospheres (82 feet or about 14 fathoms), or when at 6 atmospheres (165 feet or $27\frac{1}{2}$ fathoms) to 3 atmospheres (66 feet or 11 fathoms) without danger of bubbles forming. It will be seen how very important this law is, for the diver can come up quickly from the dangerous depths to a depth within reasonable distance of the surface. After the first long stage the subsequent stages must be taken with frequent pauses, in order to let the excess of nitrogen pass off through the lungs, the longest pause being made a few feet below the surface. It need hardly be stated that the time of the pauses must be signalled from the surface, as, very naturally, the diver has but very little notion of time.

Gymnastic Exercise when coming up.

While the diver is coming up the shot rope he must at each stop do as much gymnastic exercise as possible, especially using those muscles which were in use on the bottom. This will increase the circulation so that the blood is more rapidly desaturated. It is also a good plan to stop all but one pump after the first stage, as a little excess of CO_2 in the helmet will increase the respiration and circulation, and thus help in the removal of nitrogen.



Copyright.

Photo No. 8.

Recompression Chamber, as referred to on page 7.

MODELS ILLUSTRATING THE WORKING OF THE DIVING DRESS UNDER DIFFERENT CONDITIONS, AND THE EFFECT ON THE DIVER.

(See page 20.)

No. 9. (Pump not Working.)

Shows how the body would be squeezed dangerously if the diver went down with the pump not working, or dropped by accident quicker than the pump could keep up with the pressure of the water. The rubber bag in the glass helmet represents the head, the middle bag in the glass cylinder represents the lungs, the lowermost bag below the glass cylinder represents the body. The helmet is fixed on the rubber cork, which closes the top of the glass cylinder. The helmet has an inlet tube, connected with a syringe bulb (the pump), and an outlet valve. The bag, which represents the lung, is tied on to a tube, which passes through the rubber cork and opens in the helmet. The cylinder is closed below by a rubber cork, and is three parts filled with water, and the lowermost bag, which is tied on to a tube passing through the cork, also contains water. On sinking the model in water—the pump not working—the upper bag distends, the middle and lower bags shrink. Similarly, in a diver the blood would be driven into the head, the mouth and nose would bleed, and the breathing would become impossible owing to the pressure of the water on the body, the head and lungs being exposed only to the pressure of the air in the helmet.

No. 10. (Pump Working.)

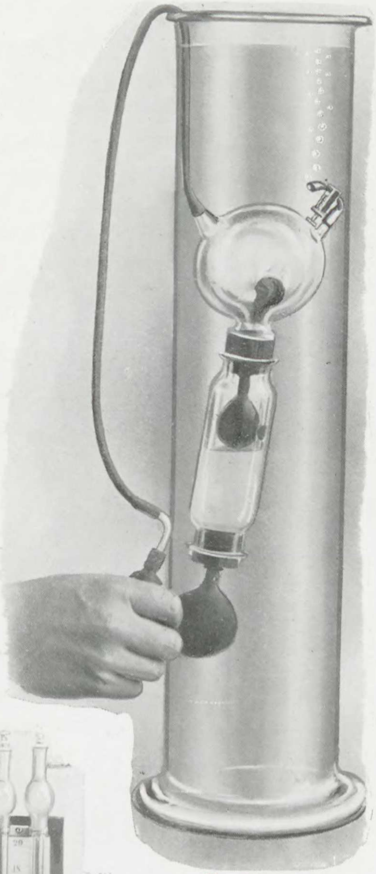
The head bag is shrunk, the lung bag and the body bag expanded, and a continuous stream of air is escaping from the helmet. The air pressure in the helmet is made slightly greater than the water pressure outside, and the conditions are then the same as when the model is suspended in air. So with the diver, all parts of his body are pressed upon equally, and as the air pressure in his helmet is equal to the water pressure outside, no congestion of blood takes place, and he can breathe comfortably.

No. 11.

The model diver shown in photograph No. 3 has a small hole pierced in the back of the helmet. An india-rubber syringe bulb is connected with a flask full of air, and this flask in turn is connected by a T-piece to a pipe in the diver's helmet and to a manometer containing coloured water. The model shows that the deeper the diver goes the greater must be the pressure to force air through his helmet. The height of the column of fluid separating the level of the liquid in the right and left-hand sides of the manometer keeps just greater than the level of the hole in the diver's helmet.

For description, see page 19.

No. 9.



No. 10.

No. 11.

NOTES ON THE SELECTION OF DIVERS AND CAISSON WORKERS.

They should be steady men, of good physique, capable of sustaining a good bodily strain; they should undergo a strict medical examination as follows:—

The candidate should be of good physique and free from obesity.

Particular attention is to be taken that he is free from any cardiac or pulmonary disease; that he suffers from no active constitutional complaint, such as syphilis, albuminuria, etc., and shows no sign of middle ear disease; that there is no history of fits of any kind, and that he is not addicted to alcohol or smoking in excess. There should be no tendency to varicose veins or arterial degeneration.

Periodical Examination of Divers.—Every man before diving should be carefully examined as to the above conditions. He should not go down directly after a heavy meal, and his general health should be good. His bowels should be kept regular.

For deep diving, or work involving *very long stays* on the bottom at more than 10 fathoms (60ft.), men beyond the age of forty-five ought not to be employed.

Very Fat Men Not Suitable for Deep Diving.

Dr. A. E. Boycott, M.D., and Lieutenant G. C. C. Damant, R.N., have carried out experiments on the influence of fatness on susceptibility to caisson disease. Their conclusions are summarised as follows:—

"The practical conclusions are clear. Really fat men should never be allowed to work in compressed air, and plump men should be excluded from high-pressure caissons (*e.g.*, over + 25 lb.) or in diving to more than about 10 fathoms, and at this depth the time of their exposure should be curtailed. If deep diving is to be undertaken, or caissons worked at pressures approximating to + 45 lb., skinny men should be selected. It is unfortunate that an increase of experience and skill in technical operations should so often be associated with the increase in waist measurement which accompanies the onset of middle life. Middle-aged men have a lower rate of respiratory exchange than young men; if fatness is not the explanation of this, they are at a double disadvantage, and the two factors must be multiplied, rather than added together."—(*Journal of Hygiene*, Vol. VIII., No. 4, September, 1908.)

DESCRIPTION OF THE DIVER'S APPARATUS, AND HINTS AS TO THE CARE OF SAME.

DIVING PUMPS.

The following types of Hand-worked Diving Pumps are in general use :—

(*a*) *Two-cylinder Double-acting, for two divers working simultaneously in moderate depths,* or *one diver in deeper water.* This type is supplied to the British Admiralty ; it is also largely used on Harbour and Dock Works.

(*b*) *Four-cylinder Single-acting,* for the same duty as above.

(*c*) *Three-cylinder Single-acting* Pump for one diver. This is largely used on Harbour, Dock and Bridge Works, and for Pearl and Sponge Diving, etc.

(*d*) *Two-cylinder Single-acting,* for one diver working at moderate depths.

(*e*) *One-cylinder Double-acting,* for one diver working in moderate depths. This type is also used by the British Admiralty, for depths not exceeding 40 to 50 feet.

(*f*) *One-cylinder Double-acting,* for one diver. This is a very light, portable pump for shallow water work.

THE WHOLE OF THE ABOVE PUMPS ARE OF THE ROTARY TYPE.*

The *Baseplates, Valve Chambers* and *Cylinders* are of *Gunmetal.* To ensure absolute reliability under all working conditions, *iron for any of these parts should be avoided.*

The *Valves* are *interchangeable,* and are *readily accessible* without removing the pump from its chest.

Each pump is fitted with a compound *gauge, which indicates* both the *pressure of air and the depth of water* at which the diver is working.

Air-distributing Arrangement.—The Two-cylinder double-acting and Four-cylinder single-acting pumps are provided with a patent air-distributing cock, which enables each double-acting cylinder, or each pair of single-acting cylinders to act independently of the other, the pump then supplying air to two divers at different pressures if necessary, or both double-acting cylinders, or all four single-acting cylinders, as the case may be, to deliver their air through one nozzle and length of piping at will. The arrangement is worked by a rod, operated from the upper part of the pump chest by means of the lever shown in photo No. 12.

* Illustrations and further particulars of the pumps will be found in Siebe, Gorman & Co.'s General Catalogue.

There are two positions for the cock:

(1) When the lever is moved over to "*One diver, deep water*," the air from *both* cylinders is delivered at the left-hand nozzle only, none issuing from the right-hand nozzle;

(2) When the lever is moved over to "*Two divers*," each cylinder delivers air through its own nozzle, so that two divers can work independently of each other.

Photo No. 12.

Nozzle for One Diver, Deep Water.	Nozzle for Second Diver, Ordinary Depths.
Lever to Right-hand side.	Lever to Left-hand side.

Copy of Direction plate placed near Air Delivery Nozzles of Pump.

When sending a *single* diver down, his air-pipe must always be joined to the *left-hand* nozzle, even if it is intended to use one cylinder only. Should the diver ask for more air, the second cylinder can then be switched on; but were the diver joined up to the right-hand nozzle, putting the handle over to "one diver, deep water," would cut off his air supply altogether.

Instructions as to when one double-acting cylinder may be used, and when both are necessary, will be found on page 47.

DIVING HELMETS.

There are eight different types of Diving Helmet in use, each pattern having its particular adherents in different parts of the world, viz.: 12-bolt; (with round and square-shaped corselets); 8-bolt; 6-bolt; 3-bolt; 2-bolt; lock—without bolts (two patterns).*

THE 12-BOLT AND 8-BOLT HELMETS have four metal bands, between which and the outer edge of corselet the flat indiarubber collar (punched with 12 and 8 holes respectively) of the diving dress is clamped watertightly.

* Illustrations and further particulars of these will be found in Siebe, Gorman & Co.s' General Catalogue.

The 6-bolt helmet has two metal bands, the under side of each having three recesses into which corresponding ribs formed on the indiarubber collar of diving dress fit.

The 3-bolt helmet has a flanged ring at the lower end of the head-piece and another on the breastplate, to correspond, each being formed with three lugs spaced equi-distant, the lugs of the breastplate being fitted with metal bolts, the lugs of the upper ring having holes to correspond. The indiarubber collar of diving dress has a similar flange, which is clamped between the metal rings above described, the whole being secured watertightly with three metal nuts.

The 2-bolt helmet is fitted with a metal clamping piece, back and front of which is fitted a bolt. The diver having put on his diving dress, the clamping piece is placed under the indiarubber collar, just inside the bead formed on the edge of the latter. The corselet, which is formed with the helmet in one piece (the former having a hole back and front, corresponding with the two bolts in the clamping piece), is put over the bolts, and the whole is then screwed up with the two nuts provided, the clamping piece and corselet, with the rubber collar between, thus being drawn together and making a watertight joint. The clamping piece is strengthened from the back and front towards the shoulders, so that there is no fear of its buckling.

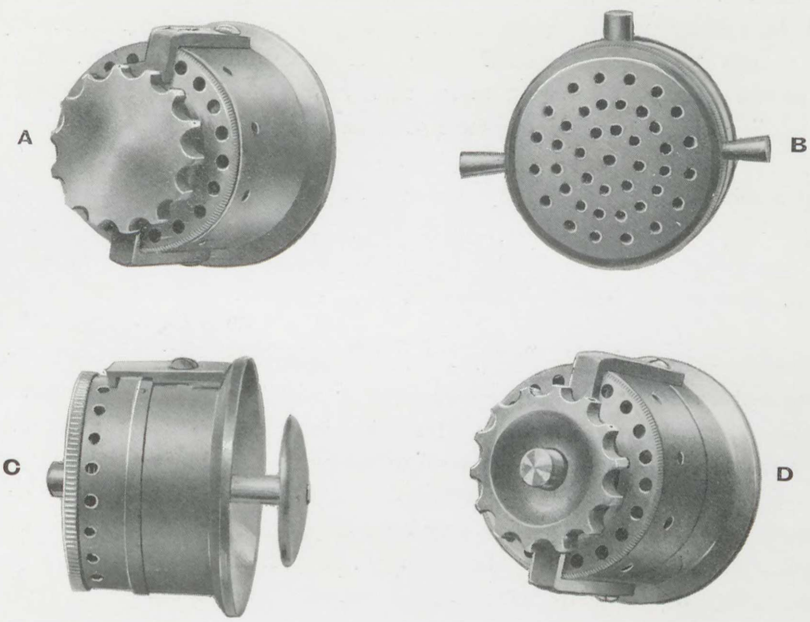
Lock Helmet (two forms) :—(*a*) has a ring, formed with a nipple, on the lower part of the head-piece, and a recessed ring, in which is fitted a rubber washer, on the breastplate. The rubber collar of the diving dress is formed with a flange which fits into the recessed ring described; the head-piece, which is hinged on to the back of the breastplate, is then closed down on to the rubber collar (the nipple of the upper ring entering the orifice of the breastplate and pressing against the inner side of the rubber collar), the whole being clamped securely with a special locking device.

(*b*) is somewhat similar in principle to the helmet described above (*a*), excepting that in the present case the joint between helmet and dress is made by screwing the head-piece to the breastplate, the flange of the rubber collar of the dress fitting in a recess in the breast-plate.

The air-inlet connections of all these helmets are fitted with non-return valves, which, together with the regulating outlet valves, are described on pages 25, 26 *and* 27.

The Regulating Outlet Valves are of four types, each of which, when adjusted, works automatically. Those lettered A. B. and D. are regulated by hand. When it is desired to let air escape the screw is turned outwards; when it is required to retain more air in the dress the screw is turned inwards.

REGULATING OUTLET VALVES.



Copyright. **Photo No. 13.**

(*a*) For regulating by hand.

(*b*) For regulating by hand.

(*c*) For regulating by pressing the head against it, inside the helmet.

(*d*) For regulating by hand. This valve, which in general construction is similar to (*a*), has been specially designed for use with helmets fitted with the telephone. When receiving a message, the diver presses the spindle which passes through the cap of the valve. This holds the valve on its seating and thus stops the noise caused by vibration and by the air escaping into the water. This arrangement is specially useful to divers who may be somewhat deaf, as is often the case with men who work under compressed air.

Helmets and Corselets (Breastplates).—The following is a description in detail of the patent helmets as used in the British Navy. The other types of helmet described differ only in mechanical detail, the principle being the same in all.

Corselet (12-bolt and 8-bolt).—The corselet, or breastplate, is made of tinned copper; the outer edge is strengthened with a broad metal band (sometimes the whole corselet is made in one solid gun-metal casting, but this, of course, is heavier), twelve or eight brass screw studs being securely fixed in it at intervals. These pass through corresponding holes in the indiarubber collar of the diving dress, and also through metal straps (four in the case of the 12-bolt and 8-bolt helmets) which are forced down on to the rubber collar by wing nuts, and thus clamp the collar watertightly to the corselet. The neck of the corselet has a segmental screw ring (an interrupted screw thread) on which the helmet, which has a corresponding ring, is screwed securely by one eighth of a turn; a recessed washer makes the joint quite watertight. Two studs in the front of the corselet are for the metal clips of the weights to take over, but some divers do not use these, preferring to use slip-lines for the weights.

The 6-bolt Corselet has only two metal straps (of a stronger description than those of the 12 and 8-bolt corselets), these being recessed on the under side to take ribs which are formed on the indiarubber collar of the dress. As in the case of the 12-bolt helmet, the clamping is done by means of wing nuts.

Helmet.—The helmet, which is of tinned copper, is, as already mentioned, fitted with a segmental ring at the neck corresponding with that on the corselet. A small stop, or pin, is provided at the back of the helmet which is turned down into a recess on the corselet as a precaution against the helmet unscrewing.

Three strong flat glasses, half an inch thick, are fitted in brass frames in the helmet; those at the sides being oval and protected with brass guards, the front glass being circular; the latter can be unscrewed, enabling the diver to give orders and get fresh air without removing any other part of the dress, or if he has to come up for a rest, the whole helmet may be unshipped by one-eighth of a turn. Sometimes an additional window is fitted at the top of the helmet, to enable the diver to look upward without bending his body back.

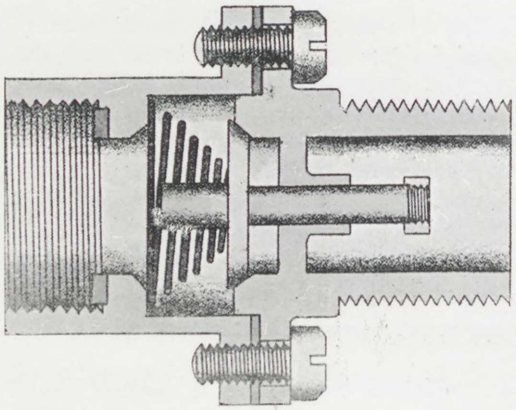


Fig. No. 14.

Inlet Valve (Fig. No. 14).—The air from the pump enters the helmet through the non-return "inlet valve," the outer end of which has a male thread to which the air pipe is screwed.

The inlet valve consists of a metal disc and spindle which is pressed on to a coned metal seating by a light metal spring. Air coming in from the air pipe can easily overcome this spring and lift the valve, but none can pass backwards from the helmet to the air pipe. The object of this arrangement is to prevent injury to the diver in the event of his air pipe being injured some distance above his head, or the pump becoming so seriously damaged as to fail to maintain a pressure. If either of these things happened the pressure in the air pipe would fall considerably, and if there were no non-return valve on the helmet the highly compressed air in the latter would escape up the air pipe, and the result would be that inside the rigid helmet there would be far less pressure than the surrounding water was exerting on the body of the diver through the flexible parts of the dress. 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 taken into deep water. Quite a slight pressure applied in this way is known to be very dangerous. THE EFFICIENCY OF THE INLET VALVE, THEREFORE, IS A MATTER OF THE UTMOST IMPORTANCE. Were the pipe to burst or the pump to fail, the joint action of this valve and the outlet valve, which could be closed by the diver, would retain enough air in the helmet to last for several minutes, and enable him to reach the surface. The air, after entering the elbow pipe, is conducted down inside the helmet by conduits arranged so as to give the best ventilation and prevent the accumulation of moisture on the glasses.

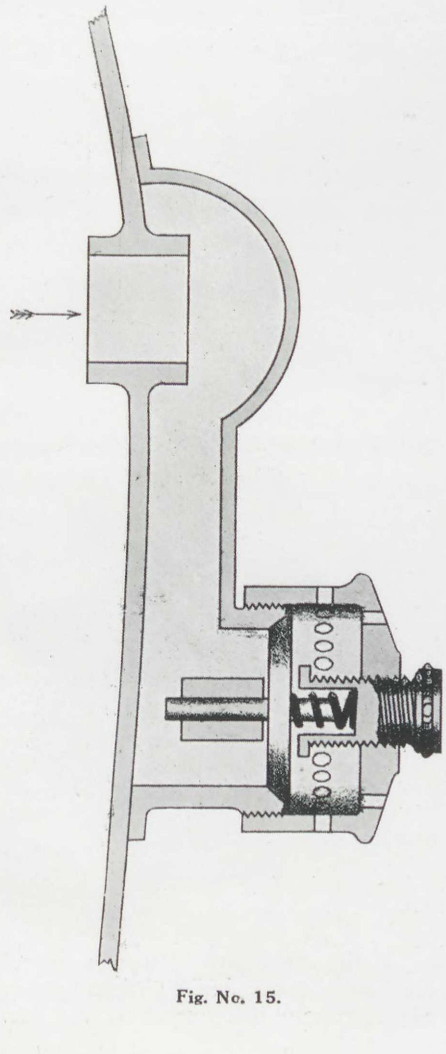


Fig. No. 15.

OUTLET VALVE (Fig. No. 15).—The foul air escapes through the outlet valve (photos A and D), which is fixed in such a position as to be behind the diver's right ear when the helmet is screwed on; the bubbles issuing from it do not obstruct the view, as would be the case were the valve in front. This also is a non-return valve, which works in the opposite way to that of the inlet valve; and, while allowing the air to escape from the helmet, prevents water from flowing in. The pressure of the surrounding water tends to keep the valve pressed hard down upon its seating. Before air can lift the valve and escape, it must be raised to a slightly higher pressure than the water. In addition to the water pressure, a small metal spring is fitted which bears the valve down on its seating; the force exerted by this spring can be varied by a screw regulator, which is adjusted by the diver himself when under water. By screwing it up he increases the pressure of the spring upon the valve, and consequently the pressure of the air inside the dress, making it equal to the pressure of a lower level of water. The air then reaches farther down beneath the corselet, and breathing is rendered easier.

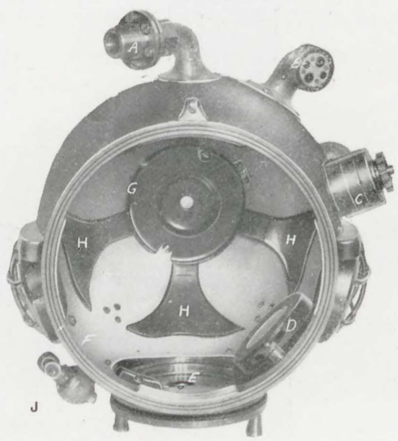
DIVING HELMET.

Copyright.

Helmet and Corselet Disconnected to show Details.

Copyright.

A—Air Inlet Valve.
B—Telephone connection for Cable.
C—Regulating Outlet Valve, type D, as per page 25.
D—Telephone Transmitter
E—Chin Contact for ringing bell.
F—Segmental Rings.
G—Telephone Receiver.
H—Air-ways from Inlet Valve, with outlets over glasses.
J—Spit-cock.



Copyright

Above photos show the Helmet and Corselet disconnected. The segmental rings, by means of which the helmet is removed from the corselet by one-eighth of a turn, are clearly shown, as also is the arrangement of the telephone instrument, valves, etc.

Front Tap.—A small gun-metal cock (sometimes called the "spitcock") is fitted on the left side of the face glass; when the handle is *vertical* the tap is *closed;* when the handle is *turned outwards* the tap is *open.* Its use is explained on page 55. Sometimes a wheel valve is fitted here instead of the cock as described.

Brass hooks are fitted on each side of the neck, over which the lanyards of the lead weights pass.

The front and back weights are of lead, and are shaped to fit close to the body. They have gun-metal clips to fasten to the studs on the front of the corselet, or they may be fitted with lanyards for slipping.

The Diving Dress is made of solid sheet indiarubber, between two layers of tanned twill. It has an inner and an outer collar, the *inner* one (sometimes called the "bib") of the same material as that of the dress, to pull up round the neck, and the *outer* one, of vulcanised indiarubber, to go over the breastplate to form a watertight joint. The cuffs are also of vulcanised indiarubber, and fit tightly round the wrists, making, when secured by the vulcanised indiarubber rings, a watertight joint, at the same time leaving the diver's hands free.

Rings for Wrists.—These are made of vulcanised indiarubber, and go over the indiarubber cuffs to form a watertight joint; two or more may be required on each wrist. They are made in three patterns: (1 and 2) Broad and Narrow, plain; and (3) Broad, fluted. The Broad plain ring is worn one half on the end of the diver's cuff, the other half on his wrist. In the case of the fluted ring, the beaded edge of the diver's cuff rests in the recessed part of the ring.

Air Pipe.—Air pipes are made in 30ft., 45ft., 50ft. and 60ft. lengths; and are fitted with suitable gun-metal couplings at each end. The pipe is made in *sinking* and *floating* patterns. In cases where both kinds are used, the *floating* should be *connected to the diver's helmet,* and the *sinking to the air pump.* This arrangement prevents the pipe from being heavy on the diver, and at the same time keeps the upper part of the pipe from floating up, and perhaps fouling propellers, etc.

Double male connecting pieces are provided, which enable two female ends of two lengths of air pipe to be joined together, and similarly double female connections are provided for joining up two male ends.

By embedding the wire in the walls of the pipe, instead of winding it inside the bore, it is protected from corrosion, and, the bore being thus kept quite smooth, the friction of air passing through is lessened. The internal diameter of the air pipe is about ⅝ths of an inch. It is tested to 200 lbs. to the square inch, and under this pressure should not shew any increase of diameter.

The strength of the piping lies in the layers of canvas and the steel wire, the indiarubber only serving to protect them from the action of the water.

LEATHER WASHERS must always be inserted in the female couplings when joining up the air pipes.

4-WAY JUNCTION (Photo No. 16).—The junction is used for connecting up two or more pumps to one diver when going into very deep water (see tables on pages 47-49). It has four connections; three of them, fitted with shut-off taps, are for joining up pumps; the fourth, which has no tap, is for connecting the air pipe of the diver.

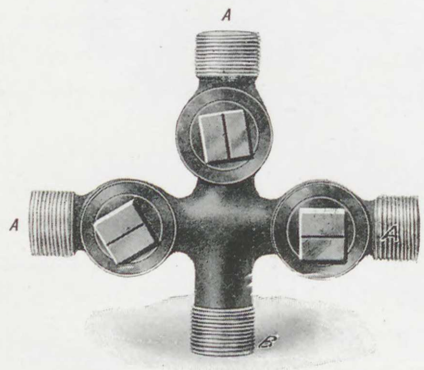


Photo No. 16.

A A A — *Connections to Air Pumps.*

B — *Connection to Air Pipe.*

If, when using this junction, the diver being under water, it is desired to *take off* one of the pumps, the tap on the connection to which that pump is joined up *must first be shut.* When *putting on* an additional pump, it must first be hove round, delivering its air against the shut-tap till its gauge shows the same pressure as the other pumps heaving for this diver; after this the tap may be opened. The greatest caution must be exercised in opening taps on the junction when a diver is down, as, should the air be allowed to escape, the diver would most likely be killed, particularly if his inlet valve failed to act.

ON NO ACCOUNT WHATEVER SHOULD THE PIPES OF TWO DIVERS BE JOINED UP TO THE SAME JUNCTION.

Shot-belt.—This belt, weighing 45lbs., is made of stout canvas, weighted with slabs of lead. It may be used instead of the back and front weights when working about a ship's bottom, or it may be worn in addition to the back and front weights when working in a very strong tideway. The belt is fitted with rope braces which come over the shoulders and are secured in front. Some belts are made with the leaden slabs in pockets, so that the weight can be adjusted to requirements.

Boots.—The boots are of stout leather, with wooden soles, to which are riveted lead soles, the weight of each boot being about 16lbs.; metal toe-caps are also fitted. Straps and metal eyelets for lanyards are provided for lacing on the boots. Brass boots with renewable leather uppers are sometimes used.

Overall Dresses.—Canvas overalls (combination suits) are supplied to be worn outside the diving dress for protecting it when rough work has to be done. They are made to fasten at the back, and in front is a large pocket in which the diver can carry tools, etc. These overalls are also made with the jacket and trousers separate.

Shoulder Pad.—The helmet cushion, or shoulder pad, is worn on the shoulders inside the dress, and protects the body from the weight of the helmet and corselet.

Ladder.—An iron ladder should be provided by which the diver goes out of and comes into the boat; in addition to the hooks on the ladder which fit on the gunwale, the upper part should be secured by a lashing. A small rounded spar to rest under the width of the ladder outside the gunwale will give the necessary inclination to the ladder, and also protect the gunwale of the boat.

Shot-rope.—This should be kept with the diving gear. Twenty or thirty fathoms of hemp rope, not smaller than three inch, should be spliced to a fifty-pound sinker. The distance-line, consisting of about 5 fathoms of 1½in. line, should be spliced in, about 3ft. above the sinker. Both the shot-rope and distance-line should be of brown (tanned) rope, which will not be found slippery under water.

Lamp for Divers.—The diving lamp should be placed under water before being switched on, to prevent the glass shade from being broken through being plunged into cold water after becoming heated.

Telephone (*Single Diver Type*), Photo 17. — This apparatus consists of a wooden box containing the following gear:—A battery of eight wet or dry cells, telephone transmitter and receiver for the use of attendants, a wrench, and a spanner for nuts.

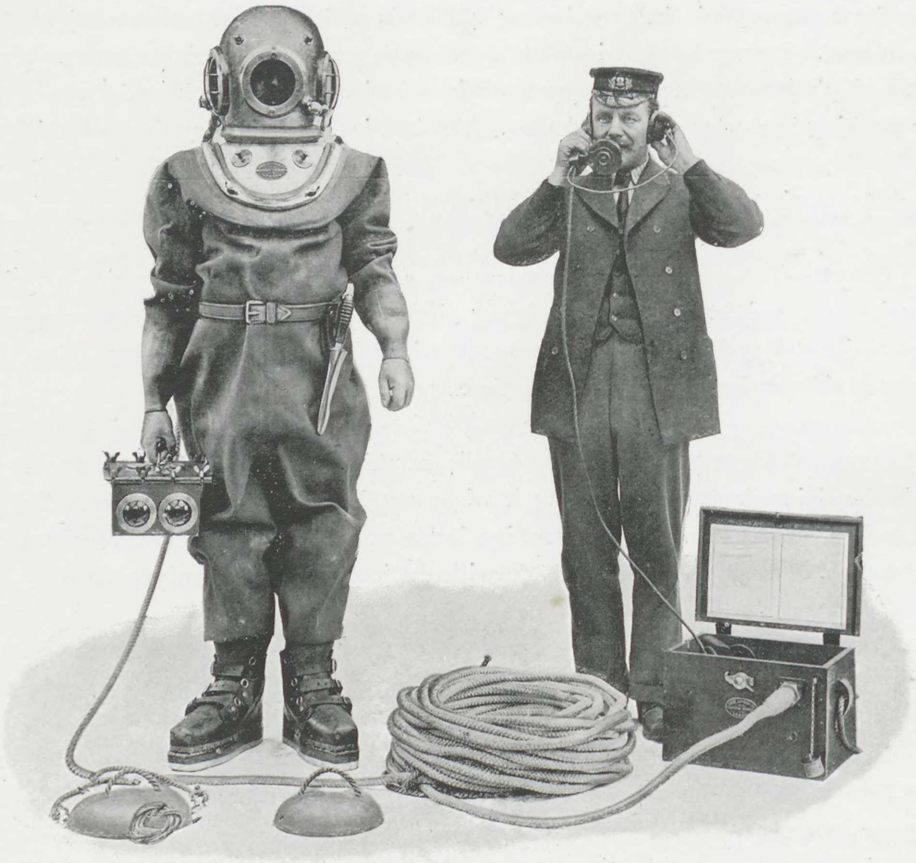


Photo No. 17.

SINGLE DIVER TELEPHONE.

The electric cable is in the centre of the signal line. When using the telephone gear, the plug fitted to one end of the life-line is attached to the connection on the battery box, the other end is attached to the connection on the helmet; the diver's receiver is fitted in the top of the helmet, inside, and his transmitter on the right-hand side of the helmet. The diver, when speaking, should turn his head slightly to the right, and *talk slowly and distinctly in a moderate voice.* HE SHOULD NOT SHOUT. The telephone must be handled with care, especially when passing it into or out of boats. The box must be kept dry. After much use, the battery becomes exhausted, when the cells should be renewed.

TELEPHONE (Double diver type), Photo No. 18.—With two divers under water, the attendant is enabled to converse with either or both of them, and the divers themselves can also talk to one another, their conversation being audible to the attendant.

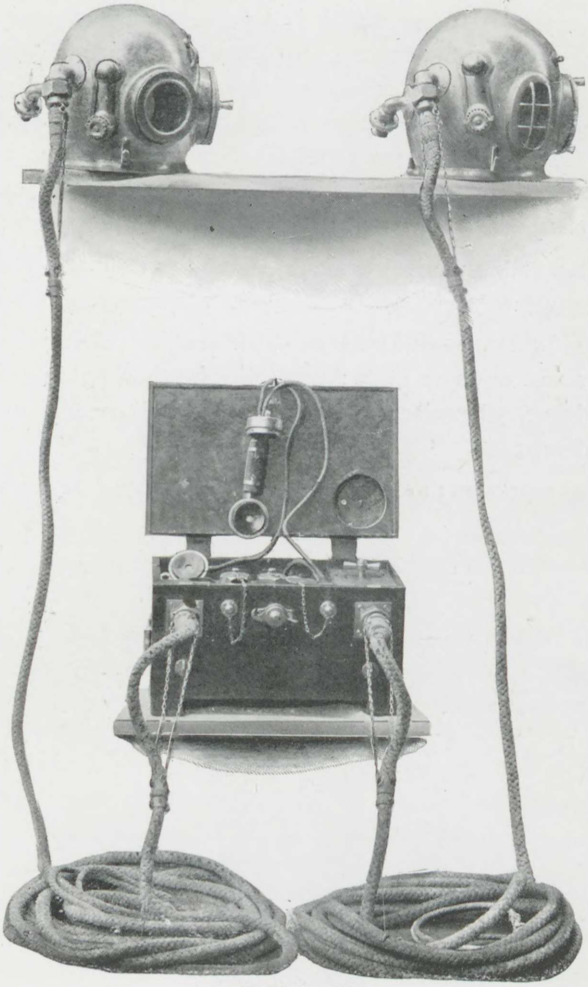


Photo No. 18.

DOUBLE DIVER TELEPHONE (Graham & Davis' Patent). *See page 32.*

CARE OF DIVING GEAR.

Cleaning the Apparatus.—After the day's work is over, the joints of the air pipes must be carefully cleaned, and the pipes coiled away in the helmet chest. The diving dress should be cleaned, and, if by any chance wet inside, or if the diver has perchance urinated in it, it should be turned inside out, and hung up *in the shade* to dry; the *dresses*, if used in salt water, *should be washed* at least once a week *in clean fresh water*. The underclothing must be kept dry and well aired.

If the pump is kept in store for long periods.—When in store, the pump, etc., must be kept clean and free from verdigris, and the clothing occasionally aired, etc. When wanted for use after lying by for some time, the pump should be taken to pieces by a good fitter, and examined to see that it is in proper working order. The helmet valves should be unscrewed and examined to see that they are free from verdigris, and should be slightly greased with tallow to prevent leakage, and the springs should be examined and renewed if necessary. All the screws of the helmet, breast-plate, air pipes, etc., must be kept free from verdigris, and clean. SEE THAT NO OIL OR GREASE OF ANY DESCRIPTION, OR TAR, COMES IN CONTACT WITH THE DIVING DRESS, AIR PIPE, OR OTHER INDIARUBBER ARTICLES.

When a piston rod of a double-acting pump works loose, the screws at the top of the stuffing box must be tightened a little with a spanner.

CARE OF THE INDIARUBBER DRESSES.—Indiarubber diving dresses should never be packed away in a wet or damp state; they must be thoroughly dried, both inside and outside, before so doing, otherwise they will mildew, and become so rotten as to be of very little service afterwards.

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

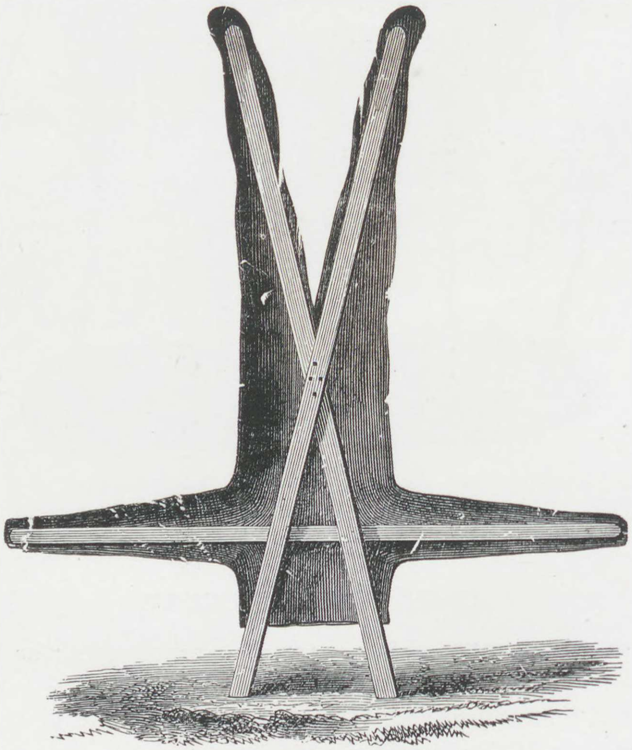


Photo No. 19.

Take two pieces of wood about 8ft. long, nail or screw them together in the form of St. Andrew's cross, place them inside the dress, and pass another piece through the arms to keep them distended. The dress can be then leant at a slight angle, in as cool and shady a place as possible, until it is dry.

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

Care of Air Pipes.—The indiarubber pipes should also be cleaned and thoroughly dried before being packed away.

Repairing Diving Dresses.—Prepared twill and indiarubber solution are provided for repairing leaky dresses. If the leak is due to a tear, first wash the place in fresh water and thoroughly dry it. Cut two patches of twill of the size and shape required—one for the outside, and another for the inside of the dress. Three coats of solution are applied round the tear, each being allowed to dry before the next is put on. Applying one coat of solution to the indiarubber side of the prepared patch, put the latter in place. The patch may be smoothed down with a flat iron, or a smooth piece of wood; a flat weight should be placed on the patch to keep it down while drying. As soon as one side is dry the other can be repaired in exactly the same way. Superfluous solution can be removed with a piece of indiarubber, but it is better to lay it on the proper width, so as to avoid the necessity of cleaning off.

If the leak is due to an imperfect seam in the dress, a quick repair can often be effected by rubbing solution into the channel of the seam; if this does not answer, a long strip of twill must be applied in the form of a patch to the outside of the seam.

Always wash all salt away from the neighbourhood of the leak before attempting a repair. See that grease, tar, etc., are carefully excluded. The indiarubber solution should be kept covered air-tightly when out of use. If the solution is too thick, dissolve with pure naphtha.

Inserting New Collars and Cuffs in Diving Dresses.—Having removed the old rubber collar and inner collar—which should be done after the careful application of naphtha, to avoid damaging the dress—solution out neck of dress, inside, about 2½in. in width all round, allow two hours for drying, solution out again, and allow to dry two or three hours, according to temperature of atmosphere.

Solution out rubber collar inside and put on the canvas strip (if same is not already on the collar), then solution the outside of collar 1¾in. wide from outer edge; allow two hours for drying.

Solution the inner collar about 2¼in. wide on the inside, allow usual drying, then insert solid collar in dress and roll down. Insert the inner collar now, and roll down.

Inserting Cuffs in Sleeves.—Solution out the cuffs 2¼in. wide twice, allowing usual drying; solution out sleeves of dress twice, place cuff on cuff block, and insert in position and roll down.

Helmet Washers.—If, as a result of wear, the helmet, when screwed hard on to the corselet, will go so far round to the right that the catch at the back is past its recess, and the front glass is not directly in front of the diver's face, one or more paper washers should be cut out and inserted under the large leather washer at the neck of the corselet, *i.e.*, if new leather washers are not available.

To replace worn cup Leather on Piston.—Remove the piston, file off the burr at the end of the rod, unscrew the nut securing the piston and remove the old leather cup; having soaked a spare cup leather in oil, place it on the rod and secure the nut as before.

The glands must be tightened up or repacked if there is much leakage round the piston-rod. Whenever a pump has been taken to pieces it should be tested, after reassembling, up to the full pressure marked on the gauge.

Measuring the Delivery of the Air Pump.—The efficiency of the pump is tested by measuring its output when working against a pressure. To do this a steel reservoir or other strong vessel whose capacity is accurately known (the capacity may be measured by filling with water and weighing) is connected by means of an adaptor with the diving pump. A pressure gauge should, if possible, be connected to the reservoir as a check on the pump gauge. When all is ready, commence turning at a steady rate of, say, 25 revolutions per minute, and note the number of revolutions required to raise the pressure to 15, 30, 45, 60 and 75lbs. per square inch respectively; the theoretical capacity being ascertained, the leakage can then be calculated.

Testing the Pressure Gauges.—To ensure bringing a diver up safely from deep water, it is necessary that the gauges on the pump should indicate correctly—particularly at depths less than 60ft. In the absence of other means, they may be tested by sinking the end of the air pipe (on a lead line, for instance) to 10ft. and to 50ft., and observing whether they indicate these depths correctly. When the orifice of the air pipe is at the required depth, the pump should be worked till air escapes; it is then stopped and the front of the gauge tapped lightly while the reading is taken.

DRESSING THE DIVER AND SENDING HIM DOWN.

Duties of those in Charge of Diving Operations.

A strong broad-beamed boat should always be used for diving operations. Having got everything necessary into the boat, arrange the position of the ladder and pump. The pump must be out of the way of the diver and the men attending him; it must be placed so that the attendants can have a clear view of the pressure gauges, and so that the men working it may have as much room as possible. Secure lashings are to be passed to ensure the pump being quite rigid in the boat. While the diver is dressing, the pump should be got ready. The pump should always be worked in its chest. The iron caps protecting the crank ends should be removed, the nuts securing them being replaced. The fly-wheels should then be fitted on the crank shaft, the winch handles shipped, and the nuts on the end of the shaft well screwed up with a spanner.

The hinged flaps covering the pressure gauges and the flap at the back of the pump case should be opened, the screw cap on the overflow nozzle of the cistern removed, and the cistern filled with water; the caps of the air delivery connections should be removed; the necessary length of air pipe should be put together carefully with leather washers in place, the union nuts being tightly screwed up by means of spanners. The air pipe should be tested till the pressure shown on the pressure gauge is considerably above that corresponding to the depth to which the diver will have to descend. If a two-cylinder double-acting pump be employed, *each cylinder* should be tested. If only one diver is going down, his pipe must be joined up to the left-hand delivery nozzle on the pump.

TESTING INLET VALVE ON HELMET.—Before screwing the air pipe to the inlet valve connection of the helmet, a finger should be inserted into the valve in order to see that it is free on its seating and that the spring is working properly.

JOINING UP AIR PIPE AND SIGNAL LINE.—The air pipe and breast-rope (signal line) are now joined up to the helmet. Care must be taken that the plugs of the telephone cable are entered in the proper holes before screwing up the nut on the breast-rope, that the inlet valve on the helmet is correct, and that the leather washers of air pipe couplings are in place before the pipe is screwed up. Two spanners are always to be used in joining up lengths of pipe and in connecting the pipe to the helmet.

The breast-rope should now be joined up to the battery box, and the telephone tested.

Air pipe and breast-rope are to be coiled down in large flakes out of the way, so that they may run out easily.

DRESSING THE DIVER.—The diver puts on the woollen guernsey, drawers, and long stockings supplied. In cold weather he should put on two or more suits of flannels. If the red woollen cap is worn, it must be pulled close down over the head, care being taken to leave no loose end which might possibly obstruct the air outlet.

The shoulder pad (if one be worn) is put on and tied under the diver's arms. He then gets into the diving dress, which in cold weather should be *slightly warmed*, an assistant lifting it well up to allow him to get his shoulders in easily; he next puts his arms into the sleeves, the assistant opening the cuffs by inserting the first and second fingers of both hands, 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). A little soft soap rubbed on the inside of the cuff makes this operation easy. If required, he puts on a pair of outside stockings and a canvas overall, to preserve the dress from injury or undue chafing.

The diver then sits down, the inner collar (or bib) of the dress is drawn well up and tied round the neck; then the boots and the breast-plate are put on, great care being taken that the indiarubber outer collar of the dress is not torn in putting it over the projecting studs of the breast-plate. The four jointing straps (in the case of the 12-bolt helmet) of the breast-plate band are then put over the studs and down on to the rubber collar, the thumb-screws are then run into the studs; before tightening up the screws the shoulder holes of the collar of the dress must be borne close up to the studs on the breast-plate, and the thumb-screws next on each side of that joint screwed down first, the diver holding his arms well up to assist; *the thumb-screws at the joints are the last to be screwed down*; the overall dress is then adjusted, the wrist rings are put over the cuffs; if gloves are used, rings are put over these, as well as the cuffs.

Putting on the Boots.—The boots are put on with the buckles outwards and the lanyards well secured round the ankles.

The helmet (without the front glass) is then put on, and screwed hard into place, the stop (lock-pin) at the back being turned down. The breast-rope and air pipe are brought up under the right and left arms respectively, and secured to the front of the corselet by lanyards, rolling hitches being employed.

The lizard on the breast-rope is passed round the waist and timber-hitched securely. If a knife and belt are worn, the latter must be secured to the air pipe by the buckle provided.

The pump is now manned and hove round a turn or two, so that the diver can tell that the pipe is properly joined up by hearing the rush of air into the helmet.

He then gets on the ladder, the attendant keeping the breast-rope and air pipe in hand, lest the diver should slip and fall overboard.

Putting on the Weights.—The weights are then put on, the back one first, the lanyards being brought over the hooks on the helmet, rove through the rings in the front weight, and secured with a bow hitch. The long lanyard is then brought round the waist, rove through the thimble in the front weight, and secured at the left side. If using the clips, the front weight is put on first, the clip being placed over the studs on the breast-plate; the back weight is then put on, the clip lashings over the hooks on the helmet, the two being secured to the diver's body by the lanyard round the waist.

When the attendant is satisfied that all is correct, and that the diver understands the signals, he orders the pump to be hove round and screws up the front glass securely; this done, he takes hold of the life-line and pats the top of the helmet, which is the signal for the diver to descend. The ladder should always be used when going out of and coming into the boat, and the shot-rope to descend and ascend by.

Attendance.—Each diver while under water requires an attendant to hold the breast-rope and air pipe.

The post of attendant is a very responsible one. From the time the diver gets on the ladder to go down till he comes up again, the attendant must concentrate his mind on his charge, and never let his attention wander. The breast-rope and air pipe must be held clear of the gunwale and *moderately* taut, so that the movements of the diver can be felt, and a rough idea formed of what he is doing. But care should be taken not to have them so taut as to inconvenience the diver.

The attendant should frequently glance at the pressure gauge of the pump to ascertain any changes in depth, and he must always know whereabouts the bubbles are coming up and the directions in which they are moving. Where there is much rise and fall of tide he must see that the shot-rope is lowered, so as to keep the shot on the bottom, or hauled in to keep it taut, as the case may be.

When the diver is working on a ship's bottom or other place from which he might fall, the attendant must be on the alert to catch him with the breast-rope (signal line) and pipe should this happen, and should the breast-rope be paid out for any reason, such as sending down another rope or a slate, he must see that the air pipe is kept well taut in case of a similar accident. It is better, however, to use a separate rope for sending down articles to the diver.

When two or more divers are down together, the attendants should do all they can to prevent them from getting foul of each other, watching the two sets of bubbles and warning the men by pre-arranged signal or by telephone, if need be.

Pressure Gauges.—Great attention must be paid to the pump gauges. Should they fall quickly, it shows that either the diver is coming up, or that something is wrong with the apparatus; the signal should be at once made to the diver asking if he is all right. If he replies that he is coming up, the pipe and breast-rope must be gathered in smartly. Should, however, the diver signal back "All right," and the gauges still continue to fall, something must be wrong with the apparatus, and the diver must be at once called up. If the gauges rise quickly, it shows that the diver has fallen; ask the diver if he is all right. If he signals "All right," he has recovered himself; if no reply is received, *he must at once be hauled to the surface, but not too rapidly.*

If the diver has any difficulty in getting under water, or should he be blown up from the bottom, the attendant must use his discretion and ease or stop the pump, until the surplus air has been got rid of. If the diver cannot help himself, the outlet valve and tap on the helmet must be opened, or the cuff pulled open, so as to let the excess air escape. *Be careful to have the pipe and rope well in hand so that the diver cannot drop down suddenly.*

If the diver, on coming up, has a number of turns round the shot-rope, and it is difficult to take up the slack of the air pipe and breast-rope, it is better to pull up shot-rope, air pipe, and breast-rope, all together.

Diver coming up.—When the diver comes up, the front glass should be at once removed. If he is soon going down again, he can have his wrist rings removed, and can take the weight off his body by leaning forward and resting the front weight on the gunwale or ladder; if he is to cease work or remain up a considerable time, the weights should be removed and the diver assisted into the boat and his air pipe and breast-rope disconnected. He can then sit down, and his helmet should be removed. If he has ceased work, the waist-belt and boots are next removed, then the overall dress (if worn). The breast-plate bands should then be removed, the thumb-screws at the junction of the bands being unscrewed first; the bands being removed, the outer collar should be taken off with care to prevent the threads of the studs tearing the edges of the holes in the indiarubber in getting the collar over the screws; the breast-plate and dress are then removed, the assistant's thumbs being used to enable the diver to withdraw his hands from the cuffs; the shoulder pad and other clothes are then taken off. After the day's work is over, the instructions as to care and management of gear must be carefully carried out before stowing it away.

Signals between Divers and Attendants.

From Diver to Attendant.

On Breast-rope:—

1 pull means ... ... "I am all right."
2 pulls mean ... ... "Send me a slate."
3 pulls mean ... ... "Send me a rope."
4 pulls mean ... ... "I am coming up."

On Air Pipe:—

1 pull means ... ... "Less air (ease pump)."
2 pulls mean ... ... "More air (heave faster)."
3 pulls mean ... ... "Take up slack pipe and breast rope."
4 pulls mean ... ... "Haul me up."

Working Signals or Bells.

On Breast-rope:—

1 bell means ... ... "Hold on."
2 bells mean ... ... "Pull up."
3 bells mean ... ... "Lower."

Cleaning Ship's Bottom (using a stage).

On Air Pipe:—

1 pull means	"Foremost starboard rope."	*Followed by the ordinary ("pull up" or "lower") signal.*
3 pulls mean	"After ditto."	
2 pulls mean	"Foremost port rope."	
4 pulls mean	"After ditto."	

Signals from Attendants to Diver.

Direction Signals.

On Air Pipe:—

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."

On Breast-rope:—

1 pull means ... ... "Are you all right?"
2 pulls mean ... ... "Am sending a slate."
3 pulls mean ... ... "You have come up too far. Go down slowly till we stop you."
4 pulls mean ... ... "Come up."

Other signals will of course be arranged between diver and attendant to suit the exigencies of the particular work in hand. But where the TELEPHONE is used this method of signalling can be dispensed with.

Foul Signals.—Foul signals can be made on either Air Pipe or Breast Rope. Two bells repeated several times quickly mean that the diver is foul, and requires the assistance of another diver; on receiving such a signal no attempt should be made to haul the diver up, but the second diver sent down as quickly as possible. Three bells repeated several times in quick succession 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 show that he is in difficulties, are to be reported immediately to the officer or superintendent in charge on the spot. The person receiving a signal repeats it to show that he has understood it; *never answer a signal in this way unless you clearly understand what is meant;* if you get a wrong answer to your signal or none at all, go on making the signal until it is correctly answered.

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

If the breast rope and air pipe get turned round the shot rope, it may become impossible to get "pull" signals through, and the turns must be taken out from the boat as soon as they are noticed.

Do not try to make signals on a slack rope; pull up a foot or two till the diver can be *just* felt, and then make the signal gently but distinctly. A sudden or violent jerk may, by striking the helmet up against the diver's head, cause him injury.

Remember that a diver at work may sometimes be in such a position that he cannot answer your signals for several seconds, so allow him reasonable time before you repeat them.

Holding the Breast Rope and Pipe.—In attending the pipe and rope, give the diver two or three feet of slack when he is at the bottom, but just feel the weight of the man from time to time to make sure that you have not got too much slack out.

It is extremely embarrassing for a diver to find his pipe and rope too taut, so that his head 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 tightly, special care must be taken to avoid this.

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, and hold the breast rope. You should know from the gauge when he gets close to the bottom, and if you get one pull about that time it means, of course, that he has reached the ground; but if you were to get one pull while the gauge showed that the diver had not yet reached the bottom, the meaning would be "Hold on"; the diver has probably let go the shot rope, or for some other reason is unable to stop himself, and wants to be held by the pipe or breast rope. If you get two *bells* immediately after the diver has signalled that he has reached the bottom, the meaning would be that he wanted you to pull up the shot rope (which is probably too slack). When it was properly adjusted he would signal "Hold on," when you would turn it up.

Two *bells* immediately after the diver has signalled that he is coming up mean that he wants to be pulled up. Do this very gradually. If there was anything seriously wrong, the diver would have signalled to be hauled up by giving four pulls on his air pipe.

On going down, the diver, before leaving the surface, will signal by waving his hand that he is ready to do so.

The attendant answers this signal by one pull on the breast rope. The diver must not be allowed to go down the shot rope until he has made the above signal.

Sending down a Rope or Slate.—The procedure in sending down a slate to a diver is as follows: On receiving two pulls on the breast rope from the diver, the attendant attaches a slate, with pencil attached, to the breast rope; he then gives one pull on the breast rope. The attendant will pay out the breast rope, and the diver will steadily gather down the slack until he gets the slate. The diver gives one pull on the breast rope when he wants the attendant to take up the slack of the breast rope again.

The same routine is adopted in sending down a rope. After attaching this rope to the breast rope, the former is taken well forward or aft to prevent turns getting round the latter when the diver gets the rope. He must be careful not to dip it between his air pipe and breast rope.

Four pulls on the air pipe are an emergency signal, and the diver must never use it unless something serious has happened. There must be no delay in obeying it.

DUTIES OF THOSE IN CHARGE OF DIVING OPERATIONS.

The following gear should go in the diving boat. Where equipment is provided for two divers, the second dress, helmet, etc., complete, must be taken away as well, provided there is another diver to use them, in case of need.

GEAR TO BE USED.

Air pump with handles, wheels, etc., complete dress, helmet and corselet.
Boots.
Weights.
Suit of flannels.
Shoulder pad.
Breast rope and telephone box.
Sufficient air pipe.
Diver's knife and belt.
Rubber wrist bands.
Tool box, with air pipe spanners, butterfly nuts, etc
Spare leather washers for air pipe.
Fitted shot rope.
Diving ladder.
Slate with lanyard and pencil attached.
Lead line.
Boat's anchor and cable.
A watch for timing the diver.

Sufficient men are to be taken away to manage the boat, turn the pumps, and attend the divers.

See that the air pump is properly lubricated before use and the water jackets filled. The *water in these must be changed frequently*, so that it does not get warm. Each cylinder and all the pipe must be tested by stopping the end of the pipe with a screw blank cap, and heaving round the pump till the pressure on the gauge considerably exceeds that corresponding to the depth to which the diver is to go down.

See that the diver is properly dressed and that the pipe is correctly joined up, the oil cocks on top of the cylinders closed (if the double-acting type of pump is used), and the pump securely lashed in the boat. Explain to the diver exactly what has to be done, and see that he understands the routine to be followed in coming up, especially that to be followed in *deep diving*.

THE DEPTH MUST ALWAYS BE TAKEN BY LEAD LINE. ALL TIMES MUST BE KEPT BY WATCH AND NOTED WHEN DIVER IS WORKING IN DEEP WATER.

WORKING ON A SHIP'S BOTTOM.—When work is to be done about a ship's bottom, propellers, etc., the rigging of stages, bottom lines, or ladders that may be required for the work should be carefully supervised to ensure security. The engine-room officers should also be warned whenever a diver is going down to the neighbourhood of the propellers, valves, or submerged torpedo tubes. During such work every possible precaution should be taken to prevent the diver from falling. The boat must be kept abreast of him, and the air pipe and breast rope carefully attended. On no account must the diver be allowed to go under the keel of the ship and upon the opposite side of her to that alongside which the diving boat is lying.

WORKING ABOUT WRECKS.—In working about wrecks or in places where there is risk of the diver getting jammed or fouled, a second diver should be dressed and ready to go to his assistance if required.

The second diver need not be kept in the boat, but may be also under water and at work.

When a man is sent down to examine damage to a ship, it is generally a good plan to send him a slate, and let him make a rough sketch of the outlines of the injury and the lines of plating round it with the positions of any valves or outlets in the neighbourhood, 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.

SEARCHING FOR LOST ARTICLES.—Spots that have already been searched should be marked off by buoys or bearings, and the boat worked so as not to cover the same ground twice over. Where the object sought is a cable or anything which can best be found by moving in a straight line, the diving boat may be kept under oars with the shot rope hauled up so that the shot is a few feet off the ground ; the diver, holding the distance-line, allows himself to be towed slowly along the bottom, while the boat covers the ground systematically.

WHERE THE WATER IS VERY CLEAR AND NOT VERY DEEP, an iron grating may be slung under the boat and kept close to the bottom. The diver lies on this, and watches for the object while the boat is kept under way. In these cases special arrangements must be made so that the diver may stop the boat directly he sees the object, lest it should be lost again. One way is to keep the shot dragging on the bottom with a man attending the rope. On receiving one pull from the diver, the shot rope and the diver's pipe and breast rope are paid out freely till the boat is stopped and brought back so as to plumb the shot, when her anchor may be carefully lowered to the bottom clear of the diver (*not when he is on the grating*). In very clear, shallow water the catoptric tube may be usefully employed.

WORK IN A TIDEWAY.—In places where work has to be carried on in a tideway, the responsible official in charge of the operations should make himself acquainted with the times and run of the tides, and the duration of slack water, and arrange to be on the spot in good time. The behaviour of the shot rope gives a good guide as to when a man may usefully be sent down. When a 50 lb. sinker refuses to remain on the bottom, but is swept off by the tide, it will generally be found impossible for a diver to do anything on the bottom.

WHEN WORKING IN GREAT DEPTHS where a long time has to be spent on the shot rope in coming up, the diver must be called off the bottom in good time to prevent him from being exposed to too strong a tide while on the shot rope. On such occasions a sinker must be used of such weight as to render it impossible for the diver, while still on the shot rope, to be swept up to the surface by the tide.

DIVER ACCIDENTALLY BLOWN UP TO BE SENT DOWN IMMEDIATELY. The only treatment which is likely to be of any use to a man who has blown up *from deep water* is to send him down again at once, even though he has already begun to suffer from the effects of the sudden decompression. If he be helpless, his valve should be opened, and the man lowered down by his breast rope and pipe, another diver being sent down to look after him as soon as possible.

The official in charge must act promptly and without hesitation in such circumstances, getting the diver under water again without losing a moment. After a few minutes at the depth from which he came, the diver can be brought up in accordance with the scale.

JOINING UP TWO PUMPS TO ONE DIVER FOR VERY DEEP WATER.—To join up two or more pumps to one diver, the four-way junction described on page 30 is employed.

The air delivery nozzle of each pump is connected to one of the arms on the nozzle by a 30, 45, or 50ft. length of air pipe. (In the case of the Siebe-Gorman two-cylinder, double-acting type of pump, as used in the British Navy, the pipe connecting the arm of the four-way junction must be joined up to the *left hand* air delivery nozzle of the pump.)

The diver's pipe is joined up to that arm of the junction which has no tap. If only two pumps are connected up, the tap on the fourth arm is kept shut, the others being open. Before connecting the air pipe to the diver's helmet, its end is blocked with a screw blank cap, and both pumps are hove round till the full pressure is reached. This is to test the connections. This junction pipe should be mounted on a board and securely lashed in a convenient place where it is impossible for the taps to be accidentally disturbed.

In sending the diver down, the second pump should not be started until the man has left the surface. In coming up, one pump will generally be sufficient after the diver has reached his first stopping place. In joining up extra pumps or taking them off, the instructions on page 30 should be carefully followed.

Duration of Dives in Deep Water.—The following table gives the maximum time allowed in the British Navy for diving at various depths, and the procedure for coming up, the time to be counted from the time the diver leaves the surface (assuming that he is going down fast) and the time for all stops except the first to be taken from the end of the previous stop. The column at the end shows the number of cylinders necessary, assuming that the pump is kept working at the stated number of revolutions per minute.

A diver should not be allowed to come up from the bottom to the first stopping-place at a rate faster than 1ft. per second, and his ascent should be checked before he gets to the first stopping-place lest he should overshoot it. If this occurs he must be sent back to it (by making the signal "Three pulls on the breast rope"), and made to wait the proper time.

The table shows the system by which the diver is to be brought to the surface from various depths after having been down for different lengths of time.

At each depth the longest of the times shown on the table is the maximum allowed for the diver to remain on the bottom, and it must on no account be exceeded.

Should it be unnecessary for the diver to remain down for the full time allowable, the *decompression may be shortened according to the time he has actually been down*, as shown in the table. If, through getting foul or from some other cause, the diver is compelled to remain on the bottom longer than the maximum time allowed, the *decompression must be correspondingly extended*, as shown in Table II.

The columns showing the number of cylinders of Siebe, Gorman and Co.'s Double-acting Pumps required are calculated so as to give the diver enough air to prevent any respiratory distress while doing ordinary work. In cases of emergency, less air may be given if extra pumps are not available, but the pumps employed must be worked faster, and if the diver feels much distress in his breathing, he must not persist in trying to work without the proper quantity of air.

Enough men must be always on the pumps to keep up the number of revolutions shown as necessary, and the speed of the pumps must be frequently checked by watch and not allowed to drop. Men at the pumps should be relieved as necessary.

MANAGEMENT OF THE DIVER'S ASCENT FROM DEEP WATER.—In coming up, the time for all the stops except the first one, is to be counted from the end of the previous stop.

While the pump is working, the gauge shows a slightly higher pressure or greater depth than the diver is actually at. For this reason he should be stopped (by one pull on the air pipe) when the gauge indicates his depth as about 30ft. below the first stopping-place. The pump is then stopped and the front of the gauge lightly tapped to overcome any sluggishness of its indications, while the diver is signalled to come up, which he should do slowly until he is stopped at the right depth. The pump is then restarted. *If the diver overshoots the mark and comes up too far,* he must be sent down again to the proper depth, but the pump *must be restarted before he begins to descend, otherwise he may get squeezed.*

The importance of occasionally testing the pressure gauges as regards the correctness of their indications of depths from 10ft. to 60ft. has already been mentioned.

Extra Precautions after a Second Descent.—If a diver descends a second time into *deep water* with an interval of less than 1½ hours between the two dives, his body will be more highly saturated with nitrogen at the end of the second dive, and extra care is needed in bringing him up. A safe rule is to add together the times on the bottom in the two dives, and use the corresponding precautions shown in Table I. or Table II. The extra time is, however, only needed for the second half of the stoppages.

TABLE I., showing Ordinary Time-Limits in Deep Water, Stoppages during Ascent, and Approximate Air-Supply needed during Work, in accordance with Professor Haldane's recommendations, and latest British Admiralty practice.

Depth.		Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to Beginning of Ascent. **	Stoppages in Minutes at different Depths.						Total Time for Ascent in Minutes.	Number of Cylinders needed † ‡	Revolutions of Pump per Minute. †
Feet.	Fathoms.			60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.			
0–36	0–6	0–16	No limit	—	—	—	—	—	—	0 to 1	1	15 to 20
36–42	6–7	16–18½	Up to 3 hrs. ..	—	—	—	—	—	—	1 to 1½	1	25 to 30
			Over 3 hrs.	—	—	—	—	—	5	6		
42–48	7–8	18½–21	Up to 1 hr.	—	—	—	—	—	—	1½	1	30
			1 to 3 hrs.	—	—	—	—	—	5	6½		
			Over 3 hrs.	—	—	—	—	—	10	11½		
48–54	8–9	21–24	Up to ½ hr.	—	—	—	—	—	—	2	2	20
			½ to 1½ hrs.	—	—	—	—	—	5	7		
			1½ to 3 hrs.	—	—	—	—	—	10	12		
			Over 3 hrs.	—	—	—	—	—	20	22		
54–60	9–10	24–26½	Up to 20 mins. ..	—	—	—	—	—	—	2	2	25
			20 mins. to ¾ hr.. .	—	—	—	—	—	5	7		
			¾ to 1½ hrs. ..	—	—	—	—	—	10	12		
			1½ to 3 hrs. ..	—	—	—	—	5	15	22		
			Over 3 hrs.	—	—	—	—	10	20	32		

See foot-notes on next page.

TABLE I.—*Continued.*

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to Beginning of Ascent. **	Stoppages in Minutes at different Depths. 60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.	Total Time for Ascent in Minutes.	Number of Cylinders needed. † ‡	Revolutions of Pump per Minute. †
60–66	10–11	26½–29½	Up to 15 mins. ..	—	—	—	—	—	—	2	2	25
			¼ to ½ hr.	—	—	—	—	—	5	7		
			½ to 1 hr.	—	—	—	—	3	10	15		
			1 to 2 hrs.	—	—	—	—	5	15	22		
			2 to 3 hrs.	—	—	—	—	10	20	32		
66–72	11–12	29½–32	Up to 15 mins. ..	—	—	—	—	—	2	4	2	25
			¼ to ½ hr.	—	—	—	—	3	5	10		
			½ to 1 hr.	—	—	—	—	5	12	19		
			1 to 2 hrs.	—	—	—	—	10	20	32		
72–78	12–13	32–34½	Up to 20 mins. ..	—	—	—	—	—	5	7	2	25
			20 to 45 mins. ..	—	—	—	—	5	15	22		
			¾ to 1½ hrs. ..	—	—	—	—	10	20	32		
78–84	13–14	34½–37	Up to 20 mins. ..	—	—	—	—	—	5	7	2	30*
			20 to 45 mins. ..	—	—	—	—	5	15	22		
			¾ to 1¼ hrs	—	—	—	—	10	20	32		
84–90	14–15	37–40	Up to 20 mins. ..	—	—	—	—	3	5	10	2	30*
			20 to 40 mins. ..	—	—	—	—	5	15	22		
			40 to 60 mins. ..	—	—	—	3	10	15	30		
90–96	15–16	40–42½	Up to 20 mins. ..	—	—	—	—	3	5	11	2	30*
			20 to 35 mins. ..	—	—	—	—	5	15	22		
			35 to 55 mins. ..	—	—	—	5	10	15	32		
96–108	16–18	42½–48	Up to 15 mins. ..	—	—	—	—	3	5	11	4	20
			15 to 30 mins. ..	—	—	—	3	7	10	23		
			30 to 40 mins. ..	—	—	—	5	10	15	33		
108–120	18–20	48–53½	Up to 15 mins. ..	—	—	—	2	3	7	15	4	20
			15 to 25 mins. ..	—	—	—	5	5	10	23		
			25 to 35 mins. ..	—	—	—	5	10	15	33		
120–132	20–22	53½–59	Up to 15 mins. ..	—	—	—	2	5	7	17	4	25
			15 to 30 mins. ..	—	—	—	5	10	15	33		
132–144	22–24	59–64½	Up to 12 mins. ..	—	—	—	3	5	5	16	4	25
			12 to 25 mins. ..	—	—	2	5	10	12	32		
144–156	24–26	64½–70	Up to 10 mins. ..	—	—	—	3	5	5	16	4	25
			10 to 20 mins. ..	—	2	3	5	8	10	31		
156–168	26–28	70–75	Up to 10 mins. ..	—	—	2	3	5	5	18	4	30*
			10 to 16 mins. ..	—	2	3	5	7	10	30		
168–180	28–30	75–80½	Up to 9 mins. ..	—	—	2	3	5	5	18	4	30*
			9 to 14 mins. ..	—	2	3	5	7	10	30		
180–192	30–32	80½–86	Up to 13 mins. ..	—	2	3	5	7	10	30	6	25
192–204	32–34	86–91½	Up to 12 mins. ..	2	2	3	5	7	10	32	6	25

* If found difficult to maintain 30 revolutions, another cylinder may be used instead.
† These figures are calculated on the supposition that the pump does not leak more than 20 per cent. at pressures up to 60 lbs. Instructions as to testing of Pumps are given on page 36.
‡ *i.e.*, using a Siebe-Gorman Two Cylinder Double-acting Pump.
** For instructions as to time for descent, see pages 50 and 51.

TABLE II., showing Stoppages during Ascent after exceeding the Ordinary Limits of Time on the Bottom, in accordance with British Admiralty Practice.

Depth. Feet.	Depth. Fathoms	Pressure in lbs. per sq. in.	Time from leaving Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80 feet.	70 feet.	60 feet.	50 feet.	40 feet.	30 feet.	20 feet.	10 feet.	Total Time for Ascent in Minutes.
66	11	29½	Over 3 hrs. ..	—	—	—	—	—	—	10	30	42
72	12	32	2 to 3 hrs. ..	—	—	—	—	—	—	10	30	42
			Over 3 hrs. ..	—	—	—	—	—	—	20	30	52
78	13	34½	1½ to 2½ hrs. ..	—	—	—	—	—	—	20	30	52
			Over 2½ hrs. ..	—	—	—	—	—	—	30	30	62
84	14	37	1¼ to 2 hrs. ..	—	—	—	—	—	—	15	30	47
			2 to 3 hrs. ..	—	—	—	—	—	5	30	30	67
			Over 3 hrs. ..	—	—	—	—	—	10	30	35	77
90	15	40	1 to 1½ hrs. ..	—	—	—	—	—	5	15	25	47
			1½ to 2½ hrs. ..	—	—	—	—	—	5	30	30	67
			Over 2½ hrs. ..	—	—	—	—	—	20	35	35	92
96	16	42½	55 mins. to 1½ hrs.	—	—	—	—	—	5	15	30	52
			1½ hrs. to 2½ hrs.	—	—	—	—	—	10	30	35	77
			Over 2½ hrs. ..	—	—	—	—	—	30	35	35	102
108	18	48	40 mins to 1 hr. ..	—	—	—	—	—	10	15	20	48
			1 hr .to 2 hrs. ..	—	—	—	—	5	15	25	35	83
			Over 2 hrs. ..	—	—	—	—	15	30	35	40	122
120	20	53½	35 mins. to 1 hr...	—	—	—	—	5	10	15	25	57
			1 hr. to 2 hrs. ..	—	—	—	—	10	20	30	35	97
			Over 2 hrs. ..	—	—	—	—	30	35	35	40	142
132	22	59	½ hr. to ¾ hr. ..	—	—	—	—	5	10	15	20	53
			¾ hr. to 1½ hrs. ..	—	—	—	5	10	20	30	30	98
			Over 1½ hrs. ..	—	—	—	15	30	35	40	40	163
144	24	64½	25 min. to ¾ hr. ..	—	—	—	3	5	10	15	25	61
			¾ hr. to 1½ hrs. ..	—	—	—	10	10	20	30	35	108
			Over 1½ hrs. ..	—	—	—	30	30	35	40	40	178
156	26	70	20 mins. to 35min.	—	—	—	3	5	10	15	20	56
			35 mins. to 1 hr.	—	—	—	7	10	15	30	30	95
			Over 1 hr. ..	—	—	20	25	30	35	40	40	193
168	28	75	16 mins.to 30mins.	—	—	—	3	5	10	15	20	56
			30 mins. to 1 hr ..	—	—	3	10	10	15	30	30	101
			Over 1 hr. ..	—	5	25	25	30	35	40	40	203
180	30	80½	14 mins.to20mins	—	—	—	3	3	7	10	15	41
			20 mins.to30mins.	—	—	2	2	3	10	15	25	60
			30 mins. to 1 hr...	—	3	3	7	10	20	30	35	111
			Over 1 hr. ..	—	15	25	30	30	35	40	40	218
192	32	86	13 mins.to 20mins.	—	—	—	3	3	7	15	15	46
			20 mins.to30 mins.	—	—	3	3	5	10	15	25	64
			30 mins. to 1 hr.	—	3	5	10	12	20	30	35	118
			Over 1 hr. ..	5	20	25	30	30	35	40	40	228
204	34	91½	12 mins.to20 mins.	—	—	3	3	5	7	10	20	51
			20 mins.to30 mins.	—	3	3	3	5	10	20	20	67
			30 mins. to 1 hr.	3	3	5	10	15	20	30	35	124
			Over 1 hr. ..	15	20	25	30	30	35	40	40	238

PROCEDURE OF THE DIVER ON THE BOTTOM.

Going Down.—While standing on the ladder, and before the front glass is screwed in, the diver should note the position of the shot rope, so that he may waste no time in getting to it after leaving the ladder. He should also ascertain that his outlet valve is *open* and the tap (the excess air cock, or "spit-cock ") *closed*.

The pump should be started before the front glass is screwed in. On hearing the attendant tap the top of the helmet, the diver may go on down the ladder till the water is up to his face. He then lets go the ladder, and allows the attendant to draw him to the shot rope by means of the breast rope (signal line) and air pipe. The diver grips the shot rope between his legs, holding on to it with his left hand while he adjusts his outlet valve with the right, his head being just under water. During this brief pause he notes, from the sound in the helmet, that the pumps are working satisfactorily, and makes sure that no water is coming in at the cuffs or any other part of his dress. When he is satisfied that all is correct, he waves his hand above the surface to show that he is ready. As soon as this signal is answered, he may go on down the shot rope hand over hand, keeping it between his legs and ready to check his descent at any moment.

Pains in the Ears.—By the time the diver is a fathom or two down, he may probably notice pain in his ears, which may become worse as he goes deeper. This is due to the increasing pressure of the air in the helmet on the outside of the ear drum. There is a narrow passage (called the Eustachian tube) at the back of the throat through which air can pass to the inner side of the ear drum. If the Eustachian tubes were always freely open there would be as much pressure inside as outside the ear drums, and consequently no strain on them and no pain ; but in most persons the Eustachian tubes do not allow the air to pass through them very readily, and the pressure, therefore, is not balanced.

To get rid of the pain these passages must be opened. There are three ways in which a diver can try to accomplish this:—(1) *By swallowing several times;* (2) *By blocking up the nose as much as possible by pressing it against the front of the helmet, closing the mouth, and then making a strong effort at expiration so as to produce temporarily an extra pressure inside the throat, and so blow open the tubes;* (3) *By yawning or going through the motions of yawning.*

So far as pain in the ears is concerned, a diver who is "fit" should have no difficulty in going down as fast as 10 fathoms a minute.

Going Down Too Fast for the Air Supply.—There is, however, a second obstacle in the way of going down very fast. As a man descends, the air which is loose in his dress over the chest becomes compressed into a smaller space as the pressure increases, and unless the *pump* is delivering air fast enough to make this loss good, the air in the dress will disappear, while that in the helmet may be at a lower pressure than the surrounding water, the result of this state of affairs being that the diver gets a very severe squeeze. To avoid this the diver must keep his valve nearly closed, and go down at such a rate that there is always a little air over his chest, and a small amount escaping from the valve in the usual way ; the faster the pump is going the quicker the diver can get down. In practice it has been found easy to get down to 30 fathoms in a minute and a half with two Siebe - Gorman two - cylinder, double-acting pumps heaving for one diver. Provided there is enough air in the dress, as explained above, and the ears are not very painful, a diver may confidently slide down the rope at a good speed.

DIVER TO GO DOWN FAST.—To hang about on the shot rope when going down wastes time, and by increasing the time under water adds to the danger on coming up. If, on the other hand, severe pain is felt in the ears, and the remedies suggested will not act, there is nothing for it but to wait on the rope for a minute or two, when the pain will get less and less, and enable the diver to go down a few more fathoms till it stops him *again*.

ON REACHING THE BOTTOM the diver will signal the fact by one pull on the breast rope, which the attendant answers in the usual way. The diver should now see that the shot is *just touching* the bottom ; if necessary, signalling for it to be lowered or pulled up. (If the shot is off the ground, the breast rope or pipe may get dipped under it, which is undesirable.) He then clears away the distance line, coiling it in the left hand ; the left wrist may be slipped through the loop at the end as a precaution against dropping the line in a moment of forgetfulness, for without the distance line it will generally be impossible to find the shot rope again. The diver should now get to his work without further delay.

MANAGEMENT OF THE OUTLET VALVE.—Comfort under water depends largely upon the correct adjustment of the air regulating outlet valve. This valve is correctly adjusted when there is enough air under the corselet to support the weights so that the diver does not feel any sense of heaviness about his shoulders, and yet is heavy enough to stand firmly on the bottom. When sitting or standing up under water, the valve can be easily screwed up until these conditions are satisfied ; the surplus air will then escape freely, no further adjustment being required. One-half or three-quarters of a turn open will generally be found to be about right But since divers on the bottom are very often in a crawling or lying position, the state of affairs is then different. The air always fills up the highest part of the dress (when lying face downwards, the back) before it can escape from the valve, which is at a lower level, however widely the latter is opened. Whenever a diver is keeping his head low, air may accumulate in this way, float him up from the bottom, and so blow him to the surface. The remedy is to empty the air out of the loose parts of the dress at frequent intervals.

The best course, therefore, when working in such a position is to keep the valve wide open. No air will escape from it while the head is down. As soon as the diver feels that the accumulation of air along his back is beginning to lift him, he must raise his head, kneeling up if necessary, so that the valve becomes higher than the back, and all the air will then escape with a rush. This will enable him to get his head down again, and proceed with the work for another short spell, after which the process must be repeated.

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 may go out to the end of the distance-line, and, keeping it taut, sweep round 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, or the direction of the tide, etc.), he fleets in a short distance along the distance-line, and makes a fresh circle *in the opposite direction,* thus avoiding the twisting of his pipe and breast rope round the shot rope. 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 in too much, but should let each new circle just overlap the last.

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 reach of the distance-line. He should therefore come up and ask that the shot, or the boat, may be shifted so that a new area may be searched.

Crawling about the bottom at random, in any direction, on the chance of knocking up against the object 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 perfunctorily examined.

The method indicated above should always be followed, and will save time in the end.

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

Diver Feeling Ill while under Water.—If the diver feels "bad" while under water, the cause may be an insufficient supply of air. The usual symptoms in such a case are a sensation of distress, with deep breathing or panting, and a dazed feeling as if consciousness were going. Under these circumstances, the worst thing a man can do is to attempt to go up to the surface, since any exertion when breathing vitiated air greatly increases its bad effects.

The diver should signal for more air and stop moving about, resting quietly while the impure air in his helmet is swept out by a fresh supply from the pump, and in a minute or two he will be all right again, and able to continue his work. It cannot be pointed out too often that struggling or doing anything that requires an effort is the surest way of getting worse, and that, unless the air supply is very bad indeed, a couple of minutes' rest with the valve comfortably adjusted, and with the pump heaving fast, will restore the man to perfect comfort and efficiency.

Panting is generally a sign that the air supply is insufficient, and the diver should not hesitate to ask for more air. *In any case*, THE MORE AIR THE DIVER HAS THE BETTER HE IS FOR IT. The supply indicated on page 97 is not more than the diver can easily control with his valve.

COMING UP FROM DEEP WATER.—In coming up, after making the usual four pulls on the breast rope, the diver gives one pull on it, just as he starts up the shot-rope, as a signal that he is leaving the bottom. In ascending, the outlet valve should be screwed up until the diver is almost afloat; he is then able to come up the rope without having to pull himself up or exert himself in any way. He should go up steadily hand over hand, keeping the shot rope between his legs, and be on the look-out to stop directly he gets one pull on the air pipe. On being stopped, he can maintain himself in position on the shot rope by curling one leg round it, which will leave the other leg and both hands free. While waiting, he must keep his limbs in motion, and try to work every muscle in his body, bending backward and forward, etc., but not so violently as to tire himself. The object of these gymnastics is to quicken the circulation temporarily, and so to assist in sweeping the excess of nitrogen out of the tissues of the body.

GETTING INTO THE BOAT. On reaching the surface, and before letting go the shot rope, the diver should look up to see whether he has taken any turns with his air pipe or breast rope round it; if so, he must take them out before going to the ladder. The attendant will then draw him to the ladder. In getting a footing on it, if there be any "sea" on, the diver should keep under water as much as possible in order to avoid being knocked about. If there is any tide, he must keep his dress empty and his feet down, for it is easy to get inflated and helpless on the surface. Since this is more likely to happen if the diver rolls over on his back, he should keep on his face whenever brought into a horizontal position.

The following hints are meant for beginners rather than for experienced men:—

In any difficulty a little quiet thought will generally save time in the end. Don't take any steps under water without reflecting on their probable consequences. Keep cool.

DISTANCE-LINE LOST.—Should the distance-line be lost in the dark, feel carefully all round you before moving. Don't waste time by searching about for it. Signal that you are coming up, and then ask to be hauled up (two bells). If there is a telephone, ask the attendant to keep your pipe and breast rope close in to the shot rope. As they haul you up, you will most likely meet the shot rope, when you can signal "Hold on" and "Lower," and go back to your work.

Getting Fouled.—If you find that you are fouled, think the matter over, and try to remember how you got fouled before you start dipping your pipe, etc. Clear yourself without hurry; violent exertion will daze you, and make things worse. The distance-line is a safe guide, and will generally show the way out of the tangle. Don't let it go if you can help it. If signals can be got through, it is usually well to get the attendant to take up the slack of the air pipe and breast rope. If you start panting, take a rest.

Muddy Bottom.—If on a muddy bottom, don't flounder about and stir up the silt; a cloud of mud will prevent you from seeing anything. For the same reason, keep the lee-side of your work if there is any current. If the bottom is very soft, spread yourself out over it; don't try to stand. Make yourself light by keeping plenty of air in the dress.

Rocky Bottom.—On a rocky bottom be careful not to fall off a ledge of rock into deeper water, nor to get your arm or leg into a crevice. If the rocks are sharp, wear gloves to protect your hands.

Moorings.—When working about moorings, be especially careful not to get foul. Don't dip under chains, etc., without having your distance-line to show you the way back. Old moorings are often covered with sharp barnacles, and it is wise to wear gloves to protect the hands. If wearing india-rubber gloves make sure that you can work the valve with them on before going down. An old pair of leather gloves may be found more useful in work of this sort.

Tide.—Remember that there may be much less tide on the bottom than at the surface; therefore it is generally worth while making an attempt at diving even though the tide may seem very strong. When going up or down the shot rope in a tideway keep your back to the tide so that you are pressed up to the rope and not away from it; by watching which way the tide tends to swing you round, and pushing the shot rope over to one side so as to check the movement, it is not difficult to maintain this position. In strong tides it may be impossible to cling on to the shot rope, much less to climb up it if you keep on the wrong side. Generally the best plan is to ask the attendants to pull you up if you find it difficult to ascend.

On the bottom, hang on to the distance line at all costs, crouch close to the ground so as to offer as little surface as possible. Of course, the smaller and heavier the object the less effect will the tide have upon it; therefore the valve should be kept as wide open as reasonable comfort in breathing will allow. When searching, if you cannot get up against the tide, past the shot rope, search the lee side thoroughly, and leave the other till slack water.

Working on a Ship's Bottom.—Whenever working at a ship's bottom, never run the risk of falling off; always have something substantial to hang on to, and make your attendant keep the pipe and breast rope well in hand. Do not go under the ship and up the other side, but ask for the boat to be shifted. The weighted belt may be found more convenient than the ordinary breast and back weights for this kind of work.

Going to the Assistance of a Fouled Diver.—In going to the assistance of a fouled diver, descend, keeping his breast rope in hand; by this means you may trace the cause of his being foul. Be careful not to complicate matters by getting turns round his rope and pipe.

Cold Weather.—In very cold weather wear extra flannels; go down and work till the hands are chilled, then come up and get them rubbed till the circulation returns and they begin to glow; go down again, and it will be found possible to work for a much longer period before they become numbed again. Wool-lined waterproof gloves are provided, and should be worn if convenient, but see that when wearing them you can control the outlet valve easily.

Use of the Tap (called "Excess-air Cock," *or* "Spit-cock,") on the Helmet.—Moisture condenses on the front glass of the helmet and makes it difficult to see. A mouthful of water can be sucked in through the tap and then spurted over the inside of the glass, washing it down and making all clear again. Water which may perchance have leaked in at the collar of the dress and flowed into the helmet while the diver was lying on his face may be baled up by the mouth and ejected through the tap, which course is generally preferable to allowing it to run down and wet the body when the diver stands up again.

The tap is occasionally useful as an auxiliary to the outlet valve in adjusting the escape of air, especially when the diver is lying on his back.

Slipping the Weights in case of Emergency.—The weights can easily be slipped, the lanyard round the waist being let go first, and then the bow hitches cast off. The only occasion on which a diver might find it necessary to do this would be when an accident had occurred to the air pipe or pump, which would prevent him getting enough air in the dress to go up otherwise. *The weights must not be slipped except as a last resource, as the diver is helpless without them.*

If Diver Blown Up.—If blown up and lying on the surface, don't open up your valve unless you have a good hold on something, or the attendants have got in the slack of the breast rope and pipe and can hold you up. *Dropping down into deep water is more dangerous than blowing up.* A diver who has come to the surface in this way should get to the shot rope as quickly as possible and *go down again at once*. Even if he is beginning to feel the effects of the sudden decompression, the symptoms will pass off when he gets down, while serious consequences may result if he remains at the surface or gets into the boat. Going down again is the diver's only chance after blowing up from deep water after having been down some time.

Cleaning Ships' Bottoms.

This work will necessarily be done rather slowly by divers; a good deal depends on the proper rigging and working of the ladders or stages. In using the ladders, two may be lashed together side by side, making a breadth of 6 feet, and as the diver can reach about 3 feet on either side he can clean a breadth of 12 feet, and fleeting down from rung to rung can work down from water-line to keel. For working beneath the bilge keels of large ships, where the bottom is practically flat, a good plan is to lace a net (such as those supplied for preventing loss of coaling bags overboard) between two ladders. The whole is passed under the keel and the two ladders separated so as to stretch the net. The divers can then lie back in it and clean the bottom above them with comparative ease.

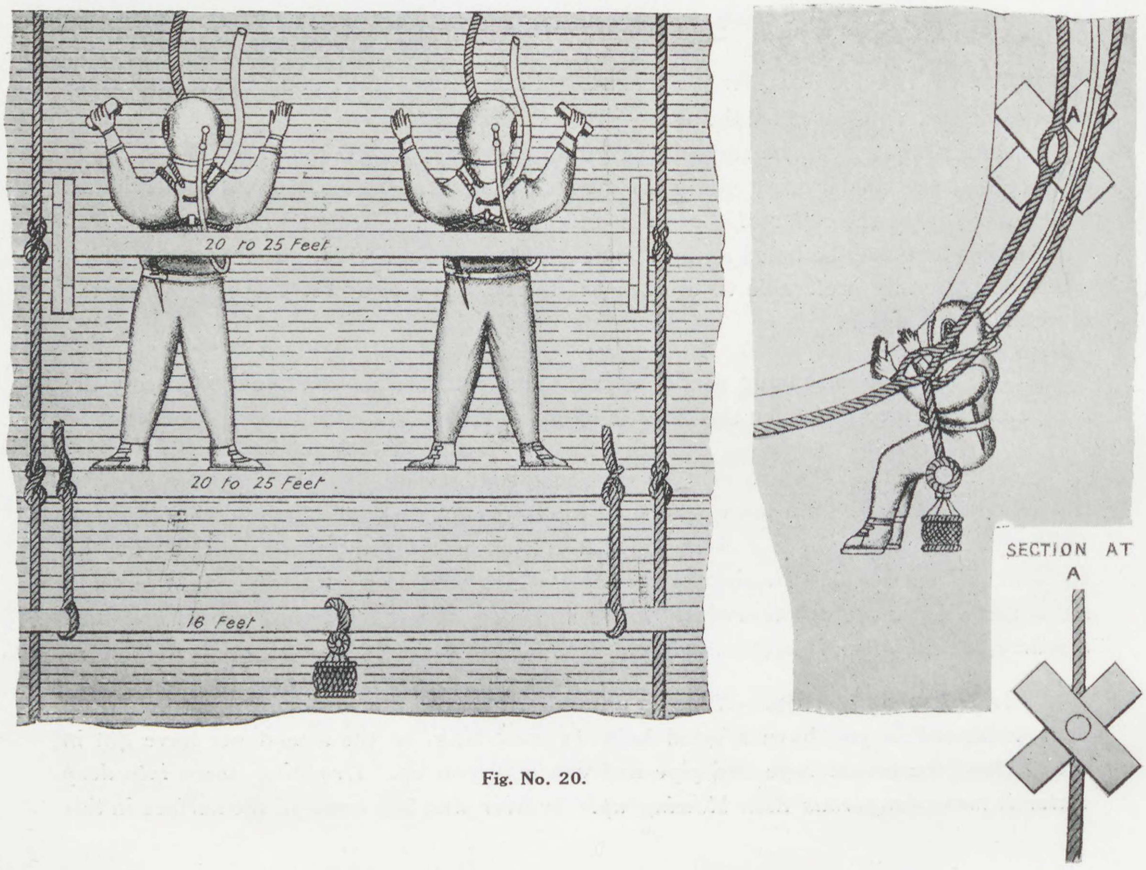


Fig. No. 20.

Another method is by means of a stage, which is very quickly made, and has been found very suitable for this purpose, or for coppering ship's bottom to any large extent.

It consists of three spars, two of which may be from 20 to 25 feet long; the other, the hanging spar, about 16 feet. The two long spars are suspended from each other about 4 feet apart, by means of rounding, the bights being clove hitched to each end of the spar, and the ends forming the top and bottom lines; the top lines are to take the weight of the stage, and the bottom lines for hauling it down and binding it into the ship's side; the third or shot spar is hung to the lower of the two spars by means of two rope tails, and is weighted in the centre by a slung shot, so as to keep it in a horizontal position about 3 feet below the lower long spar; sufficient weight must be 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, 3 inches broad, and 1 inch thick, lashed together in the form of a cross, with sufficient space for the spar to pass through; one of these crosses is secured at each end of the upper spar; a small cleat nailed on the spar prevents them from slipping inwards, and the clove hitches of the stage ropes prevent them from slipping outwards.

By this method two divers starting from the ends of the stage, and working towards each other can cover a good space in each fleet. When a fleet is finished the stage should be lowered bodily, the divers at each end making their own signals when the stage is placed; the bottom lines are steadied taut on vertical parts of the side, and hauled well taut as the stage reaches the bilge. On reaching the keel the divers should come to the surface, and the stage should be fleeted along as far as they have cleaned, all ropes being kept directly in line with the stage, and, if working from forward aft, the foremost line should take the place that the after line had before fleeting. By this means no ground will be passed over. When the stage is placed roughly in position the divers get on it and make the necessary signals to correct its position.

Practised divers can work from four to eight hours daily below the bottom of a vessel, and can clean from seven to twelve square yards per hour, according to the condition of the bottom.

Good scrubbing brushes can be made from the bottoms of ordinary long-handled deck scrubbers, sawn in two, and fitted with lanyards for securing to the diver.

If the bottom is foul with small barnacles, the wooden part of the brush should be used to remove them; a scraper should only be employed when the bottom is very foul.

Clearing Fouled Propellers and Valves.

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

First thoroughly examine the fouling, and see if it is possible to clear an end; if so, and if the turns are jambed, 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 to ensure 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 long, tedious job, with steel wire. A special wire-cutting machine, which is found to be efficient and time-saving, is illustrated on this page.

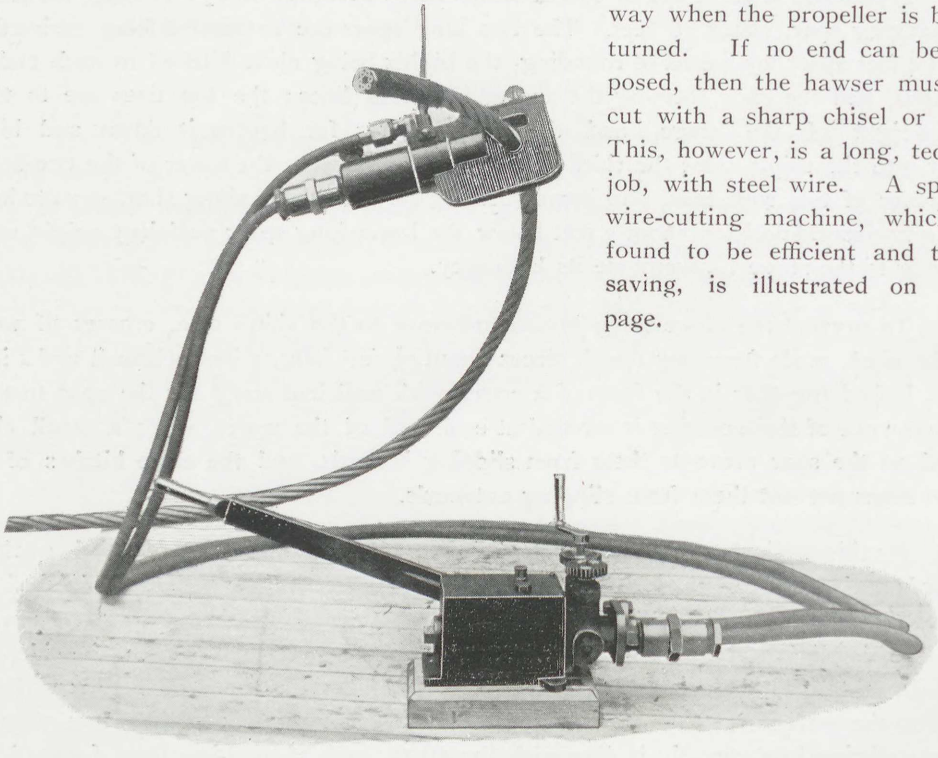


Photo No. 21

THE ENGINEERS MUST ALWAYS BE INFORMED WHEN A DIVER IS WORKING AT THE PROPELLER.

VALVES as a rule can be easily cleared from the outside by means of a 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 fearnought, to prevent any leakage inboard.

If the valve is only to be kept out a short time, this covering need not be too securely fastened, as the pressure of water on the outside keeps it in place.

Repairing Copper on a Ship's Bottom.

First rig and place a stage in the most suitable position. The time occupied in this is well spent if the stage is placed conveniently for working. Remove all jagged copper, nails, wood, etc., about the damaged part, and smooth off the bottom; if the place to be repaired is small, and does not require much copper, patches may be put on over all.

If the damage is of any extent, after clearing away the rough portions, commence the coppering by placing the first sheet on the after end of the place damaged and on the upper part, taking care that the after end of the new sheet overlaps the undamaged sheet abaft it, and that their upper edges are in the same line; fix the sheet temporarily by a couple of nails in the centre, and then commence to secure it by nailing it along the top, down the after end, and all the centre holes, in each case commencing from the centre of the sheet and working towards the ends. The next sheet will go on before this one, care being taken to keep the alignment, with its after edge overlapping the foremost edge of the first sheet, making one row of nails secure the two sheets at that end. Continue to put the sheets on in a similar manner to the first and second, until the fore end of the damaged part is reached; then commence aft again and below the first row, taking care that the foremost end of the new sheet for the second row only comes half way along the sheet above it or the first sheet, so preventing any butts coming together; proceed with the second row in a similar manner to the first, and so on for the remaining rows until the damaged part is covered. A short-handled, heavy hammer is the most useful for this work. The copper should not be struck with the hammer to take out wrinkles, but should be tapped close up to the side by means of a wooden wedge, the hammer and wedge being each fitted with a lanyard.

Each sheet should have its centre holes punched before sending down to the diver for placing. The edges of the sheets are to be punched by the diver to ensure both parts of the overlapping sheets lying close to the ship's side, and thus making a good joint. A canvas bag hung round the diver's neck is very convenient for nails, punches, etc.

Should the heads of any nails break off, the holes should be repunched, and fresh nails put in.

The canvas overall dress should be worn when coppering or cleaning ship's bottom, to protect the diving dress.

Recovering an Anchor.

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 shot rope dropped close alongside it.

The diver can then go down his shot rope, keeping the buoy rope in hand as he descends; this will prevent him from taking turns round the buoy rope.

If the wire has to be shackled on to an anchor, the following procedure will often be found the best :—

The wire is prepared 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. The wire is shackled to the shot rope or the anchor buoy rope (if watching) by the upper shackle, which acts as a traveller, leaving the end of the wire free for the diver to handle.

When the diver has found the anchor, he signals for the wire, which is carefully paid down to him ; great care must be taken to prevent the wire from 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 comes up before any attempt is made to weigh the anchor.

Where an anchor or other article is deeply embedded in the sea bottom, and is difficult to move, it will be found of great assistance if one end of a hose pipe be connected up to a pump, the other end, fitted with a nozzle, being directed on to the surrounding sand, etc. With a good pressure through the nozzle, the object will soon be released.

Diving Apparatus in case of Fire.

In cases where proper Smoke Helmets are not available, the diving gear provides a good, safe, smoke helmet for use in case of fire, or in bunkers, double bottoms, etc., where poisonous gases may have accumulated.

A fearnought jumper should be made, fitted at the neck to take over the studs of the breastplate, and at the bottom and cuffs, fitted with strings to tie the jumper close to the body and wrists. The jumper should be kept attached to the breastplate when the diving gear is not in use, and kept in a convenient place near the air pump, with the helmet and air pipe screwed on, so as to be immediately available in case of emergency. In case of fire any man can put on the jumper and proceed to the fire, other men following with the pump and placing it in position ; the air pipe from the helmet is screwed on to the pump, when, with a man to heave round, the fireman will get a plentiful supply of air.

He should, of course, wear boots, and his outer clothes should be wetted.

FIRST AID TO THE DIVER IN CASE OF ACCIDENT.

Possible accidents to deep-sea divers may be considered under four heads:—

(1) Caisson disease.
(2) Asphyxia, or CO_2 poisoning.
(3) Drowning.
(4) Hemorrhage.

We have already seen that the cause of *caisson disease* is the formation of air bubbles in the blood of tissues, owing to the too sudden decompression of the diver.

SYMPTOMS.—Symptoms vary with the severity of the case. The first class of cases is that associated with symptoms of asphyxiation. These come on about four or five minutes after the diver has come up from a fairly long stay in deep water. They commence with a feeling of indefinite distress—pain in the pit of the stomach—difficulty of breathing—the patient becomes livid and rapidly unconscious—the heart-beats become weaker and then stop. Such a case as this is alarming, but fortunately it is rare. Owing to the cause of this condition nothing that can be done at atmospheric pressure is of much service, and the only chance of recovery is quickly to recompress the sufferer. If the weights have been removed they must be rapidly replaced, the glass of the helmet screwed up, the exhaust valve freely opened and the diver lowered slowly, with the pumps heaving, for 10 or 15 fathoms. Even if the diver is quite unconscious this procedure should be followed, as it affords the only chance of his life being saved. A second diver should be sent down as quickly as possible to observe the condition of the sufferer. If the latter has recovered consciousness, he should be allowed to stay down for some time at the depth to which he has been lowered, and then very gradually, by stages, brought to the surface again.

A second class of cases is that where paralytic symptoms come on from ten minutes to half an hour after the diver has returned to the surface. In these cases there often is, as the first symptom, pain in the stomach, followed by pains of a "pins and needles" type in the arms and legs, inability to pass water, and then loss of power in the arms and legs. Recompression is undoubtedly the best treatment in these cases. If the ship is not provided with a special steel chamber in which the diver can be recompressed (see page 18), he should be lowered down again into 10 or 15 fathoms of water, allowed to stay at that depth for some time, and then very cautiously brought to the surface. In these cases the inhalation of oxygen might be substituted for the recompression if that gas is at hand.

The third class of cases is that in which severe pains develop in or about the joints, the "bends or screws" of the caisson worker. These pains develop at a later period, say from half to two hours after coming to the surface. The pains will pass off in time, but can be at once relieved by the diver descending into the water again.

Asphyxia.—As already explained, a diver under water may be affected seriously by CO_2 if his air supply is insufficient; and there is no doubt that in the past divers have often been rendered unconscious from this cause. With care in testing the pumps and arranging a proper air supply, there should be no fear of such an accident.

Its occurrence would be indicated by the diver ceasing to answer signals, probably after signalling for "more air." It should be remembered that loss of consciousness from CO_2 poisoning is in itself by no means so serious a symptom as loss of consciousness from want of oxygen, and that a diver is very unlikely to suffer from the latter condition. On the other hand, if an unconscious diver were drawn rapidly to the surface, after a stay of some time in deep water, he would run a great risk of caisson disease; and a death clearly proved to be brought about in this way was recently recorded in the Austrian Navy.

A diver who has been rendered unconscious by excess of CO_2 ought not, therefore, to be hauled up beyond the first stopping place indicated by the table according to his depth and duration of stay on the bottom. The diminution of pressure will probably at once relieve him.

If he does not now answer signals he should be hauled up, and, if he is not breathing, artificial respiration should be applied at once. On his recovery he ought, if possible, to be sent down again.

The following is the best method of performing artificial respiration :—

"Schafer's Method.—Place the man face downwards on the ground, with a folded coat or other garment under the lower part of the chest. Not a moment must be lost in removing gear other than the helmet and corselet, which should be taken off before commencing—every instant of delay is serious.

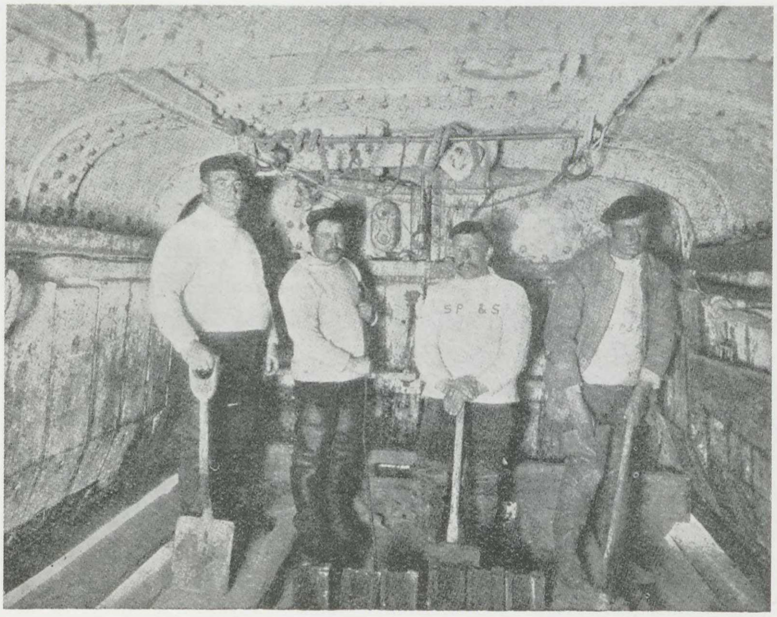
"To effect artificial respiration put yourself athwart or on one side of the man's body in a kneeling posture, facing his head. Place your hands flat on the lower part of his back (on the lowest rib), one on each side, and gradually throw the weight of your body forward on them so as to produce firm pressure—which must not be violent—upon the patient's chest. By this means the air (and water, if there is any) is driven out of the man's lungs. Immediately thereafter raise your body slowly, so as to remove the pressure, but leaving your hands in position. Repeat this forward and backward movement (pressure and relaxation of pressure) every four or five seconds. In other words, sway your body slowly forward and backwards upon your arms twelve to fifteen times a minute, without any marked pause between the movements.

This course must be pursued for at least half an hour, or until the natural respirations are resumed. If they are resumed, and, as sometimes happens, again tend to fail, artificial respiration must again be resorted to.

Drowning.—There is a case on record of drowning in the diving dress, where the diver cut his dress in trying to sever his breast rope to clear himself when foul. Cuts in the dress are not dangerous unless they are close to the shoulder. If the dress becomes damaged, the diver *should at once get into the erect position, and come to the surface without delay, taking all the usual precautions.*

The treatment of cases of drowning will proceed on the usual principles, artificial respiration being begun at once and continued until a medical officer has been obtained.

Hemorrhage.—In cases where there is bleeding from the ears of the diver from the blocking of the Eustachian tubes, there is but little to be done, since the bleeding always stops on the diver coming to the surface. When severe bleeding from the lungs, nose, or ears occurs as the result of a fall, at once remove the helmet and weights, and lay the diver down with the head and chest well propped up, until medical aid can be obtained.



Copyright. **Photo No. 22.**

Photo taken in a Diving Bell when 65 feet below the surface.

DIVERS' PAY AND HOURS OF WORK.

The WORKING HOURS depend upon the nature of the work, the depth of water, and, if the job is abroad, the climatic conditions and their effect upon the health of the divers. On foreign works, therefore, it is usual for the engineers to regulate the hours according to local conditions.

In cases where time is worked in shifts (4 hours), the diver dresses in his own time, and is allowed a spell of fifteen minutes during the shift to rest, and fifteen minutes at the end of the shift for undressing. This applies to depths not exceeding 60 feet, and is subject to variation according to the nature of the work.

A shift commences from the time the helmet is put on.

HELMET DIVERS' RATES OF PAY.

On public works in England the rate of pay to Helmet Divers is from 2s. to 2s. 6d. an hour.

In some cases, however, the men are paid a standing wage of about 30s. to £2 per week, and an extra 1s. 6d. an hour when diving; when not diving they make themselves useful about the works.

In the case of WELL WORK, FLOODED MINES, SALVAGE OPERATIONS, *etc., the* pay depends upon the depth of water and the risk incurred. WELL WORK: from 14s. to 20s. a shift. FLOODED MINES: from 20s. to 40s. a shift. SALVAGE WORK (ship raising): In some cases where vessels are sunk in shallow water, the divers are paid a standing wage of 20s. a day, "work or play"; in others the pay may be a standing wage of £2 a week, plus an extra sum per hour when diving; or the men may be paid for diving time only, from 20s. a tide and upwards. In cases where the diver provides his own apparatus and linesman, he may get 40s. per shift or tide.

In cases of DEEP SEA SALVAGE (CARGO AND TREASURE RECOVERY) the divers are sometimes paid a weekly wage, plus a percentage on the value recovered, calculated according to the depth of water, etc. In the case of the *Alphonso XII* and the *Skyro* operations, Lambert and Erostarbe received £40 and £30 a month respectively, plus 5 per cent. of the value of the specie they brought up. Lambert salved £70,000, Erostarbe £10,000.

BELL DIVERS.

The rate of pay for Diving Bell men is usually from 1s. to 1s. 2d. an hour.

SELF-CONTAINED DIVING APPARATUS.

(Fleuss', Davis' and Hill's patents.)

(See Photos, page 66.)

With this patented apparatus the wearer is supplied with a respirable air WITHOUT THE AID OF AIR PUMPS, tubes or other connection with the surface. The *maximum depth* at which the apparatus can be safely used is *about fifty feet*, and the *duration of supply*, with one charge of oxygen, air, etc., *two hours at a time*. It has been designed more particularly for work in flooded mines and other places where the use of air pumps and tubes might be impracticable. The principle of the apparatus is that the wearer breathes the same air several times over, the carbonic acid being absorbed from the exhaled breath, and the requisite amount of oxygen restored to it, thus rendering it pure and again fit for inhalation.

The apparatus consists of Patent Diving Helmet and Dress in combination with steel cylinders containing compressed oxygen and atmospheric air in certain proportions, in accordance with Professor Haldane's recommendation, and a metal chamber containing caustic soda, which absorbs the carbonic acid of the exhaled air.

The apparatus is fitted with valves, which allow the mixture of oxygen and air to pass into the helmet and dress in the proper quantity, no matter at what depth the diver may be working. There is also a patented safety device whereby, in the event of a valve failing, the diver would be enabled to supply the requisite amount of air independently of the valve. Any excess of air that accumulates in the dress escapes automatically. The ordinary weighted boots are worn, and also a lead weight on the chest, as in the ordinary diving dress ; the usual *back* weight, however, is not necessary, as the steel cylinders are heavy enough in themselves to take its place. The cost of recharging the apparatus for two hours' work is about 10s.

Large storage cylinders (containing about 100 cubic feet of oxygen and air compressed to 120 atmospheres) are supplied for recharging the cylinders of the diving apparatus, a pump with connections being also supplied for raising the pressure to the full 120 atmospheres as the mixture of oxygen and air in the storage cylinders is lowered.

For use in places abroad, where it might be impossible to get the steel cylinders charged, a portable oxygen making and compressing apparatus is supplied complete in all respects, and including several charges of the oxygen-making substance "Oxylithe," with which any number of sets of the diving apparatus can be recharged.

SELF-CONTAINED DIVING APPARATUS.

Described on page 65.

Copyright.
Photo No. 23.
Side view, showing valves.

Copyright.
Photo No. 24.
Back view, showing Oxygen Cylinders, Purifying Chamber, etc.

THE HEIGHT OF WAVES, THEIR FORCE AND THE DEPTH TO WHICH THEIR ACTION EXTENDS.

Copyright. COLOMBO BREAKWATER. *Engineers, Messrs. Coode, Son & Matthews.*

Height. The height varies considerably with different localities. At Dover, for instance, the greatest height recorded during the past sixteen years is 18 feet from crest to trough, whereas at Peterhead and Fraserburgh in Scotland, and at the mouth of the Tyne, waves measuring as much as forty feet high have been observed.

Force.

The force exerted by waves is well exemplified by what occurred during a storm at Peterhead some years ago, when blocks weighing 41 tons apiece were displaced at a level of 37 feet below low water, spring tides, the rise of the latter being 11 feet. On the same occasion a section of blockwork, weighing 3,300 tons, was shifted bodily two inches without dislocation. To move this mass, an energy equal to 2 tons per square foot must have been exerted simultaneously over the affected area.

Something similar happened at Colombo during the construction of a breakwater there, a length of wall at the outer end, 150 feet by 28 feet wide, founded at a depth of 20 feet below low water, being shifted inward as much as 15 inches, necessitating the resetting of this portion of the work.

At the Tyne north pier works much damage occurred for several winters in succession from the same cause, resulting in the reconstruction of an outer section 1,500 feet in length.

Depth to which wave action extends.

It should be added, however, that wave disturbance occurs at considerably greater depths than those at which existing sea works are founded. For example, Sir James Douglass, the well-known lighthouse engineer, recorded the fact that coarse sand was found on the gallery (120 feet above water level) of the Bishop Rock Lighthouse, off Scilly, where the depth of water is about 150 feet. Seeing that there is nowhere else that the sand could have come from, it follows that the material must have been washed up from the sea bottom and hurled into the air, a total height, from sea bed to gallery, of 270 feet.

DIVING BELLS.

There are two forms of Diving Bell in use at the present day—the Air-Lock, or Caisson Bell, and the ordinary, or what may be called the Smeaton Bell. The latter is the more generally employed by reason of its greater simplicity and mobility, and its lower cost. For a considerable time the use of diving bells was practically abandoned, but during the past ten years or so they have again come into favour. This reaction has undoubtedly been brought about by the improvements that have been made in the construction of the bells themselves, the better air supply and consequently better ventilation, the introduction of the electric light, which has displaced the old method of lighting with oil lamps, candles, etc., the carbon from which was inhaled by the bell-men and seriously affected their health, and the adoption of the telephone, which saves so much time in the working of the bell.

The Air-Lock Bell is constructed of mild steel plates. The working chamber is usually rectangular in form, and weighted internally or externally with cast-iron kentledge to overcome its displacement. The interior is fitted with telephonic apparatus communicating between bell and crane room, and between bell and air-compressor room. Two or three electric lamps are fixed in the roof, whilst there are several portable lamps for the bell-men. Running from the roof of the bell to above the water surface is a steel shaft of from 30 inches to 36 inches in diameter surmounted by an air-lock. In some cases two shafts, each with its air-lock, are fitted—one for workmen, the other for materials. Inside the shaft is fitted an iron ladder by which the bell-men descend and ascend. The electric light cable and telephone wires are also led down the shaft. The bell is worked either from a gantry (see photos on pages 70, 71 and 73), or what is found to be more convenient, from a specially constructed barge (see page 74) having a well in the centre through which it is raised and lowered by means of wire ropes over sheaves fitted to a superstructure erected over the well. The barge carries the necessary boilers, air compressors for supplying air to the bell and for working pneumatic tools, etc., hoisting engines, mooring winches, electric light engine, etc.

The Ordinary Bell is really the lower part—*i.e.*, the working chamber—of the air-lock bell without the shaft and locks. The air pipe is connected to a non-return inlet valve fitted in the roof, and lenses are sometimes fitted in the roof, but more often in the ends of the bell. (*See photos, pages* 70 *and* 73.)

When asking for estimates for Diving Bells, the following particulars should be supplied, viz :—

(a) Dimensions of bell, or number of men it is proposed should work in it.

(b) Maximum depth of water.

(c) Capacity of lifting power available for lowering and raising bell.

NATIONAL HARBOUR WORKS, DOVER.

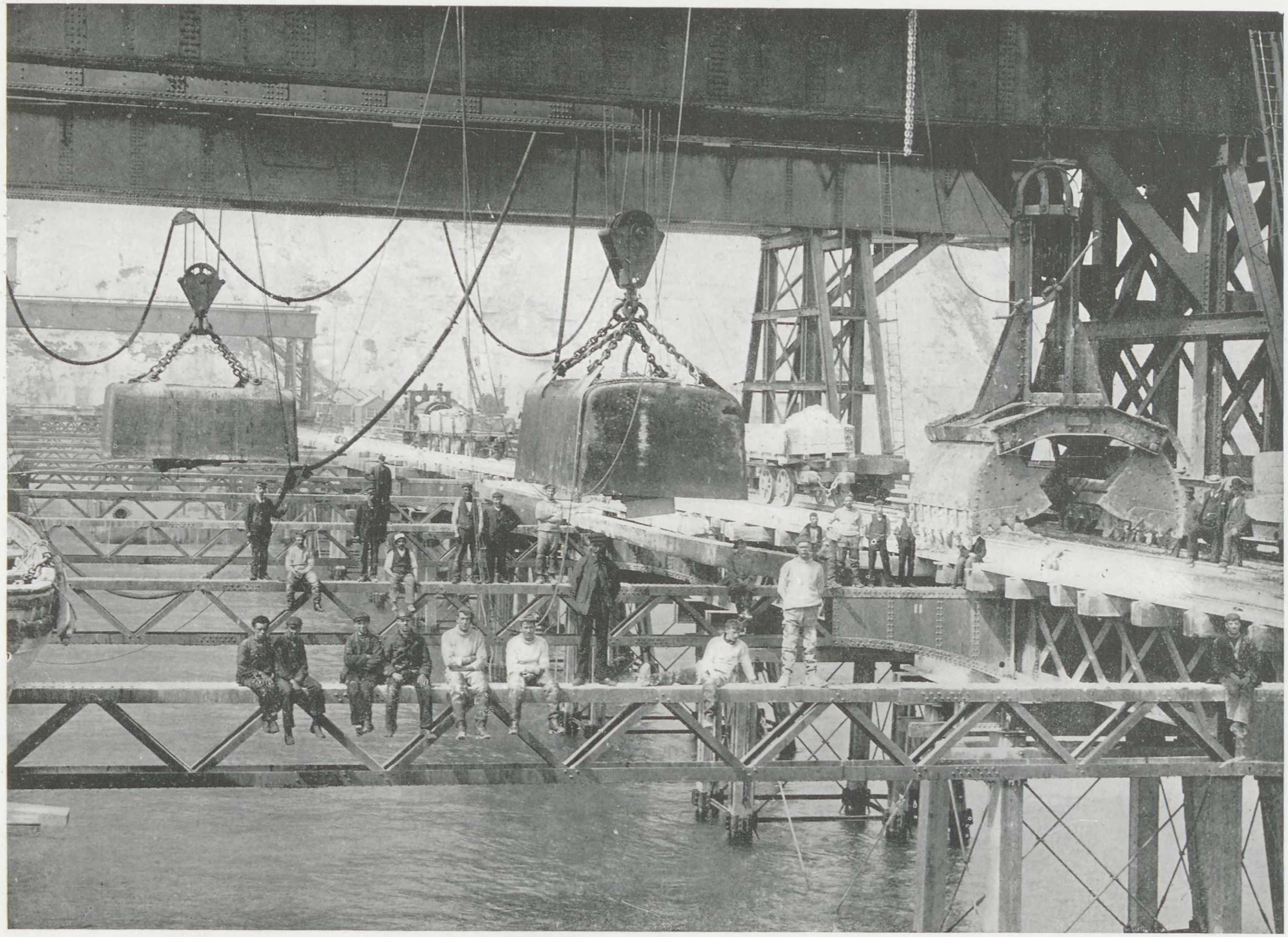


Photo No. 25.

General View of one Section of the Works, showing two of the Diving Bells. Each Bell measures 17 ft. by 10 ft. by 6 ft. 6 in. high and weighs about 35 tons.

Contractors, Messrs. S. Pearson & Son, Limited, Westminster, S.W. *Engineers, Messrs. Coode, Son & Matthews, Westminster, S.W.*

NATIONAL HARBOUR WORKS, DOVER.

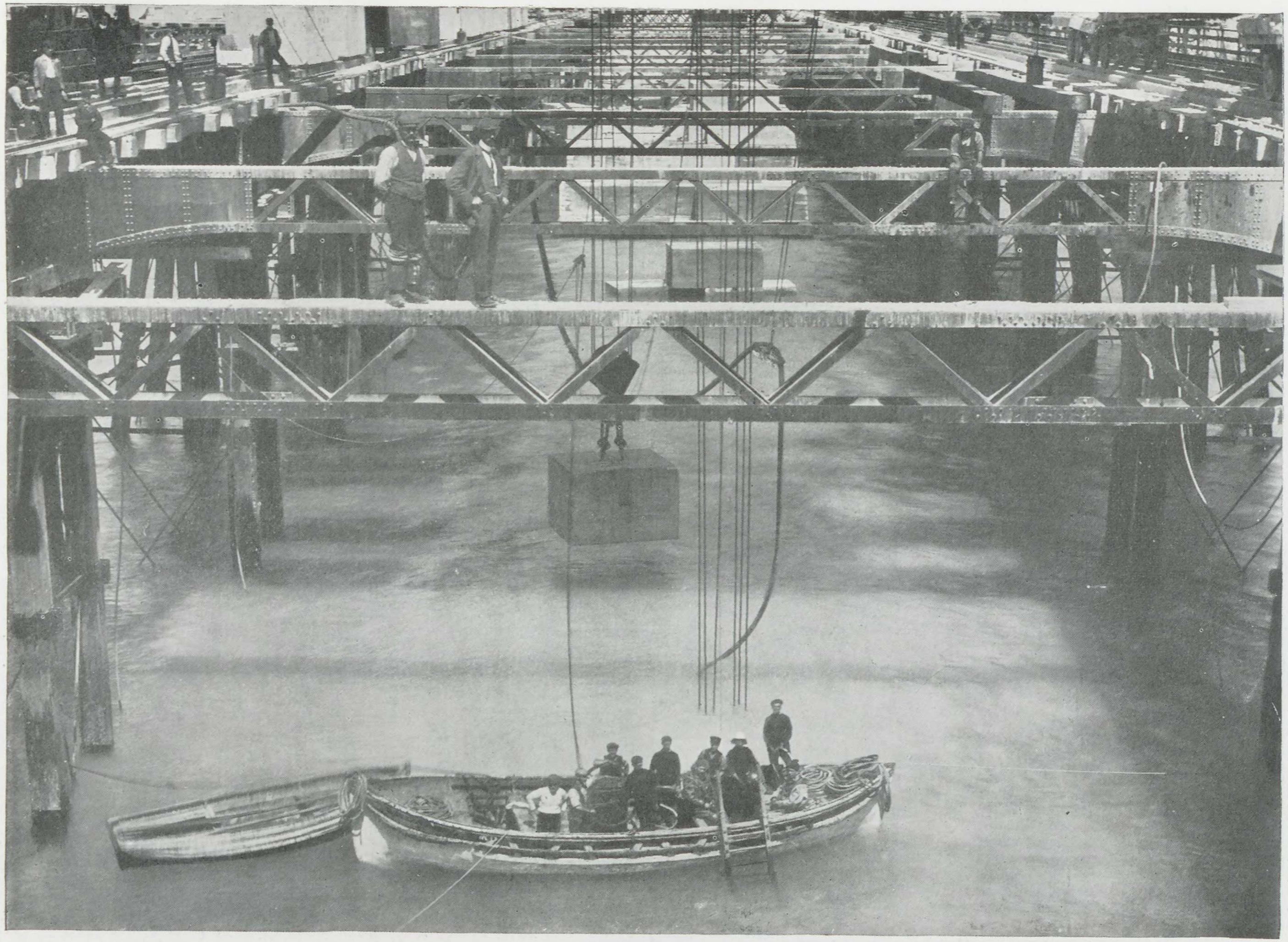


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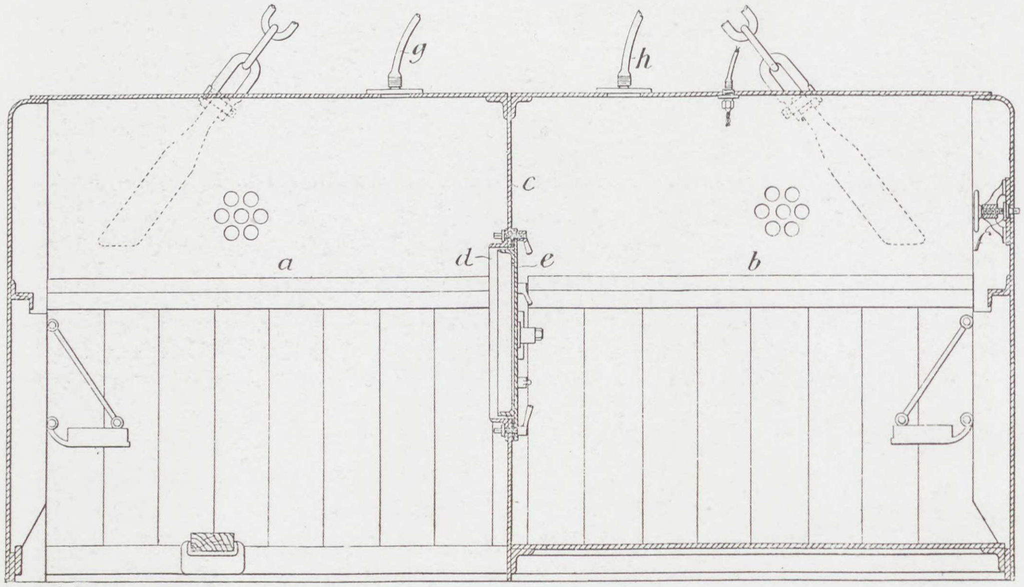
Photo No. 26.

Another view showing a 45-ton concrete block being lowered into position. After the Sea bed has been levelled and prepared by Diving Bell men, the concrete blocks are set in place by Helmet divers. One of the Helmet divers' boats can be seen in the foreground.

COMBINED DIVING BELL & DECOMPRESSION CHAMBER



Copyright.

For use in connection with deep sea operations, Professor Leonard Hill, F.R.S., has designed a special diving bell (see illustration above), which comprises also a decompression chamber. This chamber can also, in case of need, be used on deck for recompression purposes (see page 7).

The idea is to use this bell in special cases where the diver may remain for long periods on the bottom at great depths, or when stress of weather or other circumstances compel the diver to come to the surface hurriedly, so that he has not time to decompress in accordance with the tables on pages 47-49.

The diving bell, which is constructed of mild steel plates, and is weighted with kentledge in the ordinary way, is divided into two compartments by a partition (*c*), one of the chambers (*a*) being open at the bottom in the usual way, the other chamber (*b*) being entirely closed. The partition is provided with a manhole (*d*) and cover (*e*), which can be opened or closed from either side, and with a valve (*f*) operated either from the inside or outside, for allowing the pressure in the closed chamber to be gradually reduced.

Each chamber of the bell is fitted with an air inlet valve (*g* and *h*), which is connected to an air compressor or compressors ; and the diver is provided with a separate pump, the air pipe of which may be carried through a stuffing box in the roof of the open chamber of the bell, or it may be worked quite independently of the bell in the usual way. The bell may be furnished with means for electrically or otherwise heating it, and also with means for drying and for partially removing the oxygen from the air supplied to the bell, and also with a telephone and electric light.

In making use of the bell, the diver, upon entering or re-entering, passes into the closed chamber through the man-hole, which is then hermetically closed, and the bell is then raised to the surface and placed upon the deck of the diving vessel or upon the shore, the pressure in the closed chamber being meanwhile kept at the same pressure as that existing at the place where the diver entered or re-entered the bell. The air in the closed chamber is then slowly decompressed, or allowed to slowly escape through the valve (*f*) at the rates set forth in the tables given on pages 47-49.

HARBOUR EXTENSION WORKS, FOLKESTONE.

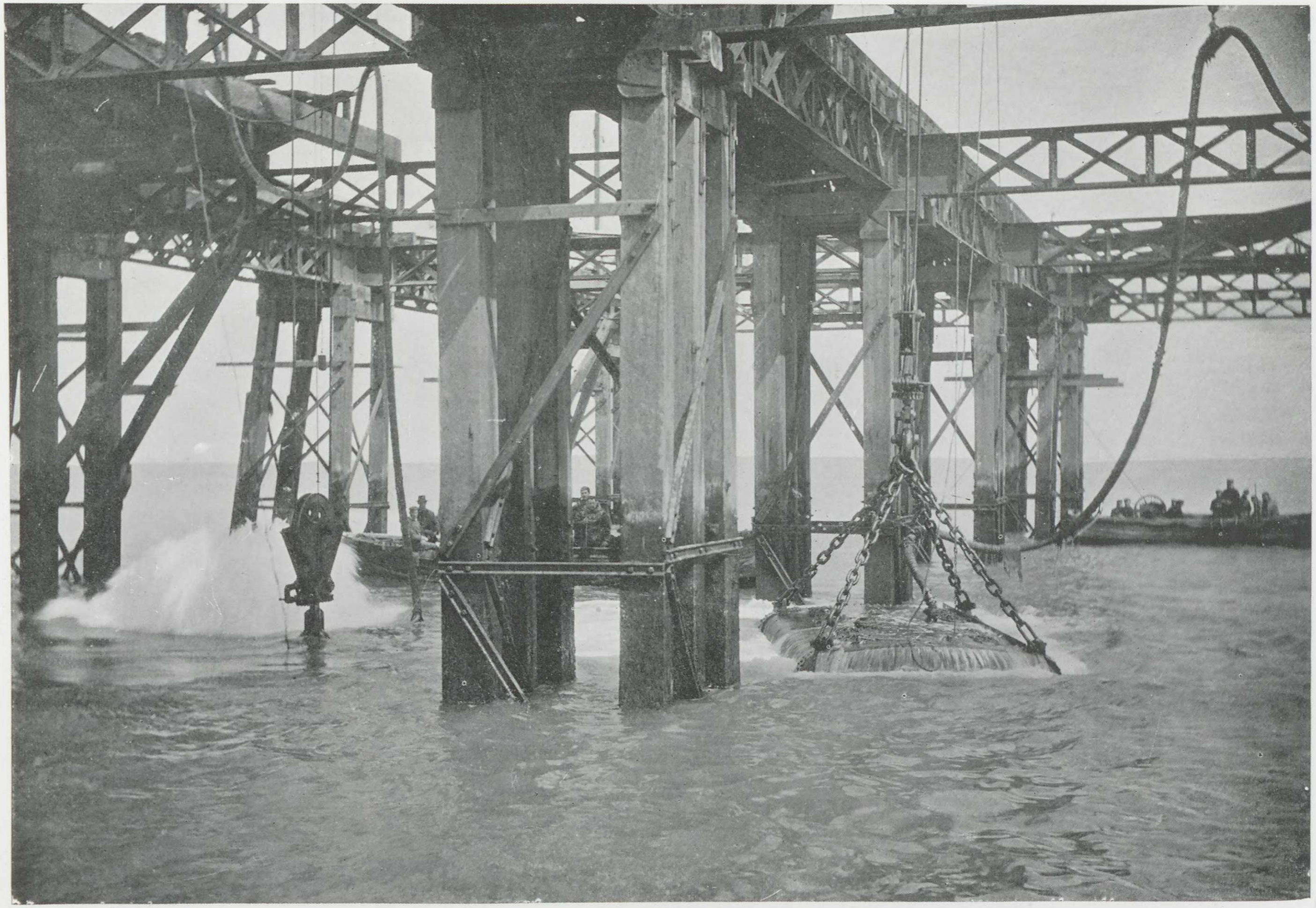


Photo No. 27.

This Photograph shows one of the two Diving Bells just submerged, and the second Bell with its roof above water. Two of the Boats from which the Helmet Divers work are also to be seen. Each Bell measures 12 ft. 9 in. by 10 ft. by 6 ft. 6 in. high and weighs about 26 tons.

Contractor, W. Rigby, Esq., London.
Works Manager, Mr. James Grice.

Engineers, Messrs. Coode, Son & Matthews, London.
Resident Engineer, Hugh T. Ker, Esq., C.E.

AIR LOCK DIVING BELL PLANT SUPPLIED TO THE BRITISH ADMIRALTY FOR LAYING MOORINGS AT GIBRALTAR.

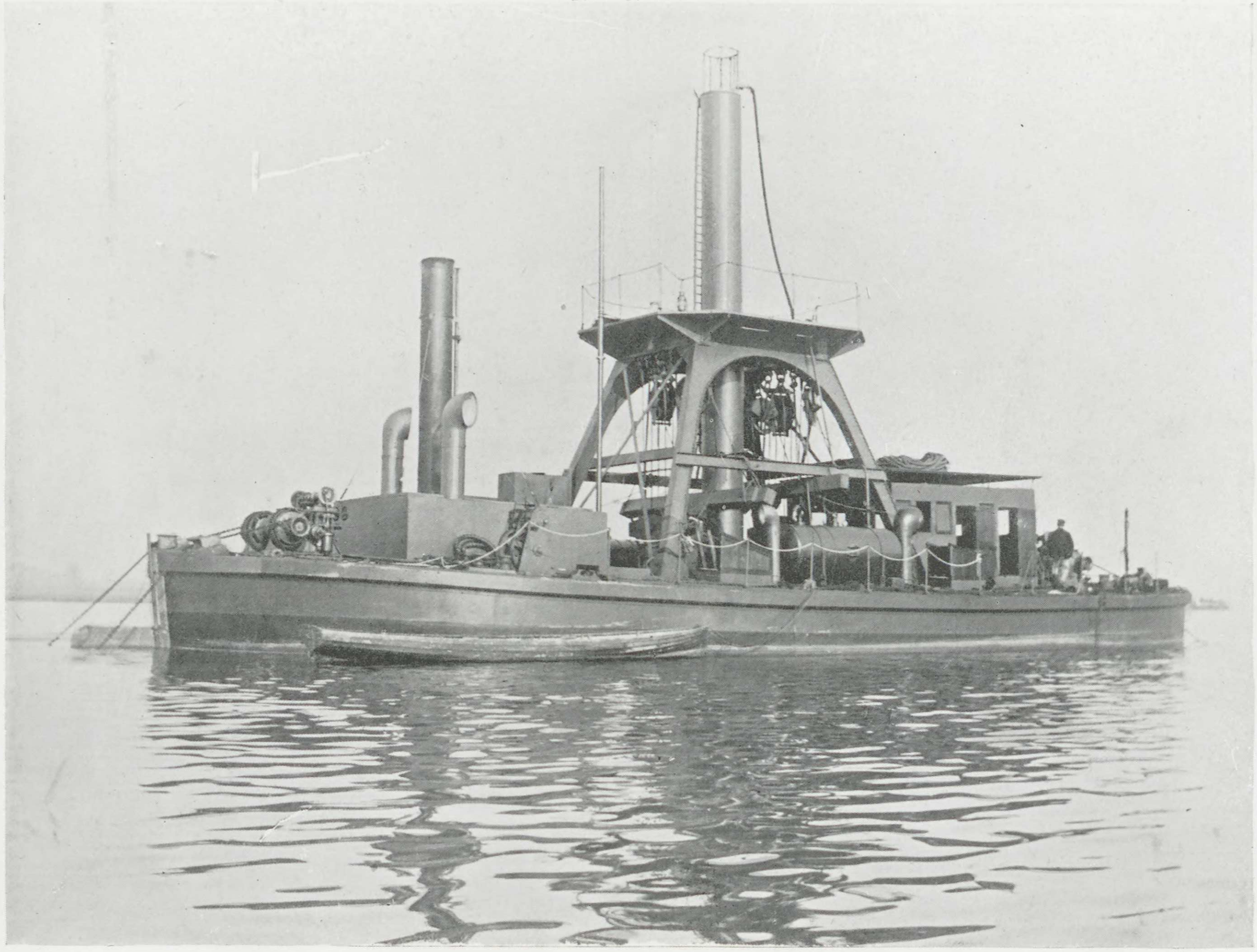


Photo Nc. 28.

The working chamber of the Bell measures 14 ft. by 10 ft. by 7 ft. high, the shaft 37 ft. by 3 ft. dia. ; total weight about 40 tons.

AIR LOCKS FOR SINKING CAISSONS, &c.

(See Illustrations on page 76.)

The following is a description of one of the best forms of Air Lock employed in connection with cylinder sinking operations, and as used by Messrs. Sir W. Arrol and Co., Ltd., on such important works as the Forth Bridge, etc.

There are two locks—the material-lock and the man-lock—placed one above the other. The lower (*man*) lock has two compartments. It is semi-circular at the ends and flat in the centre, and has room for three men in each compartment. The lock is of steel plates, strengthened where necessary with beams and angles. The doors are of cast steel, and have rubber joints. Bull's-eye glasses are fitted. The joints are caulked, and the whole is tested to a pressure of 50 lb. to the square inch. Cocks are provided to enable the workmen to regulate the air pressure when passing from one compartment to the other; the outer space is used as an intermediate stage in entrance and exit.

The *material*-lock is placed above the *man*-lock, the doors in this case being horizontal, and opened and shut by a hand rack-motion, worked from large hand wheels. A small steam-engine is provided for operating the winding drum. To throw this lifting drum quickly out of gear, a clutch is provided so that when the buckets are resting on the bottom door an overhead lifting arrangement may be brought into gear, and the buckets raised above the lock to tip the excavated material into the shoot.

QUANTITY OF MATERIAL "LOCKED THROUGH" PER DAY.

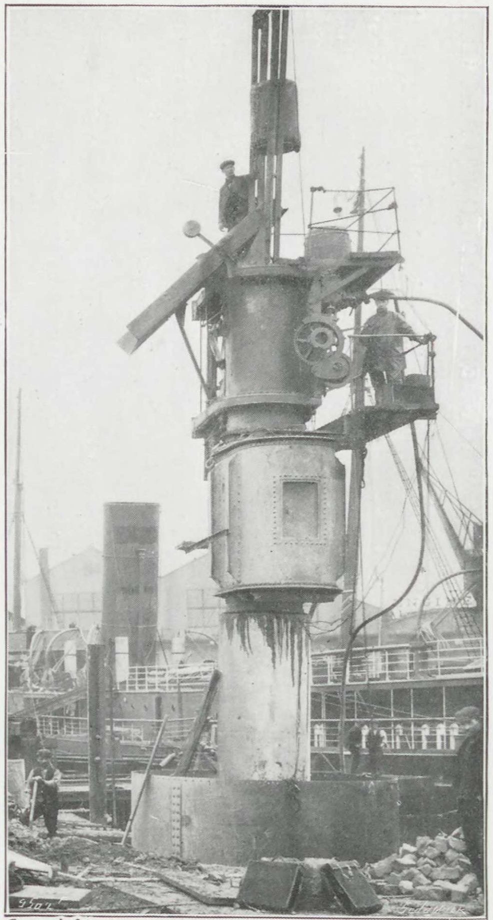
As to the rate at which excavated material can be "locked through," it may be mentioned that, with a plant as described above, 160 buckets 2ft. 9in. deep by 2ft. diameter = 8 cubic feet capacity, have been taken out in eight hours. This includes filling, hoisting 60ft., "unlocking" and emptying, also returning bucket to the working chamber.

THE TIME REQUIRED TO REDUCE THE AIR PRESSURE IN THE MAN-LOCK is regulated according to the pressure (*see remarks on "decompression" in preceding pages*). To reduce the pressure in the *material*-lock is a matter of a few seconds only.

THE AIR SUPPLY should be arranged so as to keep the CO_2 below one-half per cent. (measured at atmospheric pressure). To ensure proper ventilation and allow for the gases generated by blasting, &c., four to five cubic feet per man per minute will generally be required.

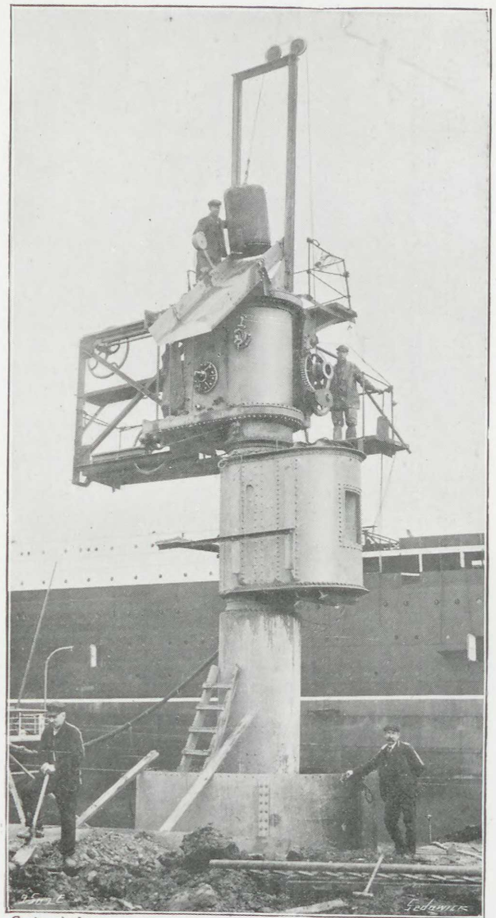
When asking for estimates for Air-locks, particulars of construction of caissons, and their dimensions should be supplied.

DOUBLE COMPARTMENT TYPE OF AIR LOCK FOR SINKING CAISSONS.



Copyright.

Photo No. 29.



Copyright.

Photo No. 30.

DIVERS SAVE A CATHEDRAL.*

The work of saving Winchester Cathedral is quite without precedent in the history of Church Archæology, and constitutes an unique instance of the employment of the Diver.

At first sight it is a difficult matter for the ordinary reader to understand, and the question is often asked, "How can a diver be employed on solid and dry ground such as that on which the Cathedral stands?"

A few words at the outset may be useful in explaining the process.

If a shaft be sunk in almost any place, the level of water will be reached sooner or later, and the excavation practically becomes a well. In order to reach a lower depth one of two courses must be adopted: either a pump must be used to lower the water, or a diver must be employed to excavate below the water level.

In the case of Winchester Cathedral, it was at once apparent that pumping was inadmissible, as by so doing silt or sand would be drawn from beneath the other portions of the fabric, and the building would be pumped down to destruction.

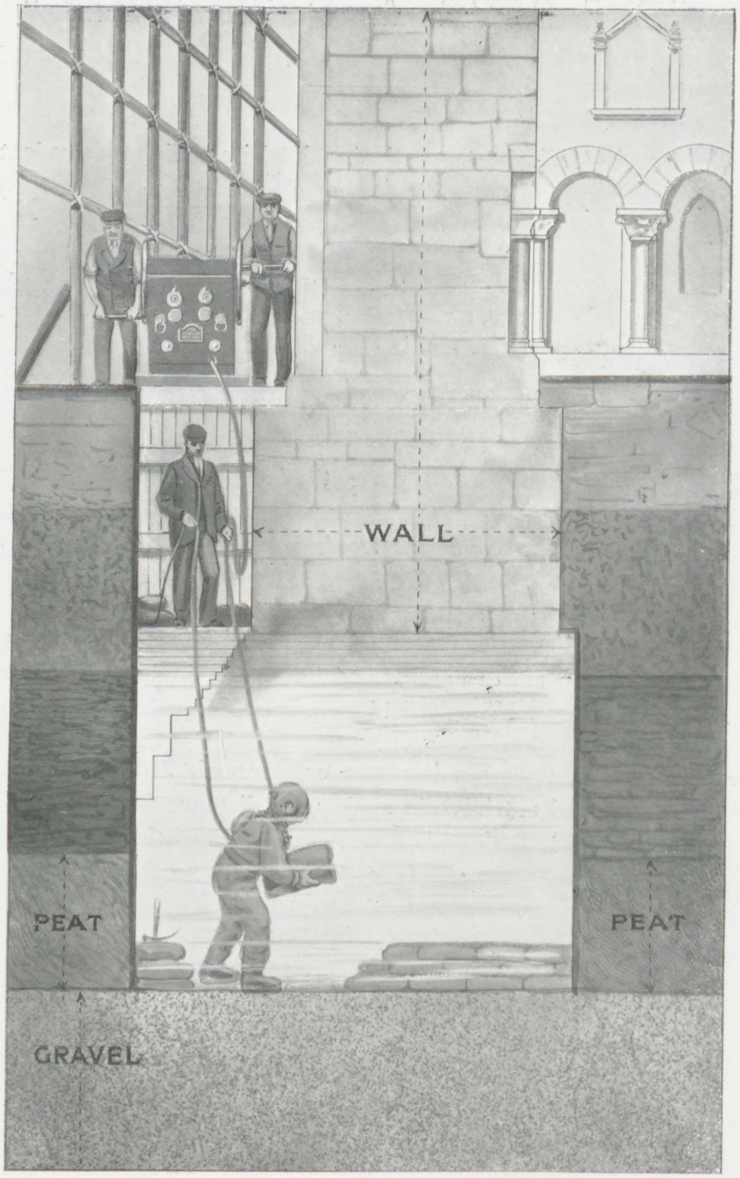
Before the work of underpinning was commenced, Mr. T. G. Jackson, R.A., the Diocesan Architect, had a trial hole sunk some distance from the building, and he found that, although the foundations had been carried down by the ancient builders in A.D. 1079 and A.D. 1202 to a depth of 10ft. below the surface, the work had been stopped at that level by water. In those days pumping was not understood, nor were the uses of Caisson, Compressed Air and other modern appliances known to the builders. They knew nothing about diving, and consequently their operations were stopped.

At the later date—A.D. 1202—beech trees of various sizes were laid side by side at the bottom of the trench—at water level—and these having been covered up with chalk, the construction of the Cathedral was proceeded with.

In this trial hole, however, it was found that below the water-level a bed of marly clay 6ft. in thickness existed which rested on a genuine peat bog 8ft. 6in. in depth. This in its turn was supported by a fine bed of water-worn flints. The existence of this gravel bed is that which renders the saving of the Cathedral possible.

The problem that presented itself was as to the best method to be adopted for the removal of the peat and the substitution of concrete or masonry without pumping.

* Copyright by R. H. Davis in the U.S.A.



Copyright. **Fig. No. 31.**

Mr. Francis Fox, M.Inst.C.E., whom the Dean and Chapter of Winchester had appointed, at the suggestion of the Marquess of Winchester and Mr. Jackson, to collaborate with the latter gentleman, at once gave this difficult problem his careful thought. His experience of bad and dangerous foundations suggested all kinds of methods, but at last he came to the conclusion that the aid of a Diver was the only solution of the trouble.

The following section will serve to illustrate the procedure. The walls of the Cathedral having first been well grouted up by means of the "Greathead" grouting machine to fill all the cracks, a length of wall from 5ft. to 6ft. is attacked.

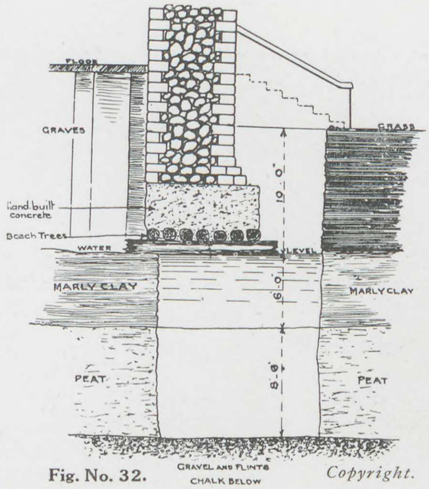


Fig. No. 32. *Copyright.*

A pit "A" is sunk, and by its means the old foundations are uncovered and the beech trees exposed. Water is then reached, and with the aid of ordinary excavation and light pumping the clay is removed and the peat bed uncovered. Pumping has then to cease.

This Peat Bog, under the heavy weight of the building, was compressed, and although it is to-day 8ft. 6in. in thickness, it was in all probability at the outset 12ft. in thickness, resulting in a very serious and unequal subsidence, and which no doubt caused great anxiety to the original builders.

The water is allowed to rise to its normal level, and the work is continued by Diver. He excavates the peat beneath the wall, the length, as before stated, being 5ft. to 6ft., whilst the extent of the drift beneath the water and below the walls varies from 9ft. to 22ft.

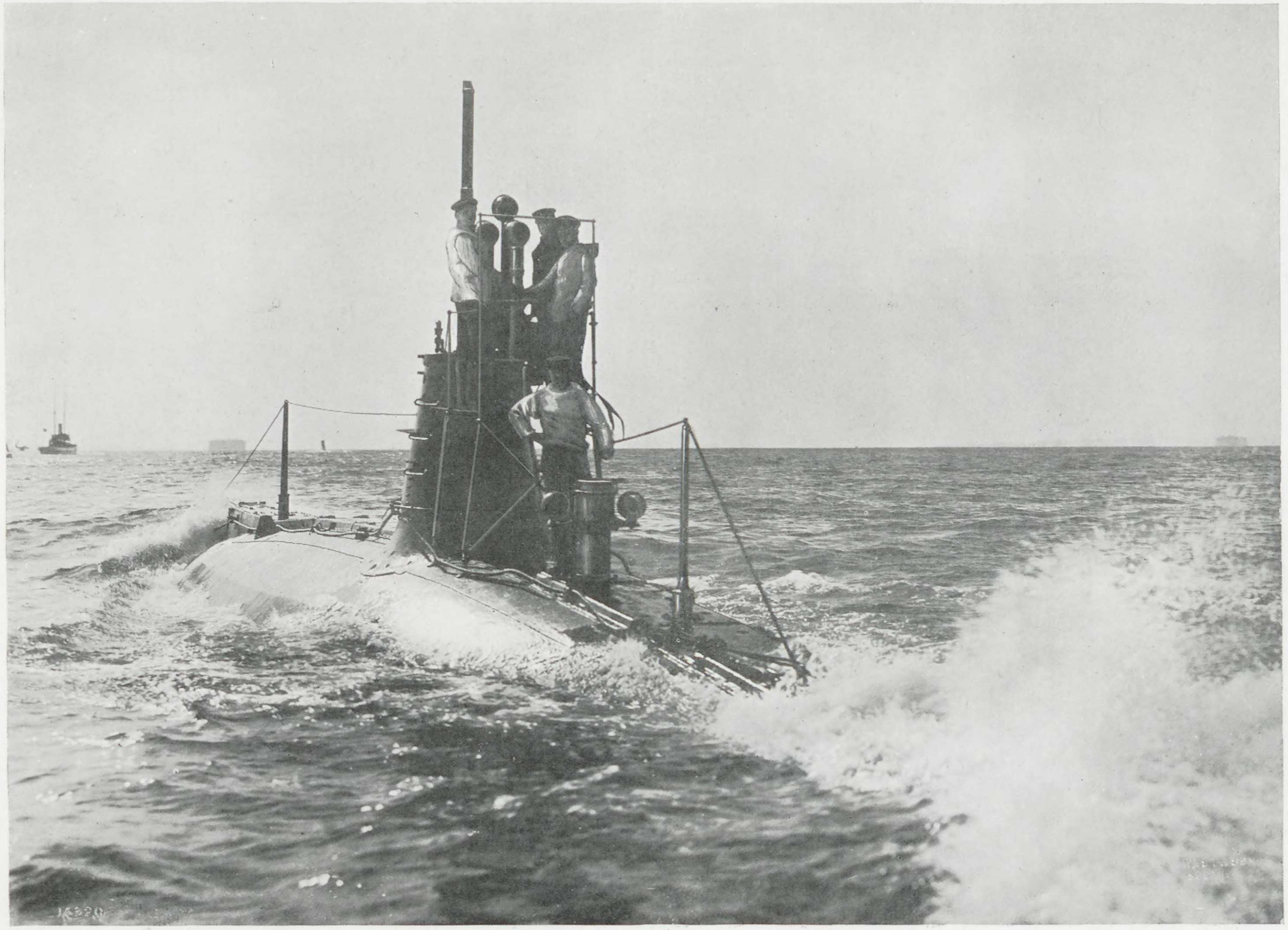
He carefully cuts down the peat to a vertical line, removing every particle from the surface of the gravel. So soon as this excavation is completed, jute bags filled with concrete in cement, ready mixed, are lowered down to him, and these he places side by side until the whole area is paved over with bags. These are then slit open with a knife to allow the material to be spread by the diver over the surface.

Four such layers of bags are thus placed in position, and when it is remembered that the whole of the work, both of excavation and concreting, is done in absolute darkness and entirely by feeling, the greatest credit is due to Siebe, Gorman and Co.'s diver for the care and zeal with which he carries out this arduous task. On every occasion of inspection under water by Mr. Fox,* he has expressed himself as fully satisfied with the work.

When the four layers of bags have thus been placed in position, a sufficient length of time is allowed to elapse for the concrete to set, the inflow of water is checked, and the water in the hole pumped out.

The work is then continued by ordinary masons and bricklayers up to the underside of the original foundation, the beech trees are removed, and the Cathedral finally stands for all time on a solid and satisfactory foundation.

* This well-known Civil Engineer, though well in the sixties, makes personal inspection of the under water work.



Copyright.

Photo No. 33.

BRITISH SUBMARINE "A 3."

THE QUESTION OF LIFE-SAVING DEVICES IN SUBMARINE BOATS

AND

SOME CONSIDERATIONS AFFECTING IT.*

During the last few years considerable attention has been given to the question of affording the crews of submarine vessels some chance of saving their lives in the event of a serious accident to their craft, and everyone will agree that the reasons for supplying surface vessels with lifeboats, rafts, etc., should apply with equal force to underwater ships. Unfortunately, however, the problem is a very difficult one to solve on account of the natural difficulties which preclude the employment of the well-known life-saving devices in use on the surface.

It should be here stated that there is no difficulty in constructing submarines that would be safe under almost any conditions, but such a vessel would be so hampered by her safety devices as to have little or no military efficiency, and, since submarines are at present only built for fighting, such a vessel does not enter into serious consideration.

In studying this question it is essential that the salvage of the submarine and the saving of the lives of her crew, after accident, should be dealt with separately. Inevitable delays in the arrival of the salvage vessel, and in getting purchases on, conditions of tide, weather, etc., render it almost certain that a submarine cannot be raised in time to save life. *The saving of life must be the first consideration;* the salving of *matériel* should be left to those who carry out such work with the aid of suitable vessels and appliances.

There are some elementary facts in connection with this subject that are not always thoroughly understood.

First of all, submarines navigate below the surface of the sea with a small reserve of positive buoyancy, so that any accident to their machinery, rudders, etc., simply necessitates an involuntary return to the surface, and, in war time, possible capture, but not loss of life. Further, the means provided in all submarines for expelling water by means of compressed air, electric or hand pumps, etc., allow for any small leakage of water to be dealt with, so that the only conditions under which one can imagine a submarine unable to rise must be such as to have involved a large and sudden loss of buoyancy due to an inrush of water into the hull from some cause or other.

* Copyright by R. H. Davis in the U.S.A.

THE PATENT SUBMARINE LIFE-SAVING DEVICE.

Copyright. **Photo No. 34.**

MAN EQUIPPED, AND READY FOR ASCENT.

Copyright. **Photo No. 35.**

APPARATUS FOLDED UP FOR STOWAGE.

Let us now consider for a moment the conditions obtaining in a submarine after a serious collision or other accident resulting in an inrush of water into her hull. The first effect of such an accident will be the descent of the vessel to the bottom, not necessarily very fast, but assuming that the water is entering more rapidly than it can be expelled, the vessel will undoubtedly sink, and continue to fill until she is either full, or, if not holed in the top, until the air in the boat is compressed to a pressure equal to that of the water at the depth in which she has foundered. The rapidity with which this takes place will, of course, depend upon the size of the hole, but taking into consideration the strength of hull and the very small weight of a submarine in diving trim, it will in all probability take her some time to fill. The next result will be that salt water will come into contact with the stored electrical energy or open terminals, and the atmosphere of the boat will be rapidly made poisonous by the formation of chlorine gas.

These considerations point to the fact that when a large quantity of water finds its way into the body of a submarine the conditions will be such that something must be done, and done quickly :—

(*a*) To render the crew independent of poisonous gases.
(*b*) To preserve the crew from drowning in the boat.
(*c*) To provide means of escape from the boat and ascent to the surface.

The life-saving devices at present known are :—

(1) *Air-locks for escape.*
(2) *Detachable chambers, or life-boats.*
(3) *Self-contained dress for escape.*

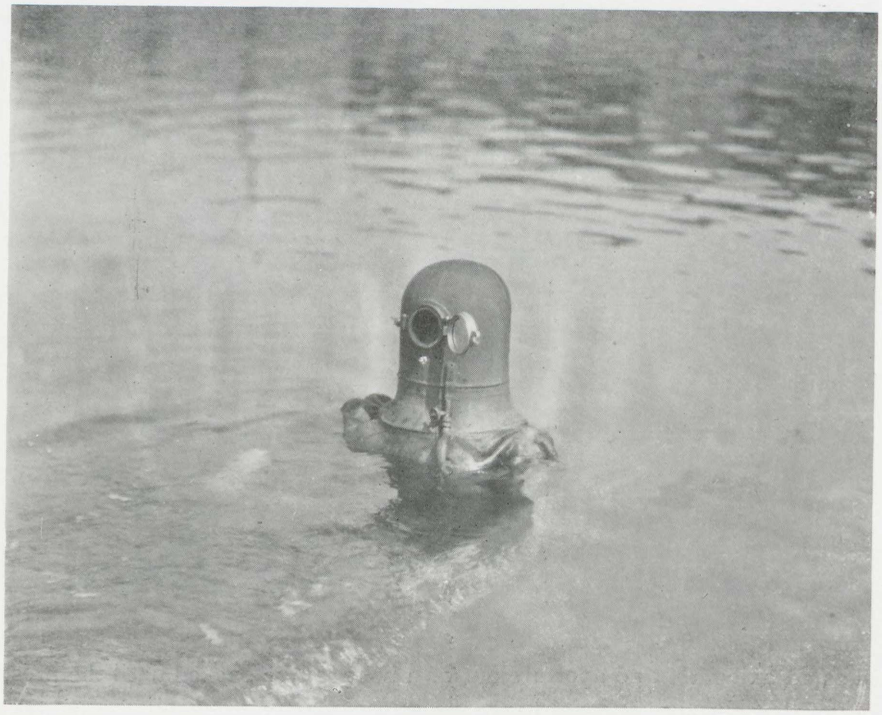
1.—*Air-locks* of themselves are of little use except in shallow water, but combined with either (2) or (3) are essential in all methods of escape.

They are the first element of escape, and are in use in every system. It must be accepted as an axiom that no aperture out of a boat can be opened until the pressure on the *inside* of that aperture is equal to the pressure of water *outside* it.

The Air-lock may be a portion of the boat provided for the special purpose, or the general cavity of the boat may be used. In the latter case the pressure inside the boat is made to equal that of the water outside by simply allowing the boat to fill with water.

2.—*Detachable Chambers, or Life-boats.* The great objection to all forms of detachable chambers or life-boats is their size, weight and resistance if made large enough to contain all the crew of a modern submarine, and as such a chamber would have to be carried as a superstructure, it would be in the likeliest position to be injured in case of collision. But what is more against any device of this kind is that the crew are expected in a moment of considerable excitement to undertake an entirely novel operation which there is no means of trying previously. Experience goes to show that even plain drop safety weights fail at the critical moment; in fact there are a great many loop holes for the unexpected in air-locks or life-boats carried in the hull, apart from the constant encumbrance to the submarine.

Another great drawback to the Air-lock or detachable life-saving chamber is, that the air in it is liable to become foul as the crew are getting into it, owing to the formation of chlorine gas.



Copyright. **Photo No. 36.**

MAN, EQUIPPED WITH THE APPARATUS, FLOATING.

It will be noticed that the window of the helmet is wide open.

A life-saving device to be efficient must be able to fulfil PROMPTLY the three conditions previously referred to, and in order to meet them a SPECIAL FORM OF DIVING HELMET, which is *quite self-contained,* and not dependent on any feature which is liable to get out of order, HAS BEEN DESIGNED AND PATENTED. This apparatus, of which photographs are reproduced on page 82, has, after exhaustive trials, *been adopted by the British Admiralty.*

DESCRIPTION OF THE APPARATUS.

The helmet, which is made large enough to allow the head free movement within it, is sloped away to fit the shoulders, and is continued into a short jacket of strong waterproof material. In front of the jacket, inside, is a pocket containing a combined purifier and oxygen generator, consisting of two small chambers formed in one case. These chambers are charged with a patented substance which, when in contact with the water vapour of the breath, gives off pure oxygen gas and forms a caustic alkali. The alkali then takes up the carbonic acid gas of the respired air, and forms an alkaline carbonate. In this way the same air, purified and re-oxygenated, is used over and over again.

The *total weight* of the whole outfit is only 16 *lbs. Folded up for stowage* (as shown in photo on page 82), it *occupies a space of* 12in. by 12in. by 15in.

It has been used in the thickest smoke and sulphur fumes, and the wearer has not felt them in the slightest degree.

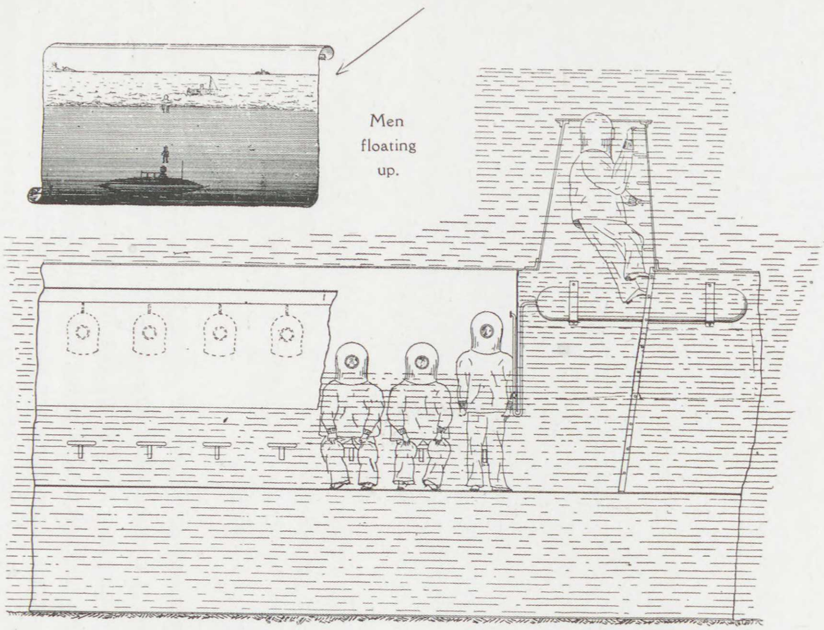
The dress, which *can be put on without assistance in thirty seconds, thus fulfils the first of our three conditions, viz.:* that the crew should be rendered independent of poisonous gases which may be generated in the boat. The chief of these, as already explained, is chlorine gas, which forms when salt water gets into the batteries, and which is fatal in very small quantities, and even apart from being actually dangerous to life, the smallest trace in the air will cause so much coughing that work is impossible just when work is most needed to enable the crew to get rid of the water in the boat, and perhaps get her to the surface.

The second condition was that the dress should be able to preserve its wearer from drowning whilst the boat was being flooded. In this connection we would mention that *the dress is now in every-day use, with perfect success,* under water, the wearer being as comfortable in it as he would be in an ordinary diving dress.

The third condition is fulfilled by the *dress acting as a lifebuoy,* and keeping the wearer afloat on the surface (see photo on page 84). A special device is fitted to enable the wearer, when he reaches the surface, to inflate a flexible chamber which surrounds the jacket, and thus forms a life-belt.

Whilst the apparatus is self-buoyant when it contains all the air originally in the jacket and helmet, yet it is not sufficiently buoyant to maintain the wearer afloat at the surface of the water when the window of the helmet is opened and permits the enclosed air to escape. The necessity of opening the window to permit of the access of fresh air to the helmet arises from the fact that the artificial air supply given by the apparatus is limited, and a wearer may not be rescued for some time after reaching the

DIAGRAMMATIC SKETCHES OF INTERIOR OF A SUBMARINE, SHOWING AIR-TRAPS AND THEIR USE.

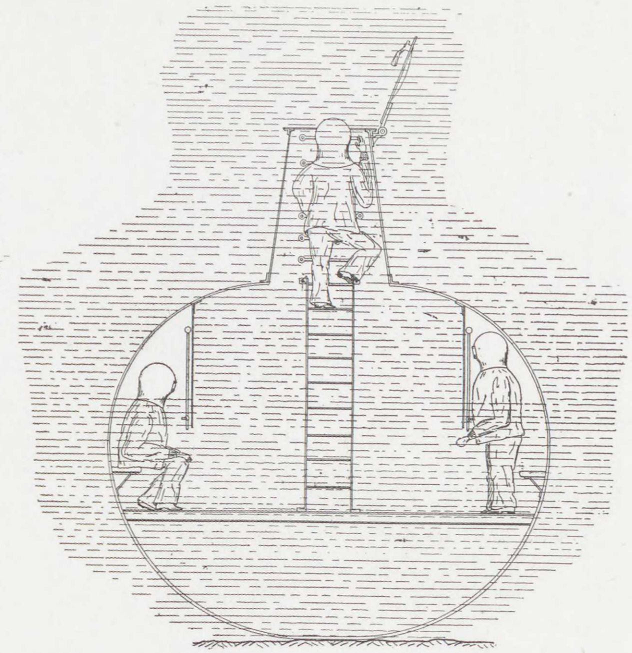


Copyright.

Fig. No. 37.

LONGITUDINAL SECTION.

As will be seen, the helmets are kept hanging up in readiness in the Air-Traps, for immediate use in case of emergency.



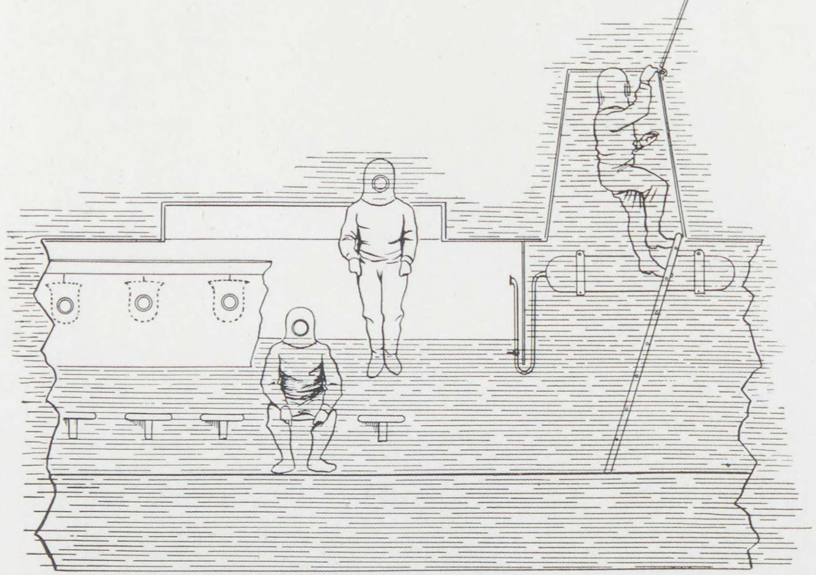
Copyright.

Fig. No. 38.

TRANSVERSE SECTION.

Showing men in Air-Traps, and a man passing through Conning Tower; also showing Air-Supply Pipes from boat's Compressed Air Cylinders to Air-Trap, with simple cock to turn on extra pressure of air when necessary.

DIAGRAMMATIC SKETCHES OF INTERIOR OF A SUBMARINE BOAT SHOWING AIR-TRAPS AND THEIR USE.

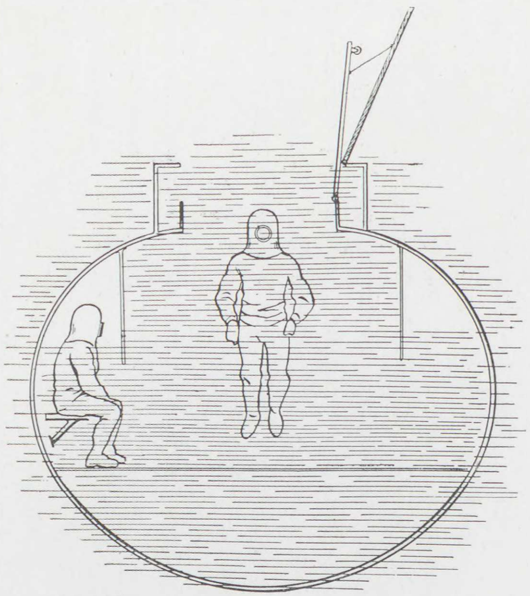


Copyright.

Fig. No. 39.

LONGITUDINAL SECTION.

As will be seen, the helmets are kept hanging up in readiness in the Air-Traps, for immediate use in case of emergency. Sketch shows a man floating through the Torpedo Hatch to the surface, and another passing through the Conning Tower.



Copyright.

Fig. No. 40.

TRANSVERSE SECTION.

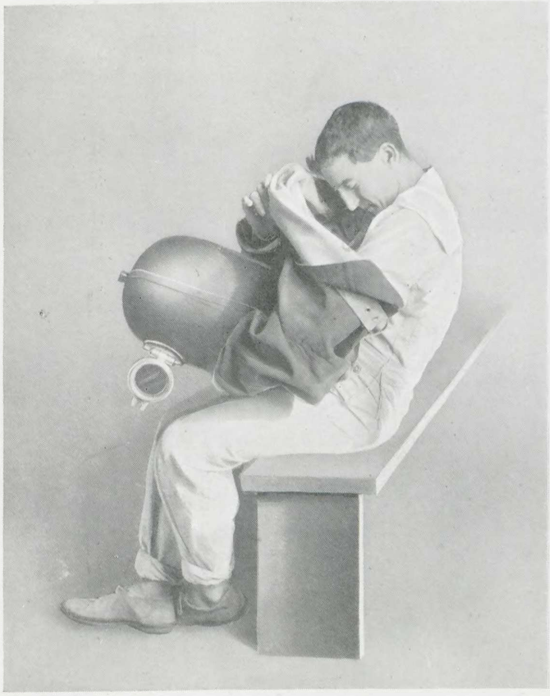
Showing man in Air-Trap, and another passing through Torpedo Hatch.

surface of the water. Attempts have been made to remedy this defect by fitting the apparatus with cork life-belts, or with a chamber, or chambers, already inflated with air, but these are found to be impracticable, owing to the necessity of employing heavy weights to keep the wearer down, and also by reason of the dangerous velocity with which he would rise to the surface on the removal of the weights. To obviate these disadvantages a flexible air-chamber, as before described, is attached to the apparatus in such a way as to enable the wearer himself to inflate it when he reaches the surface, and thus render himself buoyant enough to float when the window of the helmet is open.

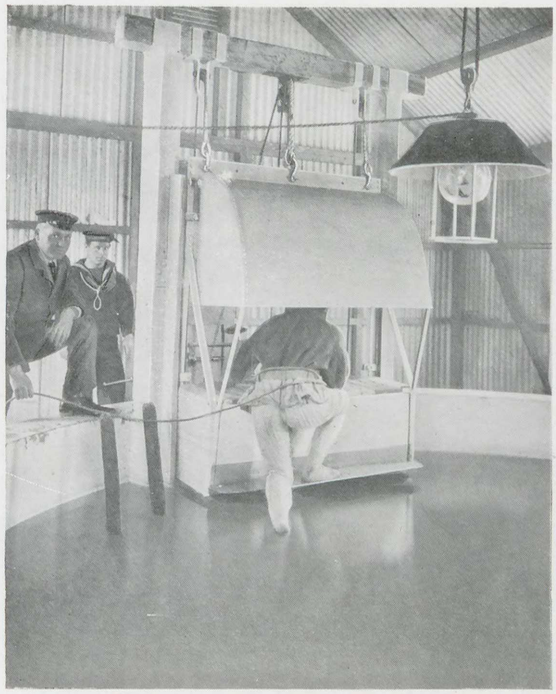
One great point about the apparatus is that it can be exercised in. We would propose to let every " submarine " man, as part of his training, go under water in the helmet, to get used to it. Men equipped in the helmet should also be trained in the boats in finding their way out of the conning tower or torpedo hatch. As a matter of fact, the British Admiralty have gone further than this in having, at Portsmouth, a huge tank of water, at the bottom of which is erected a " skeleton " submarine boat. At the surface is fitted an arrangement for lowering and raising an air-lock, as shown in photos Nos. 42 and 43. The men, having first been trained to put the dress on quickly (see photo No. 41), practise getting into and out of the air-lock. They are afterwards lowered in the lock to the bottom of the tank, where they enter the " submarine " and find their way to a ladder leading up to the conning tower, the hatch of which they open. Then they either float to the surface or return to the starting point, the operations being repeated until the officer in charge considers the men proficient. For the purpose of taking a clear photo of No. 44, the water in the tank was lowered. Photo No. 36 shows a man who has just floated to the surface. It will be readily understood that this training air-lock, used as described, brings about practically the same conditions as would obtain in a submarine boat which had been flooded, the air in the former being compressed just as that in the air-lock of the submarine.

There is one point that demands notice, and that is the effect of water pressure. It seems difficult to understand how it is possible for the men to get out of a submarine and not be at once crushed by the pressure of the water, but water pressure *per se* has no effect on the diver, provided that the pressure of the air in the dress is the same as that of the water outside.

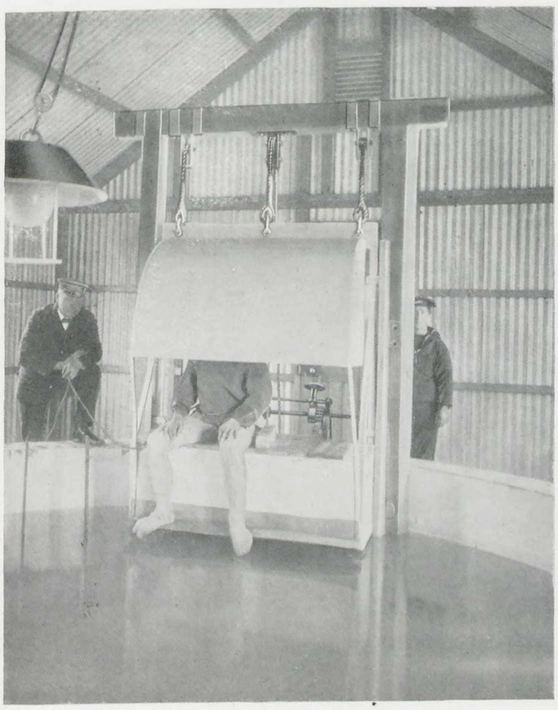
We have already explained what happens when a submarine is holed by accident. The water pouring in will, if the hole is at the top of the boat, gradually replace the whole of the air in the vessel; but if the hole is below the highest point, then the water as it enters will compress the air until the pressure of the latter is equal to that of the water outside. If, now, the men in the boat close up their helmets whilst standing in this reserve of compressed air, the pressure of the air in the helmet will be the same as the water pressure, and the conditions of safety are secure. The crew can now, without difficulty, open the torpedo hatch, or the hatch of the conning tower, and ascend to the surface.



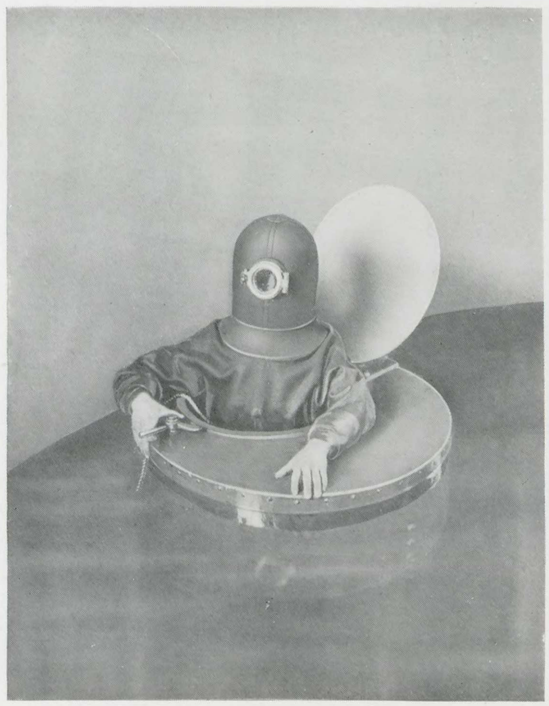
Copyright. **Photo No. 41.**
Putting the Apparatus on.



Copyright. **Photo No. 42.**
Practising getting into and out of Air-lock.



Copyright. **Photo No. 43.**
Man in Air-Lock being lowered to bottom of tank.

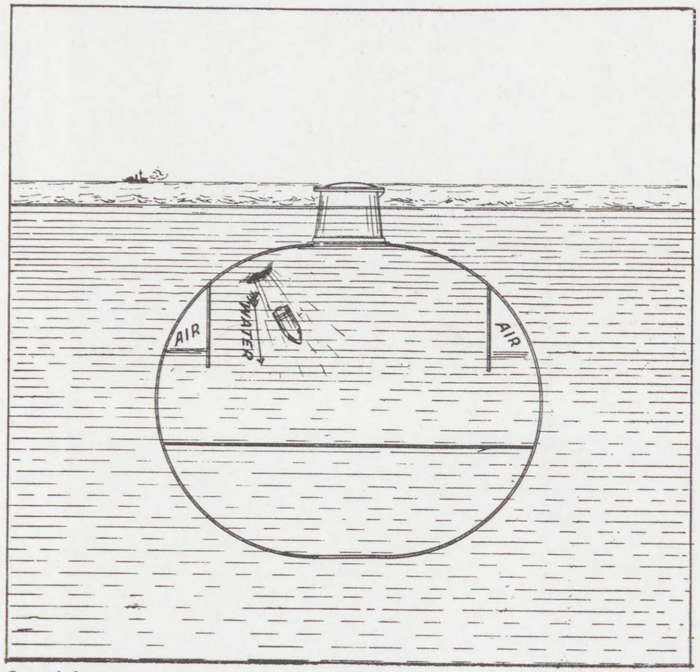


Copyright. **Photo No. 44.**
Man emerging through hatch of "dummy" Conning Tower.

The water has been lowered to enable the Conning Tower to be clearly shown.

TRANSVERSE SECTION OF SUBMARINE BOAT.

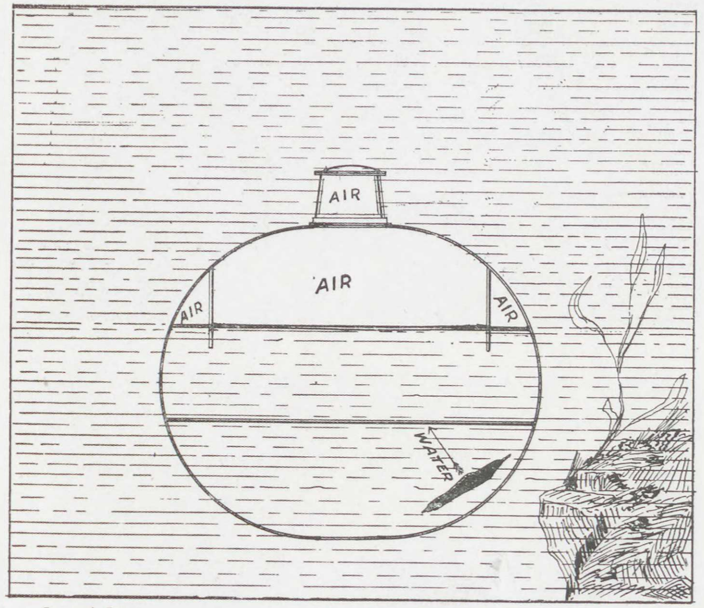
Showing what happens when a vessel is holed *high up*, and when holed *low down*.



Copyright. Fig. No. 45.

BOAT HOLED AT THE TOP.

In this case the water would gradually replace the whole of the air in the vessel, hence the provision of watertight bulkheads to trap a supply of air at a pressure equal to that of the water at the depth at which the boat has foundered.



Copyright. Fig. No. 46.

BOAT HOLED LOW DOWN.

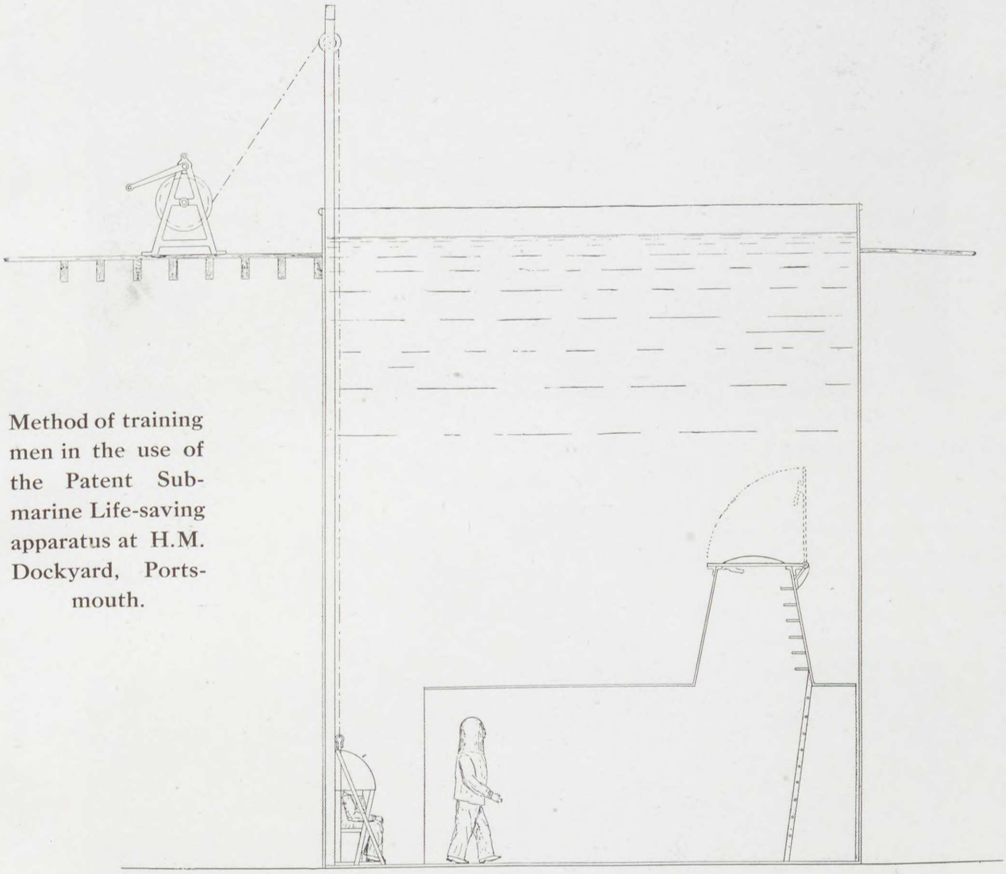
Here the water entering compresses the air upwards until the pressure is equal to that of the water. It is obvious from our earlier remarks that the flooding of the boat in the above circumstances would have to be completed, as shown in first drawing on this page, before the hatch could be opened. This would be done by allowing the compressed air to escape through a valve provided.

In the case of a boat unable to rise through any other causes than those explained above, the vessel would, of course, have to be deliberately flooded to bring about the conditions necessary to enable the crew to escape to the surface.

But it is evident that we must provide for the case of the boat being holed high up, and this can be done by the provision of bulkheads so arranged as to trap the air. (*See illustrations on pages* 86, 87 *and* 90.)

The fitting of air-traps does not in any way impair the habitability or efficiency of the vessel, and all the newer submarine boats in the British Navy are so fitted, whilst the older types also are being converted.

On one occasion, when a vessel, fitted with an air-trap, was accidentally sunk in a dock, two men escaped by means of the air-trap, without any helmet, but this was in shallow water, and the fore-hatch was open.



Method of training men in the use of the Patent Submarine Life-saving apparatus at H.M. Dockyard, Portsmouth.

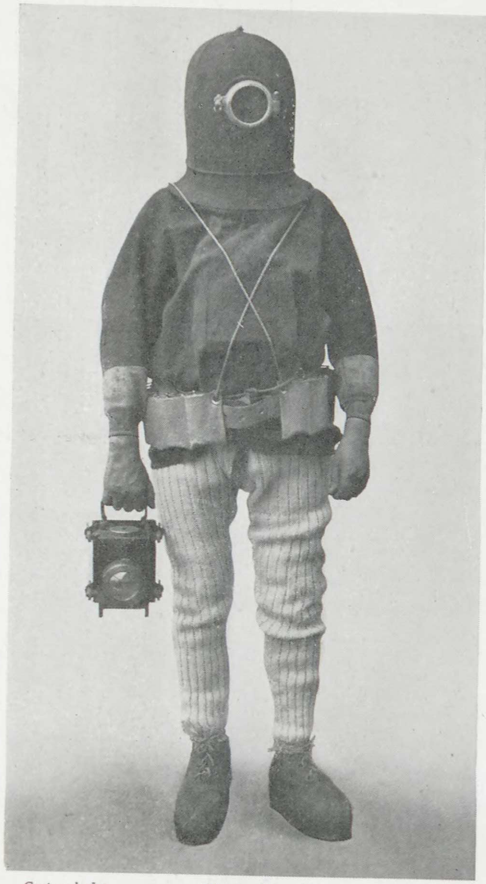
Copyright.

THE APPARATUS AS A SHALLOW WATER DIVING DRESS, AND SMOKE HELMET.

The same apparatus makes an efficient shallow-water diving dress, but since the conditions of use are altered, the object in the case of life-saving being to carry the wearer to the surface, whilst in the other case it is to keep him under water, it becomes necessary to weight him. For this purpose the ordinary diver's boots and a weighted belt are provided, as shown in photo No. 47. As a shallow-water diving dress the apparatus can be used for about forty minutes, at a maximum depth of twenty-five feet, on one charge of the oxygen-producing compound. Thus an adequate time is allowed for the majority of the emergency cases where such apparatus is likely to be employed, such as examining or clearing propellers, clearing Kingston valves, examining hulls below the water line, recovering articles lost overboard, etc.

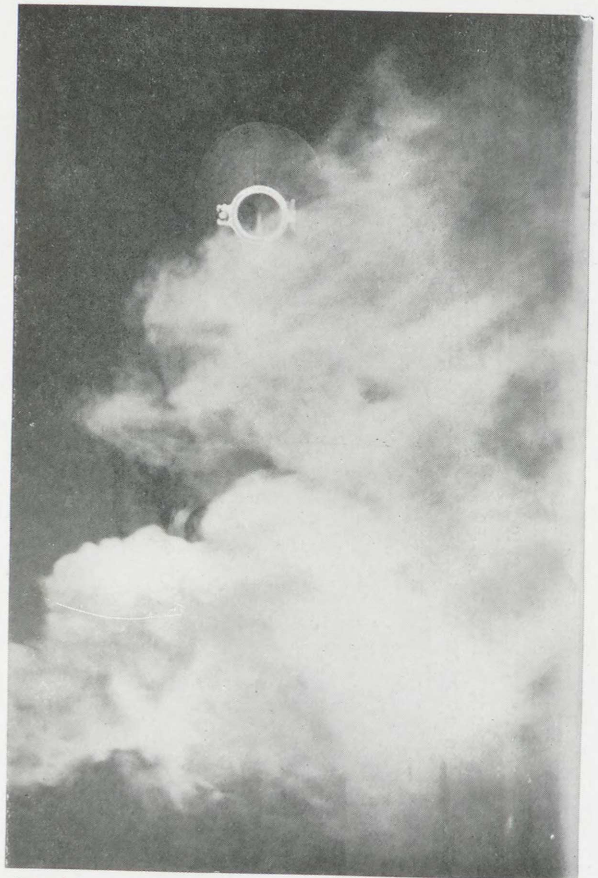
As a SMOKE HELMET (see photo No. 48), the apparatus can be used for hard work for about forty minutes on one charge, or for light work for about one hour.

THE APPARATUS AS A SHALLOW WATER DIVING DRESS AND SMOKE HELMET.



Copyright. **Photo No. 47.**

Man equipped ready for shallow water work.



Copyright. **Photo No. 48.**

Man equipped with the Apparatus emerging from a room filled with smoke in which he has been working.

USEFUL DATA RELATING TO DIVING.*

WATER.

Its Weight. A cubic foot of *salt* water weighs 64lbs.

A cubic foot of *fresh* water weighs 62.5lbs.

Pressure. Every one foot height of *salt* water increases the pressure by nearly ½lb. on the square inch.

A column of *salt* water 33 feet high presses on the bottom with a pressure of about 15lbs. per square inch, or one atmosphere.

A column of water 27 inches high = about 1lb. pressure per square inch.

A ton of fresh water = 35.90 cubic feet = 224 gallons.

A ton of sea water = 35 cubic feet = 218¾ gallons.

Boiling Point 212 deg. F. = 100 Centigrade.

Freezing Point 32 deg. F. = Zero Centigrade.

The following table gives the additional pressure above atmospheric pressure per square inch for every fathom of depth (*salt* water), with the nearest equivalents in metres and kilogrammes per square centimetre respectively:—

Fathoms.	Feet.	Metres.	Lbs. pressure per square inch.	Kilograms per square centimetre	Fathoms.	Feet.	Metres.	Lbs. pressure per square inch.	Kilograms per square centimetre
1	6	1.8	2.7	0.19	26	156	47.6	69.4	4.88
2	12	3.6	5.3	0.37	27	162	49.4	72.0	5.06
3	18	5.5	8.0	0.56	28	168	51.2	74.7	5.25
4	24	7.3	10.7	0.75	29	174	53.0	77.3	5.45
5	30	9.1	13.3	0.93	30	180	54.9	80.1	5.60
6	36	11.0	16.0	1.12	31	186	56.7	82.8	5.80
7	42	12.8	18.7	1.32	32	192	58.5	85.4	6.00
8	48	14.6	21.3	1.50	33	198	60.3	88.1	6.20
9	54	16.5	24.0	1.70	34	204	62.2	90.7	6.37
10	60	18.3	26.7	1.87	35	210	64.0	93.4	6.50
11	66	20.1	29.3	2.06	36	216	65.8	96.1	6.75
12	72	21.9	32.0	2.25	37	222	67.6	99.0	6.90
13	78	23.8	34.7	2.45	38	228	69.6	101.4	7.12
14	84	25.6	37.4	2.62	39	234	71.3	104.0	7.30
15	90	27.4	40.0	2.82	40	240	73.1	107.0	7.50
16	96	29.3	42.6	3.00	41	246	75.0	109.4	7.70
17	102	31.1	45.2	3.17	42	252	76.8	112.0	7.87
18	108	32.9	48.0	3.37	43	258	78.6	114.7	8.06
19	114	34.7	50.7	3.57	44	264	80.5	117.3	8.25
20	120	36.6	53.4	3.75	45	270	82.3	120.1	8.43
21	126	38.4	56.1	3.90	46	276	84.1	122.7	8.62
22	132	40.2	58.7	4.12	47	282	85.9	125.3	8.80
23	138	42.0	61.4	4.32	48	288	87.8	128.0	9.00
24	144	43.9	64.0	4.5	49	294	89.6	130.6	9.13
25	150	45.7	66.7	4.68	50	300	91.4	133.3	9.37

* The figures given may be assumed sufficiently accurate for all practical purposes.

AIR.

Constituents of Atmospheric Air.

The chief constituents of atmospheric air and their proportions are:—

Nitrogen	79.1	per cent. by volume.
Oxygen	20.9	,, ,,
Carbon Dioxide (CO_2)	.03	,,

Aqueous vapour is also present in varying quantity.

Nitrogen has neither taste nor smell nor colour, and, although it is non-poisonous, it will support neither life nor combustion. Its chief use appears to be to dilute the *Oxygen* which is the life-supporting component of the atmosphere, and is also odourless, tasteless and colourless.

Its Weight.

The WEIGHT OF THE ATMOSPHERE is about 15lbs. to the square inch ; thus, in speaking of one atmosphere we mean 15lbs. on the square inch ; two atmospheres 30lbs., and so on.

$$\text{TEMPERATURE FAHRENHEIT} = \frac{\text{Temperature Centigrade} \times 9}{5} + 32$$

$$\text{TEMPERATURE CENTIGRADE} = \frac{\text{Temperature Fahrenheit}-32}{9} \times 5$$

Column of Mercury.

A column of mercury 30 inches high = 1 atmosphere = say 15lbs. pressure. A column of mercury 2 inches high = say 1lb. pressure.

Expansion.

AIR EXPANDS $\frac{1}{493}$ of its volume for every increase of 1 deg. F., and its volume varies inversely as the pressure.

Quantity of Air breathed by man.

Normally, THE VOLUME OF AIR BREATHED by an average healthy adult male is about 30 cubic inches per inhalation × 15 inhalations = 450 cubic inches = about .25 cubic feet = 7.3 litres per minute. EXHALED AIR CONTAINS on the average 79.1 per cent. of nitrogen, 16.5 per cent. of oxygen, 4.4 per cent. of carbonic acid (CO_2). The "dead space" formed by the larger air tubes is about 10 cubic inches. The air in the lung contains about 14% O_2 and 5% to 6% CO_2.

SUPERFICIAL AREA AND DISPLACEMENT OF A DIVER.

Superficial area of a naked man's body and the pressure thereon.

The superficial area of an ordinary sized man's body is about 2,160 square inches, so that in atmospheric air the total pressure on the man's body is 2,160 × 15lbs. = 32,400lbs. At a depth of 33 feet of sea water, the total pressure would be 64,800 lbs. So long as the pressure is EQUALLY distributed throughout the body by the body fluids, it has no effect.

Weight of a Diver fully equipped.

The total weight of a diver's equipment (*i.e.*, the part which he actually wears, and exclusive of his air pipe) is about 175lbs. ; therefore a diver (say a 12-stone man), fully equipped, would have a total weight of 343lbs.

Displacement of a man with and without Diving Dress.

An ordinary-sized man (*naked*) displaces about .075 ton of sea water ; a fully equipped diver, with dress *deflated*, about 0.15 ton, and with dress fully *inflated*, about .31 ton. But if fully inflated he would float, and in so doing would displace exactly the weight of himself and dress, or 343 lbs=.153 ton, as his displacement would be greater than the equivalent weight of water if entirely submerged.

BUOYANCY OF SUBMERGED OBJECTS.

A submerged body displaces in the sea a weight of water equal to the cubic capacity of the body × 64lbs. (the weight of a cubic foot of sea water). Thus a pontoon or camel, measuring 15 feet long by 4 feet diameter, = 188.5 cubic feet, would displace nearly 5.4 tons of sea water if entirely submerged, and its buoyancy would be represented by this figure, minus the weight of the pontoon itself.

METRIC WEIGHTS AND MEASUREMENTS WITH ENGLISH EQUIVALENTS.

1 Metre	=	39.37 inches = 3.281 feet
.915 ,,	=	1 yard
.3048 metre	=	1 foot
1 millimetre	=	$\frac{1}{25}$ inch = .03957 inch
1 centimetre	=	.3937 inch
2.54 centimetres	=	1 inch
25.4 millimetres	=	1 inch
1 kilometre	=	1093.61 yards = 3280.9 feet
1.609 kilometre	=	1 mile
1 imperial gallon	=	277.274 cubic inches
,, ,,	=	.16 cubic foot
,, ,,	=	10.00 lbs.
,, ,,	=	4.543 litres
1 cubic inch of water	=	252.6 grains
,, ,, ,,	=	.03612 lb.
,, ,, ,,	=	.003607 imperial gallon
1 cubic foot of water	=	6.235 imperial gallons
,, ,, ,,	=	28.315 litres
,, ,, ,,	=	.0283 cubic metre
,, ,, ,,	=	62.355 lbs.
1 pound of water	=	27.632 cubic inches
,, ,,	=	.10 imperial gallon
1 cwt. of water	=	11.2 imperial gallons
,, ,,	=	1.795 cubic feet
1 ton of water	=	224 imperial gallons
,, ,,	=	1017 litres (approx.)
,, ,,	=	1 cubic metre (approx.)

1 litre of water	=	022 imperial gallon = $1\frac{3}{4}$ pints
,, ,,	=	61 cubic inches
,, ,,	=	.0353 cubic foot
1 cubic metre of water	=	220.1 imperial gallons
,, ,, ,,	=	1.308 cubic yards
,, ,, ,,	=	61025 cubic inches
,, ,, ,,	=	35.3156 cubic feet
,, ,, ,,	=	1000 kilos
,, ,, ,,	=	about 1 ton
,, ,, ,,	=	1000 litres
1 kilo.	=	2.2046 lbs.
1 atmosphere	=	1.0335 kilos. per sq. cm. = 14.7 lbs. per sq. in.
1 gramme	=	15.432 grains (Troy)
1 kilogram	=	2.2046 pounds or $2\frac{1}{5}$ lbs.
1 millier (metric ton)	=	2204.62 pounds or 0.9842 ton
1 ounce (avoirdupois)	=	28.35 grammes
1 pound	=	.4536 kilogram
1 cwt.	=	50.80 kilograms
1 ton of 2240 lbs.	=	1016 kilograms
,, ,,	=	1.016 metric tons
1 square inch	=	6.45 square centimetres
1 ,, foot	=	0.092 ,, metres
1 cubic inch	=	16.38 cubic centimetres
1 ,, foot	=	0.028 ,, metres
1 lb. per square inch	=	0.07 kilogrammes per square centimetre
,, ,, ,, foot	=	4.88 kilogrammes per square metre

Capacities of Various Sizes of Centrifugal Pumping Engines, as used for Salvage and other purposes.

Size.	Quantity of water discharged per hour.	Size.	Quantity of water discharged per hour.
Inches.	Tons.	Inches.	Tons.
6	190	15	1150
8	330	18	1800
10	600	20	2200
12	840	24	3000

Comparative Breaking Strains of Flexible Steel Wire Hawsers and Cables, Chain Cable, Short Link Chain and Hemp Rope.

Bullivant's Flexible Steel Wire Hawsers and Cables.				Chain Cable.				Short Link Chain.			Tarred Hemp Rope.		
Size of Circumference.	Weight per Fathom.	Guaranteed Breaking Strain.	Diameter of Barrel or Sheaves round which it may be at a slow speed worked.	Size.	Weight per Fathom.	Proof Strain.	Breaking Strain.	Size.	Proof Strain.	Breaking Strain.	Size.	Weight per Fathom.	Breaking Strain.
Inches.	Lbs.	Tons.	Inches.	Inches.	Lbs.	Tons.	Tons.	Inches.	Tons.	Tons.	Inches.	Lbs.	Tons.
12	115	320	72										
11	97	270	66										
10	80	220	60										
9	65	180	54										
8	53	150	48	$2\frac{5}{16}$	280	$96\frac{1}{4}$	$134\frac{3}{4}$	—	—	—	25	146	125
$7\frac{1}{2}$	47	130	45	$2\frac{3}{16}$	256	$86\frac{1}{8}$	$120\frac{1}{2}$	—	—	—	24	134	115
7	41	116	42	$2\frac{1}{16}$	231	$76\frac{1}{2}$	$107\frac{1}{10}$	—	—	—	23	123	106
$6\frac{1}{2}$	37	102	39	$1\frac{15}{16}$	204	$67\frac{1}{2}$	$94\frac{1}{2}$	—	—	—	21	106	89
6	33	88	36	$1\frac{3}{4}$	166	$55\frac{1}{8}$	$77\frac{1}{8}$	—	—	—	19	84	72
$5\frac{1}{2}$	28	74	33	$1\frac{5}{8}$	143	$47\frac{1}{2}$	$66\frac{1}{2}$	—	—	—	17	67	60
5	$23\frac{1}{2}$	64	30	$1\frac{7}{16}$	112	$37\frac{1}{8}$	$55\frac{1}{2}$	—	—	—	15	56	50
$4\frac{1}{2}$	15	39	27	$1\frac{1}{8}$	68	$22\frac{3}{4}$	$34\frac{1}{8}$	—	—	—	13	39	34
4	12	33	24	1	54	18	27	$1\frac{1}{8}$	$15\frac{1}{8}$	$30\frac{1}{4}$	12	33	29
$3\frac{1}{2}$	9	26	21	$\frac{15}{16}$	48	$15\frac{8}{10}$	$23\frac{7}{10}$	1	12	24	11	28	$24\frac{1}{2}$
$3\frac{1}{4}$	8	22	$19\frac{1}{2}$	$\frac{13}{16}$	35	$11\frac{7}{8}$	$17\frac{8}{10}$	$\frac{15}{16}$	$10\frac{1}{2}$	21	10	23	20
3	7	18	18	$\frac{12}{16}$	30	$10\frac{1}{8}$	$15\frac{1}{8}$	$\frac{13}{16}$	$7\frac{9}{10}$	$15\frac{4}{5}$	9	19	$16\frac{1}{2}$
$2\frac{3}{4}$	$5\frac{1}{2}$	15	$16\frac{1}{2}$	$\frac{11}{16}$	25	$8\frac{1}{2}$	$12\frac{3}{4}$	$\frac{3}{4}$	$6\frac{3}{4}$	$13\frac{1}{2}$	$8\frac{1}{2}$	$16\frac{1}{4}$	14
$2\frac{1}{2}$	$4\frac{1}{2}$	12	15	—	—	—	—	$\frac{11}{16}$	$5\frac{5}{8}$	$11\frac{1}{4}$	$7\frac{1}{2}$	13	$11\frac{1}{2}$
$2\frac{1}{4}$	$3\frac{3}{4}$	9	$13\frac{1}{2}$	$\frac{10}{16}$	21	7	$9\frac{1}{2}$	$\frac{5}{8}$	$4\frac{5}{8}$	$9\frac{1}{4}$	$6\frac{1}{2}$	$11\frac{1}{4}$	10
2	$2\frac{3}{4}$	7	12	—	—	—	—	$\frac{1}{2}$	3	6	$5\frac{3}{4}$	9	8
$1\frac{3}{4}$	2	$5\frac{1}{2}$	$10\frac{1}{2}$	$\frac{9}{16}$	17	$5\frac{1}{2}$	$7\frac{1}{4}$	—	—	—	5	$6\frac{1}{4}$	6
$1\frac{1}{2}$	$1\frac{3}{4}$	4	9	—	—	—	—	—	—	—	4	4	4
$1\frac{1}{4}$	1	$2\frac{1}{2}$	$7\frac{1}{2}$	$\frac{1}{2}$	14	$4\frac{1}{2}$	6	—	—	—	$3\frac{1}{2}$	3	$2\frac{3}{4}$
1	$\frac{3}{4}$	$1\frac{3}{4}$	6	—	—	—	—	—	—	—	$2\frac{3}{4}$	2	$1\frac{3}{4}$

Quantities of Air, calculated at Atmospheric Pressure, required by a Diver working at various depths down to 210 feet = 35 fathoms.

Depth in fathoms.	Feet.	Quantity of air at atmospheric pressure required per minute.	Number of cylinders needed of Siebe, Gorman & Co.'s patent double-acting pumps (hand-worked). *	Revolutions of the pump per minute.
		Cubic feet.		
0	0	1.5	1	15
2¾	16	2.2	1	22
5½	33	3.0	1	30
11	66	4.5	2	22
16½	99	6.0	2	33
22	132	7.5	4	21
27½	165	9.0	4	27
33	198	10.5	6	23
35	210	11.0	6	28

In cases where power-driven, instead of hand-driven pumps are used, the air should be delivered into a steel receiver, and the divers supplied from the latter, the quantity of air delivered to them being regulated according to the levels at which they may be working. It is well to have a non-return valve on the inlet side of the receiver from the air compressor.

* This Pump is of the Two-Cylinder, Double-Acting type, and is the standard pump used throughout the British Navy.

APPROXIMATE AMOUNT OF WORK THAT CAN BE DONE WITH PNEUMATIC TOOLS.

Drilling Mild Steel.—A 1in. hole can be drilled at the rate of 1in. to 1¼in. per minute; smaller and larger sizes in proportion.

Boring Timber.—A pneumatic auger will bore a 1in. hole at the rate of 3in. to 6in. per minute, according to the nature of the material. The following is an example of work actually accomplished with a pneumatic wood-boring auger operated at a depth of 50 feet below the surface, viz. :—

Nature of Work.—Cutting off to six inches above ground level pitch pine sheeting piles, 24in. by 6in. In each of these piles eleven 2in. holes are bored, one diver doing twelve piles in eight hours = 132 holes 2in. diameter by 6in. deep.

Rock Drilling.—See pages 98 to 105.

THE REMOVAL OF SUBMERGED ROCK AND THE DISPERSAL OF WRECKS BY BLASTING.

So much depends upon the varying conditions under which work of this description is conducted that it is impossible to lay down any hard and fast rule for the carrying out of submarine blasting operations; but on receipt of particulars of any rock removal work that may be contemplated, viz., depth of water at high and low tide, nature of the rock to be removed, its situation and approximate depth and area, we shall be pleased to advise as to the best method and appliances to employ.

The following notes as to preparation of explosive charges and general mode of procedure, and particulars of some methods employed, may prove useful.

SOME METHODS EMPLOYED IN BLASTING ROCK.

Of the two systems of power-operated drills—Pneumatic and Steam—the former is undoubtedly the more economical and satisfactory.

COMPRESSED AIR ROCK DRILLS.

Three systems of pneumatic boring are employed in connection with submarine rock removal:—

(1) *Drills operated from a floating vessel or raft, or from a staging.*

(2) *Hand Drills which the divers take under water with them.*

(3) *Tripod Drills, which are heavily weighted and lowered under water, and are controlled by divers.*

HAND-WORKED JUMPER DRILLS.

Where the quantity of work to be done is so small as not to warrant the purchase of pneumatic tools, the old-fashioned *Jumper Drill*, operated by men pulling on ropes carried over sheaves, can be recommended for efficiency and simplicity

In all cases where the boring is conducted from the water surface, the drill rods should be carried through iron piping resting on the sea bed, and reaching up to the craft or staging. This arrangement gives lateral support to the drill rods, and, on completion of the hole, the pipe acts as a conduit for the placing of the explosive charge in the hole. In many cases, however, the charges are placed by divers.

DIAMOND ROCK DRILL.

Excellent work has been accomplished with this type of drill, but its cost makes the use of this appliance almost prohibitive, except in very special cases.

APPROXIMATE AMOUNT OF WORK THAT CAN BE DONE WITH PNEUMATIC ROCK DRILLS.*

HAND DRILLS.

The drilling capacities of various sizes of Hand Rock Drills working on *granite* are as follows:—

DIA. OF HOLE.	DEPTH.	PERIOD
2 inches	45 feet	Per day of 10 hours.
$2\frac{1}{4}$,,	50 ,,	,, ,,
$2\frac{1}{2}$,,	55 ,,	,, ,,
$2\frac{3}{4}$,,	60 ,,	,, ,,
$3\frac{1}{8}$ and upwards	70 ,,	,, ,,

* The above figures represent the amount of dry work at the surface. In the altered conditions of submarine work the quantities would, of course, be less.

Tripod Drills.

With a $3\frac{1}{4}$in. Tripod Drill, a hole $1\frac{1}{2}$in. to $1\frac{3}{4}$in. dia. by 4ft. deep can be bored in hard rock in from 20 to 25 minutes. Much, of course, depends upon the nature of the rock, and also whether it is solid or fissury. In the case of jointy rock, or rocks of uneven hardness, the time might be slightly increased.*

The *most suitable pressure* for pneumatic tools is 90 to 100 lbs. per square inch.

In determining the depth of holes, spacing apart and the size of explosive charge, the engineer will be guided by the peculiar conditions of the case in hand, and the appliances available. But it should always be borne in mind that the disintegrated rock has to be removed; therefore it should be blasted in pieces of such size as to be easily handled by the ordinary dredging appliances. Regard must also be had to the proximity of buildings on shore, dock walls, river banks, etc.; in many cases it is necessary to proceed with great caution, using only small charges of explosives at a time, so as to avoid risk of damage to such constructions and their foundations.

CHOICE OF EXPLOSIVES.

In the choice of explosives the engineer or superintendent in charge of the operations will, of course, use his own discretion.

Nobel's "Dynamite" is largely used, although "Blasting Gelatine," "Tonite," and "Gelignite" have also been employed with considerable success in submarine operations.

"Blasting Gelatine" we have found from experience to be the most powerful explosive agent, but when frozen it is, in our opinion, more dangerous to handle and more difficult to explode thoroughly.

"Tonite," when made up in water-tight cartridges fitted with connections for attaching the insulated wire from battery, is a very good explosive for submarine work, and one great advantage in its favour is that, in the event of a charge misfiring, it can be dredged up with the disintegrated rock without danger of its exploding.

The "Tonite" cartridge cases are fitted at the end with brass glands for securing a water-tight joint, which protects the detonator from damp. These cartridges are made $2\frac{1}{8}$in. outside diameter, and of any length required, and 1 lb. of explosive occupies 7in. in length of the case. For dispersing wrecks, where large charges are used, the explosive is prepared in metal cases with glands, as above, but made in 5 lb. cubes, and the cases are made to contain 1, 2, 3, 4, or 10 of the cubes, as required, thus making 5, 10, 15, 20, and 50 lb. charges, two or more of which can be lashed together if larger ones are needed. A 5 lb. cube measures about $5\frac{1}{2}$in. each way.

Nobel's "Gelignite."—The advantages which are claimed for this explosive are:—

1. It is offered at the same price as Dynamite, and being more powerful it is relatively cheaper.

2. Its plasticity in the bore hole affords a distinct economy over all rigid blasting agents, whilst its explosive energy is greater than Dynamite by fully 12 per cent.

3. It is practically uninjured by damp or submersion in water for a reasonable period—a most valuable property, especially in the case of submarine blasting.

4. It is considered more economical than Dynamite.

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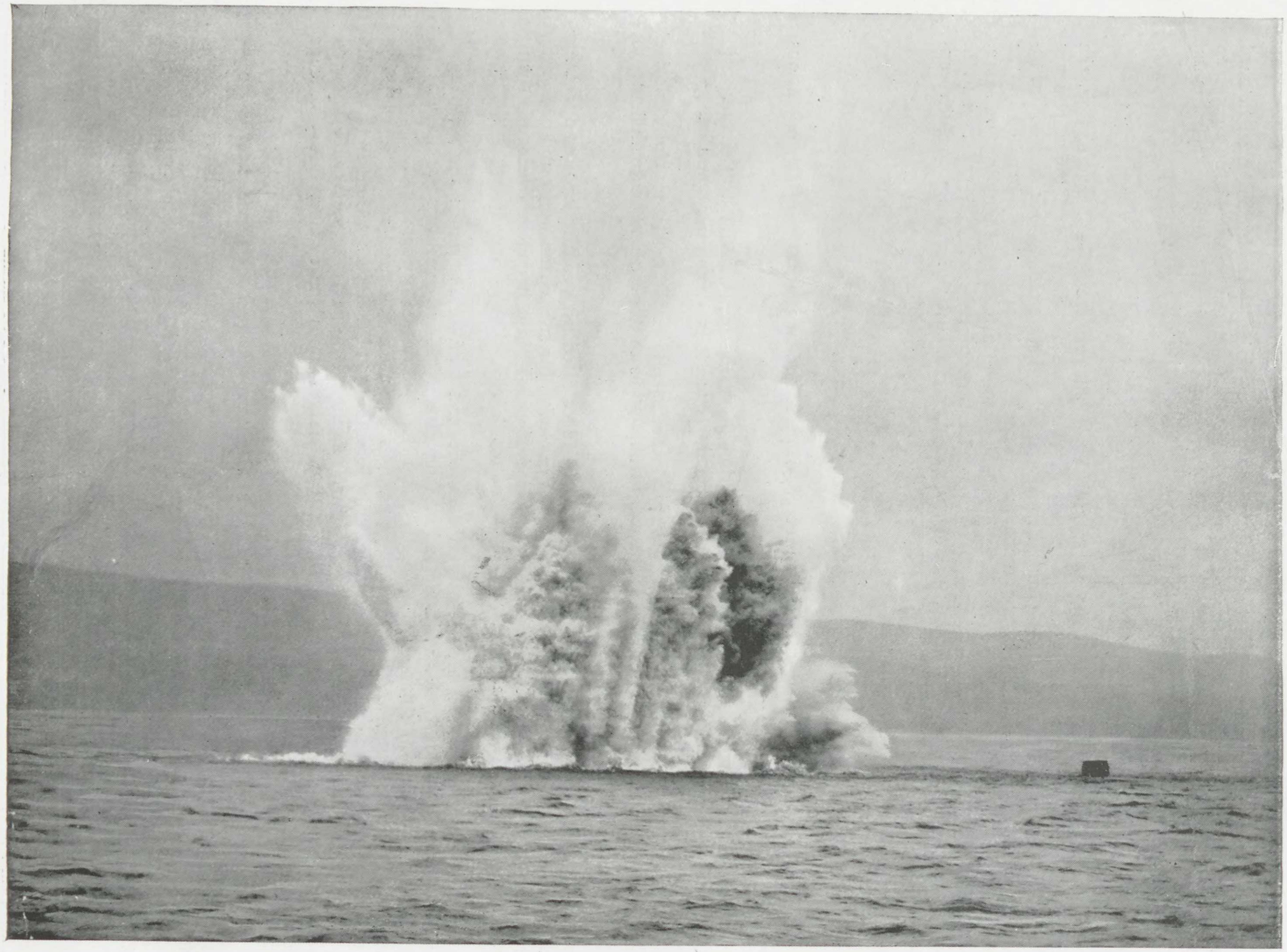
* See foot-note on preceding page.



Copyright, Adamson.

Photo No. 49.

A SUBMARINE ROCK BLAST.

TRIPOD DRILL (PNEUMATIC) WORKED UNDER WATER BY DIVER.

It has been found in some cases that if the rock is of a precipitous nature, the best method is to commence drilling a row of holes parallel to the edge, and at a distance from it equal to the depth of the holes; the holes being driven to about 3ft. below the required level. After blasting out these holes a fresh series are drilled parallel to the former ones, or to the face left by the blasts, and these also blasted out—a third line—and so on, progressing regularly across the rock, continually blasting it off in parallel blocks extending downward a little below the depth required.

The advantage of this mode of operating is that it enables the blasts to act laterally, in which direction they are more powerful, and the rock is left after each series of blasts with a nearly vertical side or face, in which the presence of seams can be detected and the character of the strata observed, so that the most favourable positions for the next blasts to produce the greatest effect can be selected.

Sometimes the craters following the strata run under or leave an overhanging face, in which case a large charge usually has the effect of throwing off the overhanging portion, and often dislodges large masses of rock.

With a rock drill of good construction, it is possible to do as much work in a few hours as would take several days with hand tools. The Diver can easily be taught the use of the drill on land, and when conversant with its working, he will not find the slightest difficulty in carrying out the boring operations under water.

The working vessel (some engineers prefer to work the drill from a raft, or a barge, with a well in the centre, having water-tight compartments) having been moored over the rock, the Diver descends and selects the exact position for the blast, and then signals to have the drill and stand lowered to him. This being done, he fixes the drill in position by means of its adjustable legs, and then signals to commence supplying the drill with compressed air. Sometimes the drill works uninterruptedly till the hole is drilled to the required depth; at other times its working requires the attendance of the Diver, either in replacing drill-heads broken by contact with hard crystals, or in regulating the turn or "hoist" of the drill, or in clearing the holes of cuttings, or "spooning out," as it is termed, and rectifying the direction of the drill by adjusting the legs or guys.

In a rapid current the stoppage of the drill for the purpose of "spooning out" the holes becomes unnecessary, as the motion of the drill works up the powdered cuttings to the mouth of the hole, whence they are sucked out and carried off by the current.

As soon as the hole is drilled to the required depth the drill is stopped, and, after an examination of the hole and clearing away any cuttings remaining in the bottom, the Diver telephones or signals for the charge of explosive (which has previously been carefully prepared with detonators hermetically closed, and with insulated wires extending to, but not yet connected with, the electric battery on deck) to be lowered to him, and he inserts it in the drill hole, carefully pressing it to the bottom with a rod. The tamping,* if any is used, is then inserted above the cartridge (the charges should be of such size as to pass into the bore holes easily—*i.e.*, the diameter of the bore hole should be $\frac{1}{16}$ in. to $\frac{1}{8}$in. larger in diameter than the diameter of the cartridge). The Diver then ascends, and the working vessel is hauled to a safe distance. The wires are then attached to the battery, a few turns given to the handle, and the operator makes the contact, when a shock, followed instantly by a second shock and the upheaval of the water, announces the explosion of the charges.

The working vessel is then brought back to the position as before, and the same operation repeated.

In cases where the rock is naturally "fissured," it is not necessary to bore holes, as the crevices or fissures themselves form very good receptacles for the placing of the explosive charges. As a rule, under these circumstances it is difficult to apply tamping in such a way that the full efficiency is obtained from the explosive. In such a case a waterproof bag filled with dynamite would be the best form of charge to use, as it would shape itself to the inequalities of the rock.

* If a tamping rod be used, it is important that it be cylindrical throughout—not pointed at the end.

AN EXAMPLE OF ROCK DRILLING BY DIAMOND DRILLS WORKED BY STEAM ENGINES.

We quote an extract from a paper read at the Institute of Naval Architects, describing the removal of the rock in deepening the River Clyde and the means adopted, viz. :—

"Any history of the improvement of the river would be incomplete if reference were not made to the removal of Elderslie Rock, a huge vein of trap which extends across the river a short distance above Renfrew. In the early reports on the condition of the Clyde no mention is made of this rock, but the Blawarthill Sand, one of the many shallow fords on the river, was situated where the rock was subsequently found, and in 1755 there was a depth on this sand of only 18in. at low water, and 4ft. 9in. at high water.

"It was not till 1854 that the existence of the rock was discovered by the grounding on it of the *Glasgow*, one of the first steamers trading between Glasgow and New York, which, while passing up the river, knocked a hole in her bottom on the rock. It was at first thought it might be a large boulder that had done the damage, but borings showed that it was rock, that it extended over an area of the bed of the river 925ft. in length by about 320ft. in breadth, and that it was a hard whinstone or trap dyke. From the time of its discovery till the beginning of 1869 boring from a movable stage and by diving bell and blasting with gunpowder, had given a minimum depth at low-water springs of 14ft. for half the width of channel, and a minimum depth of 8ft. to the other half, the total width of the river there from bank to bank being only 410ft., at an expenditure of upwards of £16,000; but it was not until 1880 that the removal of the rock, so as to give a uniform depth of 20ft. at low-water springs over every portion of the channel, was commenced with diamond drills.

"The boring was done in longitudinal belts, in sections of five rows of holes transversely, by 40ft. long; the holes were transversely 5ft. apart centres, and so that the holes longitudinally would be opposite one another in each alternate row. Eight holes longitudinally were bored simultaneously, then charged and blasted, and the other four rows dealt with in the same way. When all the five rows in the section had been bored, charged and blasted, the boring barge was shifted up-stream and commenced operations on the next 40ft. long section, and an ordinary but powerful single-ladder small bucket dredger following, lifted the broken rock and left an open space for the next belt of holes.

"It was early found that where the depth of hole was more than 10ft., the rock was not sufficiently disintegrated to enable the dredger to clear it freely away to the bottom of the holes, and the deeper portions of the rock were therefore taken in two depths or breaks, the first depth being bored to 17ft. at low water, blasted and dredged.

"The longitudinal belts of holes were continued from the south side, outwards, into the middle of the river until the whole ground in the southern half was cleared away to 20ft. at low water, the whole up and down traffic being meantime confined to the north half of the river. The whole traffic was then diverted from the north into the new south channel, which was marked by three of Pintsch's compressed gas-lit buoys, capable of burning for three months continuously. The operations were then continued northwards until the whole depth of the river bed was cleared to 20ft. depth.

"The explosives used were Nobel's Dynamite and Blasting Gelatine, Tonite and Potentite. Dynamite was found most satisfactory; Blasting Gelatine proved the most powerfu explosive, but when frozen was more dangerous to handle and more difficult to explode thoroughly. Tonite and Potentite were found to be somewhat less powerful than Dynamite.

"Two horizontal engines on the deck of the boring barge, supplied with steam from two boilers, drove the eight drills by a main shaft which extended the whole length of the barge.

"The diamond boring tool was a steel annular ring 2¼in. in diameter and ½in. thick, studded with diamonds overlapping one another. This annular ring, or crown, was screwed on to the bottom of the boring rod, which, in suitable lengths, was carried inside an iron guide-tube, extending down to the bottom of the river bed. The rod was connected at the top to a drill bar suspended from an iron diagonal framework on the barge. Rotary motion was given to the drills by means of phosphor-bronze bevel wheels, working in a frame and driven from the main shaft on deck by an ingenious arrangement of ropes and loose pulleys, which allowed for any lateral or vertical movement of the drill through rough weather, the rise and fall of the tide, and the ranging of the barge through the suction of passing steamers. The drill-bar was driven at the rate of 400 revolutions per minute, and during the whole time that the boring was proceeding, water, at a pressure of 40lbs. per square inch, was forced down through the hollow boring rod to wash out the detritus and keep the face of the diamond crown cool. The pressure of the drill was applied by means of counter-balance weights, varied according to the hardness of the rock being bored. In the hard blue whinstone the boring of the holes of 2¼in. diameter proceeded at the rate of 2ft. per hour, and 5ft. per hour in softer stone. When the necessary depth of hole was bored the drill rods were withdrawn, and the dynamite charges were fitted with detonators and fixed in the holes. Attached to each charge were electric cables, which were led up to the surface of the water. All the charges were then connected, and the shot-hole wires were attached to a main cable, which was carried to the positive and negative poles of an electric exploder. The barge was then withdrawn about 60ft. from the place of the explosion, and the row of eight holes was fired simultaneously, resulting in the displacement of something like 100 tons of rock; the only disturbance was a slight upheaval of water. The greatest amount lifted by the dredger in one day was 280 tons. A diving bell afterwards went over the ground, and removed any large stones that had been left by the dredger.

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PREPARING THE EXPLOSIVE.

Most Nitro-Glycerine compounds are, when the temperature is below even 45 deg. Fahr., liable to congeal or become hard from the effect of cold. In this condition they should not be used until they have been carefully softened or thawed in a warming pan specially constructed for the purpose. It is in the highest degree *dangerous* to attempt to soften or thaw explosives by placing them on or near a fire, or in a can heated by a candle or lamp, and many lives have been lost through this criminally reckless practice.

PREPARING THE BOREHOLE.

Borehole.—After the Borehole is carefully drilled—and for economical reasons it should be as nearly circular as possible—it is cleaned out so that no *débris* remains.

CHARGING.

Cartridges (*i.e.,* Dynamite or other Explosive in watertight cases).—The Cartridge or Cartridges should be of such a size as to pass in easily—that is, the diameter of the borehole should be $\frac{1}{16}$in. to $\frac{1}{8}$in. larger than the diameter of the cartridges, and they should be inserted singly in the borehole. Cartridges ordered of, say, 1in. diameter are made somewhat smaller so as to suit boreholes of that diameter.

Fixing Fuse.—When the last Cartridge (or Primer Cartridge) comes to be inserted, a hole should be made in it by means of a small pointed wooden stick, and the Detonator (attached to the fuse wires) should be pressed lightly therein until it is *completely* buried in the cartridge, the operator then tying the cartridge tightly over the wires with a piece of twine, to prevent the withdrawal of the Detonator from the explosive. The Primer Cartridge is then gently pressed into the borehole by the wooden tamping rod, and brought into contact with the main charge.

It has been claimed that in many instances there is a distinct advantage in inserting the Primer Cartridge (*i.e.*, the cartridge into which the Detonator is inserted) in the borehole with the Detonator downwards. This will also prevent the Detonator being withdrawn by any chance during the operation of tamping. But when such procedure is adopted, special care should be taken not to injure the wires during the process of tamping.

Tamping.—A lump of clay should be pressed in after the last cartridge, next a cushion of paper to withstand the tamping, and then the usual tamping material should be rammed in without using rough force; care should be taken that a *wooden* Tamping Rod (not worn to a point, but cylindrical throughout) alone is used. The topmost 3in. or 4in. of the hole need not be tamped, but should be filled with tempered clay lightly squeezed in. Ordinary clay is apt to become soft and is liable to disintegrate under water when being applied as a tamping. It has been found that a mixture of dried clay and oil of the consistency of putty forms an excellent medium for the purpose. In submarine blasting, where so much depends upon the efficiency of each shot, the extra trouble of preparing such a tamping is amply repaid.

Connecting the Cable.—The ends of the Fuse wires and Cable wires should be stripped for a length of about 2in., and made perfectly bright and clean. They should then be carefully joined together by twisting the bare end of the Fuse wire tightly round the bare end of the Cable wire (this precaution will tend to prolong the life of the Cable). To ensure perfect insulation of the wire connections of importance, especially in simultaneous or circuit shot-firing, the use of Chatterton's Compound and of Prepared Rubber Taping is recommended.

TWIST EXPLODER.

High and Low Tension.—This Exploder has been specially designed as a Machine capable of firing both High and Low-Tension Fuses. It is provided with a cover, which protects the firing handle and the connecting screws, and also with a strong shoulder strap for convenience in carrying.

NOTE.—Care must be taken that the hands do not touch the terminals during shot-firing.

Disconnecting the Cable.—Immediately after a shot has been fired, the shot-firer should disconnect the Cable from the Exploder. This instruction should be followed even when, by defective manipulation, a miss-fire has occurred.

Missed Shot.—On no consideration attempt to withdraw the tamping, but the "tempered clay lightly squeezed in," as described under "Tamping," may be removed, and in its place may be put a Cartridge having a fresh Electric Detonator Fuse inserted therein. Then cover up with a lump of clay, and fire. In nine cases out of ten the missed shot will explode. If a fresh hole has to be bored, it should always be parallel to the old one, and in no case nearer to it than 6in.

A missed shot in electric blasting may occur from one of the following causes, namely:—

(1) Defective Exploder. (2) Faulty or imperfect connections, due possibly to the wires twisted together being coated with dirt instead of being bright and clean. (3) Short circuiting caused by compression of the insulation of the electric fuse wires due to damage in tamping. (4) Short circuiting by injury to the insulation of cable, or by a break in the wires.

In order to determine where the defect exists, the Exploder should be immediately disconnected and its effectiveness tested, then the cable should be tested by means of a Galvanometer.

SIMULTANEOUS ELECTRIC BLASTING.

Method of Procedure.—Use Low-Tension Fuses, and connect the wires in series, as shown in the illustrations on page 108. If the holes are far apart a connecting wire may be used for joining the fuse wires together. The connecting wire should be of the same class and same diameter as the fuse wires. Special care should be taken that the wires at all joints have the ends clean and bright and free from dirt or grease; they should, if necessary, be scraped with a knife. The ends of the wires where connections are formed should be covered with Chatterton's Compound or prepared Rubber Taping as a precaution.

If high-tension fuses are used in simultaneous blasting, they should be joined *in parallel,* as shown in the illustrations on page 108.

Galvanometer Test.—When several holes are charged and the low-tension fuses are connected, and have the main cables attached, the machine ends of the cables should be connected with the Galvanometer in order to ascertain that there is no break in the circuit. If the needle of the Galvanometer deflects (or when the Bell-Galvanometer is used, if the bell rings) it shows that there is no break in the circuit, and that the group may be fired simultaneously with certainty. It is obvious that this test should be made by the shot-firer from the position he will occupy when actually firing the charge. All others should remove to a place of safety.

CAUTIONS.

Electric Fuses, especially High-Tension Fuses, which must be chemically perfect, should be stored in a dry place.

Care should be taken not to "kink" or twist the fuse wires in handling or fixing so as to cut the insulation. If the insulation is cut the fuse is useless, and should be set aside.

Care should be taken, under all circumstances, not to cut the insulation of the fuse wire during the process of tamping.

Exploders.—Store carefully, when not in use, in as cool and dry a place as possible. Make the shot-firer responsible for the care of the Exploder, and allow him alone to handle it. Exploders, if taken care of, will last a long time in good condition.

Be careful to use with High-Tension Fuses a High-Tension Exploder, and connect *in parallel*; and with Low-Tension Fuses a Low-Tension Exploder, and connect *in series.* The only Exploder supplied as being suitable for *either* High or Low Tension is the *Twist Exploder.*

NOTE.—There is no economy in purchasing cheap Exploders or cheap Cables.

DISPERSING OR BLOWING UP WRECKS.

Having ascertained whether the wrecked ship is of wood or iron, a plan of the vessel and its dimensions should be procured, and also a statement of the depth of water in which it lies, and of the nature of the bottom on which it rests (whether rock, sand, gravel or mud); in fact, all information available should be obtained as to the wreck, its surroundings and its contents.

Wooden Vessels.—A wooden ship can easily be blown to pieces by a concentrated charge of two or three hundred pounds of Blasting Gelatine or other gelatinous compound, or No. 1 Dynamite, the quantity required depending upon the size and strength of the wrecked vessel. If dynamite (which in most instances will prove the most effective compound) is used, the charge should be made up in india-rubber cloth bags, containing five to ten pounds each. These should be tightly packed into a strong bag made of sailcloth to protect the waterproof bags from being torn by rough handling on the wreck. One of the india-rubber cloth bags loaded with dynamite should contain the Electric-Detonator Low-Tension Fuse, with electric cable attached for firing the charge. The detonator should be placed in the centre of the explosive, and, to prevent the charge from floating or moving about after it is placed in position on the wreck, it should be, before being lowered, weighted with fragments of old iron chain or other scrap-iron securely tied on the outside. The charge should be carried by the diver through the main hatchway, and placed as far as possible into the hold. The main electric cables should be about 400ft. in length, to allow the operator to get a sufficient and safe distance away when firing the charge. The charge should be lowered to the diver by a rope, and care must be taken that no strain is placed on the electric cable. WHEN ALL IS IN ORDER AND READY FOR FIRING, THE DIVER'S BOAT AND ALL CONCERNED IN CARRYING OUT THE OPERATION SHOULD MOVE OFF TO A SAFE DISTANCE, SAY TWO OR THREE HUNDRED FEET, AND CARE SHOULD BE TAKEN TO WARN OFF ALL BOATS FROM THE VICINITY OF THE WRECK. The charge should then be fired by a Twist Exploder, these machines being most suitable on account of portability and certainty of exploding the charge. If Blasting Gelatine, or any of the gelatinous explosives be used, it should be made up into a charge in precisely the same way as described above, except that the priming charge containing the Electric Detonator Fuse should consist of about two or three pounds of dynamite in the middle of the ten-pound waterproof bag of Blasting Gelatine (or other gelatinous compound, as the case may be). This will ensure a complete detonation of the whole charge with greater certainty than if the primer consisted of a gelatinous explosive only. The priming charge must be placed as near the centre or middle of the main charge as possible. On explosion of the charge, the hydraulic pressure set up inside the wreck will burst it open in all directions. Should any portions of the wreck remain too large to be conveniently handled, they can easily be broken up by a few light charges of explosive of five to ten pounds each.

Iron Vessels.—Iron wrecks cannot be broken up in so simple a manner as wooden ones can. Concentrated charges are practically of little use, except in breaking out the stern frame and the bows, as such charges only act locally in blowing holes through the wreck in the immediate vicinity. The best plan for this work is to use long charges of dynamite made up in sailcloth canvas hose or tubing. For the heavy shots, canvas hose $3\frac{1}{2}$in. diameter has been found most suitable, and for breaking through the lighter parts of the wreck, hose 2in. diameter is most suitable. The sailcloth canvas to be used for making the hose should be spread out on dry, clean ground or on a floor, and made waterproof by painting it on both sides to saturation with thin india-rubber solution. When dried, it should be dusted over with wood ashes, or some other suitable material, to prevent it sticking together when rolled up. It should then be cut up into suitable lengths and dimensions for making the various-sized tubes, say 9ft., 15ft. and 22ft. lengths. In sewing these lengths into tube form, after the first 3 or 4in. are sewn, the cartridges must be forced in by hand quite closely in order to completely and tightly fill the tube, and as the sewing proceeds, every 3 or 4in. of the tube must be tightly packed with cartridges, and so on until it is finished, so that when the canvas tube is completed, and the ends sewn up, it must present a solid cable or rope-like appearance, with no slack places in it. A ready-made canvas tube cannot be packed with cartridges so solid as when the cartridges are packed in whilst the tube is sewn up and made as above indicated, and it is necessary that the canvas tube be made up and charged as described, so that the cartridges shall lie together solidly and compactly, with no air space between them. To insure perfect detonation throughout these long lengths of hose charges, if the explosive used is Blasting Gelatine (or other gelatinous explosive of a like nature), the centre cartridge or core should consist of dynamite throughout the whole length, so as to form a detonating core, and thus insure complete detonation.

In commencing operations on a wreck, the diver should go down and explore the upper deck as far as practicable, and report what length of the deck is fairly clear for laying charges upon. This is then noted on the plan of the wreck in the possession of the operator. If the diver reports that he can get a charge of 50ft. or 60ft. in length placed on the deck alongside the bulwarks on one or both sides of the deck, this long length of charge is made up of various pieces of canvas tube containing explosive, joined together by overlapping joints—that is, the ends overlap 6in., and are tied firmly together by strong string so that they cannot break apart. The full length of canvas tube is then weighted at intervals of 1ft. to 2ft. apart, with pieces of 6in. to a foot of old iron chain (say ½in. or ¾in. chain), and with fragments of old iron, such as bolts, nuts, etc., to keep the charge in position and in close contact with the wreck. The chain and iron fragments should be tied on firmly and tidily with strong string, so that nothing is left to chance. The end of the canvas tube, in which the Electric Detonator Fuse is fixed, should have a piece of strong marline tied around it with 5ft. or 6ft. of loose ends free to enable the diver to tie the charge firmly to some convenient part of the wreck to prevent the charge being shifted by any strain from the Electric Cable. A charge 60ft. to 70ft. long, containing 120 lb. or more of Dynamite, is readily disposable in the way described.

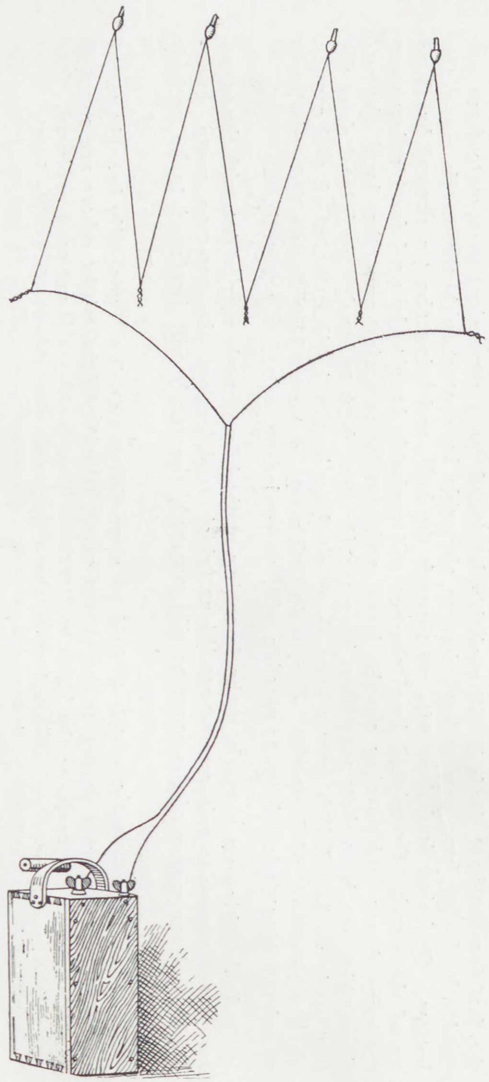
The explosion of a suitable charge, prepared as above and properly placed, will cut through the deck and break off all the beams and stays through the whole length of the charge, besides bulging out the side of the vessel, and breaking and releasing all woodwork in the vicinity. After each shot the diver must descend and explore the wreck for other clear spaces for laying down fresh charges, the main object being to get the charges placed along the sides on the deck close to the bulwarks, so as to break off the iron beams and stays supporting the deck, and to bulge out the sides. When very powerful beams require to be broken, it may be necessary to employ extra quantities of explosive. At intervals of, say, 30ft. or 40ft. apart, or wherever practicable, a canvas tube charge of 10ft. or 12ft. in length should be hung over the side and fired, which will cut a gash through the hull plates. The wreck will then be found to bulge out and flatten down considerably.

In the event of its being impracticable for the diver to get about in the wreck after the first few shots are fired, it will probably be found more convenient to operate from the outside by laying long canvas hose charges alongside in contact with the wreck along the bottom. On being fired these will cut through the hull, and bring about a general breaking up of the wreck. Occasional local charges will probably have to be used for blowing away the stern frame and opening out the bows, and also for removing any other local obstructions which the long shots may have been too far away from to break. Such local shots are best made up in sailcloth canvas bags about 3ft. long by 7in. in diameter, which will contain about fifty pounds of Dynamite. For cutting off masts, a canvas hose charge tied completely round the mast as low down as possible will, on exploding, completely sever it.

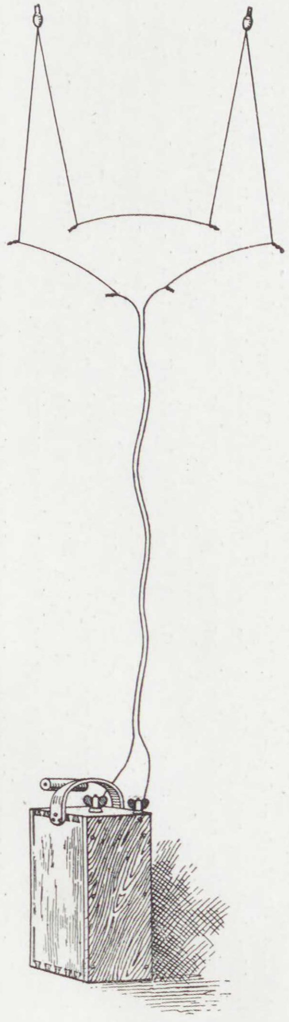
In breaking up a wreck, if the foregoing method be properly carried out, with the necessary modifications to suit varying conditions (which modifications the common sense, knowledge, and experience of the operator will suggest), the result will be found to be entirely satisfactory.

NOTE.—When the first shot is fired on a wreck, many fish are generally brought to the surface, those that were nearest to the charge being killed outright, whilst others are stunned, and struggle on the surface; the latter will recover from the shock if not soon captured. The fish in the locality soon get educated up to shot-firing, and give the wreck a wide berth.

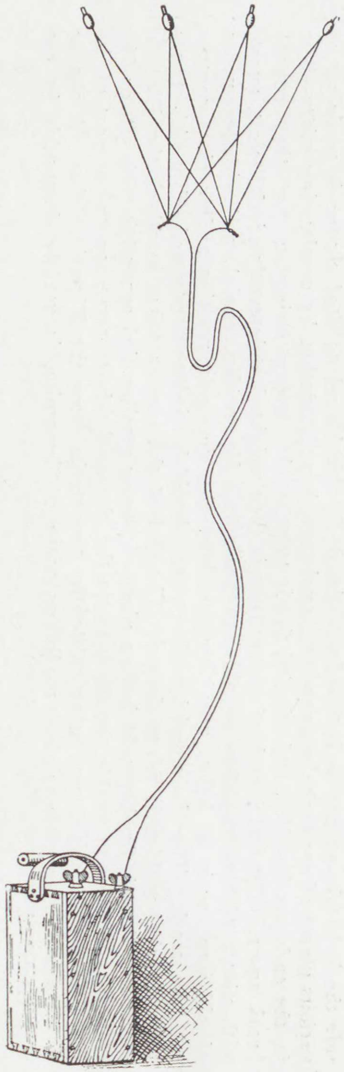
Methods of Connecting Electric Detonator Fuses in Series and in Parallel, for Submarine Blasting of Wrecks, Rock, &c.



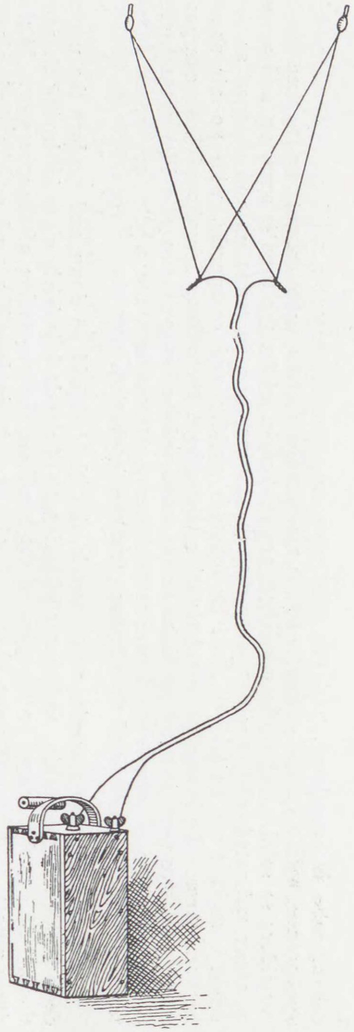
Method of Attaching Four Low-Tension Electric Detonator Fuses in Series.



Method of Attaching Two Low-Tension Electric Detonator Fuses in Series.



Method of Attaching Four High-Tension Electric Detonator Fuses in Direct Contact or in Parallel.



Method of Attaching Two High-Tension Electric Detonator Fuses in Direct Contact or in Parallel.

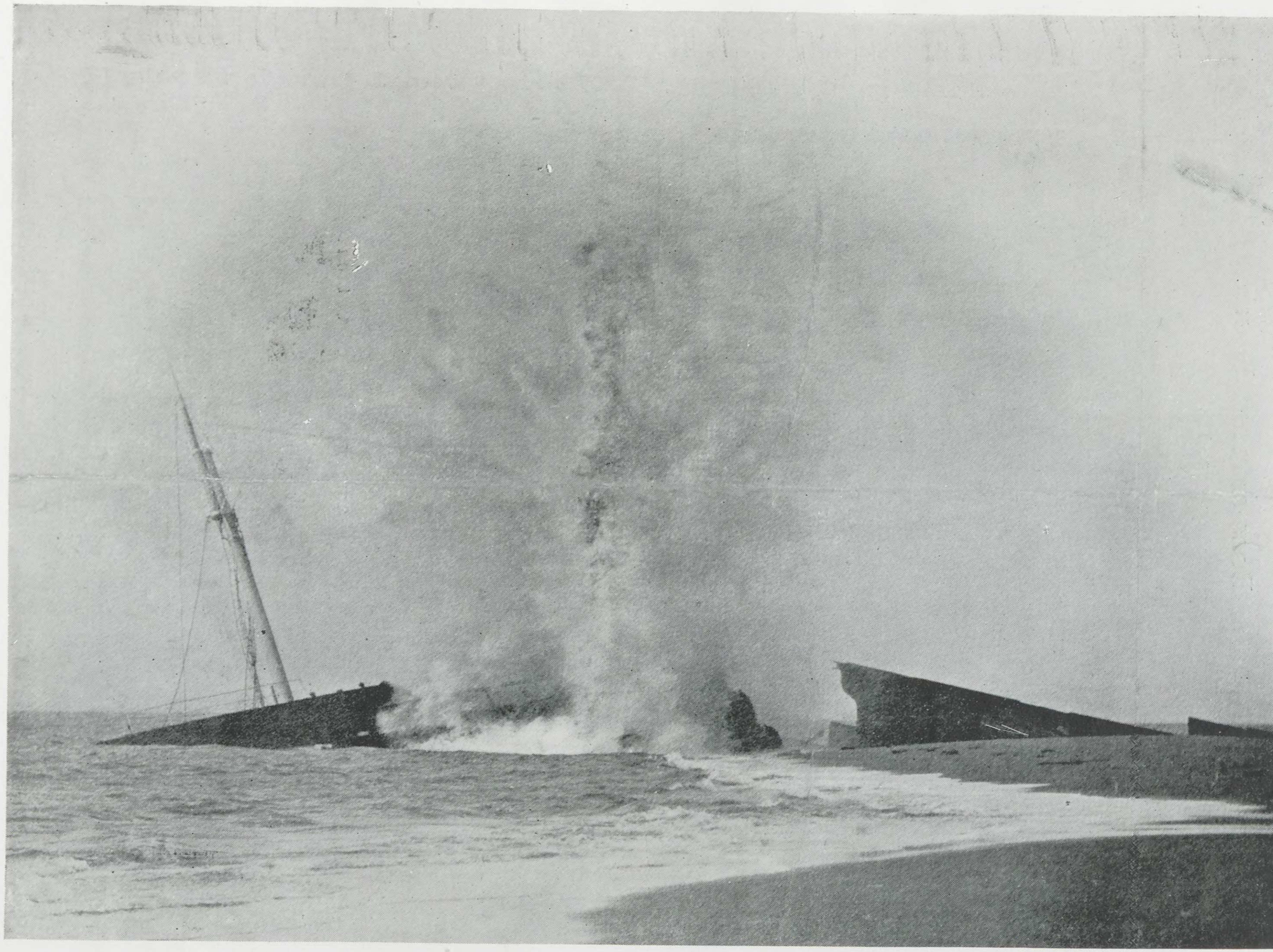


Photo No. 50.

BLOWING UP THE S.S. "EGRET"

BY THE TRINITY CORPORATION. (*"TONITE" USED.*)

ROCK REMOVAL WITHOUT EXPLOSIVES.

Submarine Rock-cutting Plant.

(Illustrated on page 111.)

Another method of rock removal which has been very successfully employed, and in which the use of explosives is not required is the Lobnitz system, which is worked from a barge or other vessel. The expense of plant of this description would, however, only be justified in cases where large quantities of rock had to be dealt with.

Description of the Cutter.

Briefly, the plant consists of a forged steel circular bar called the "cutter," which is fitted with a removable point similar in form to that of a large projectile and made of armour-piercing steel. In certain cases, however, a chisel-shaped point has been found more suitable for driving into very tough rock; in other instances a point with a series of tooth edges has been used, as in the Irrawaddy River operations where the current made it difficult to ensure that the blows would be struck on the same spot every time. In every case these points are separate so that they can be replaced without necessitating the renewal of the whole bar.

The bars themselves are tapered according to the stresses due to the drop, their weight per metre of length being one ton. The composition of the steel for the points varies according to the material to be pulverised; for instance, what would answer for granite would not give such satisfactory results in limestone. The plant is built in sizes having rock-cutters weighing from six tons upwards.

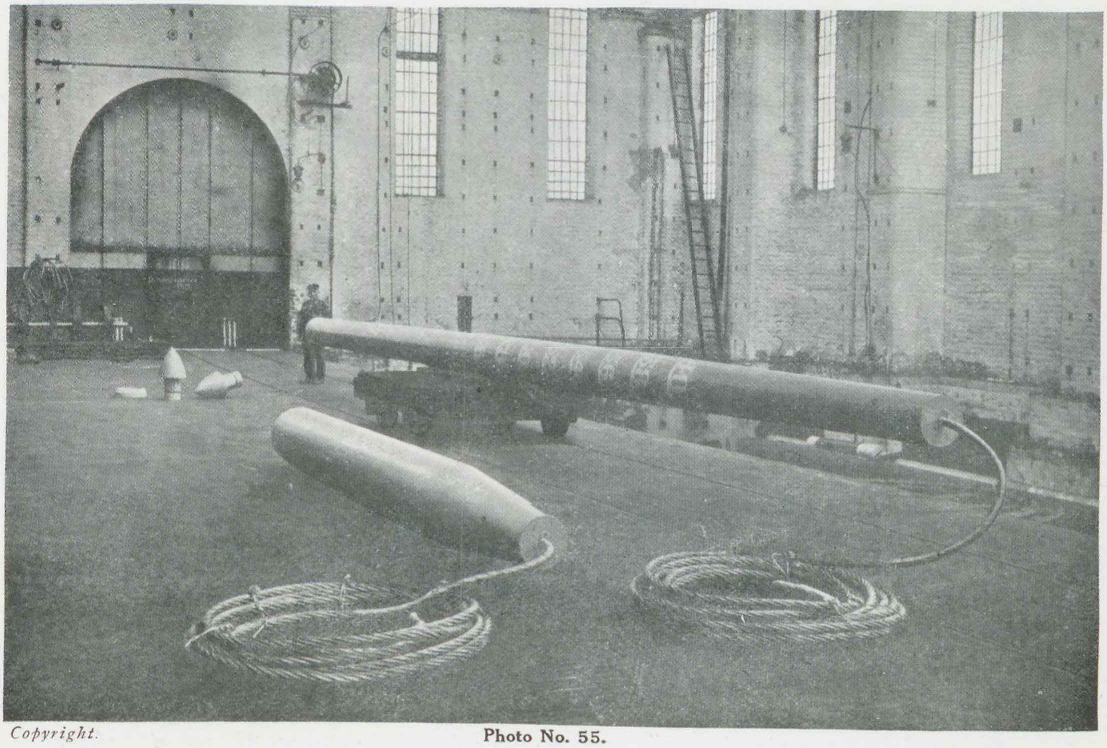
Working Principle.

The principle of working this rock-cutter is that it is hoisted by a powerful steam winch and then released, and the cutter allowed to fall freely by its own weight on to the rock, the whole force of the blow being concentrated on a very small surface as many times as may be necessary to effect the required disintegration.

Special devices are employed to ensure that successive blows are struck on the right spot, and for quick hoisting and release. The barges from which the cutters are worked can be built self-propelling if required. The cutters are worked from the middle of the barge, or they can be supplied to work from one end to suit the exigencies of the work. When asking for estimates for this plant, the following particulars should be sent, viz. :—

(1) Approximate quantity of rock to be excavated.

(2) Nature of the rock (a small sample piece will assist in determining the most suitable cutter).



Copyright.

Photo No. 55.

Rock Cutters, showing Points removed from the Bars.

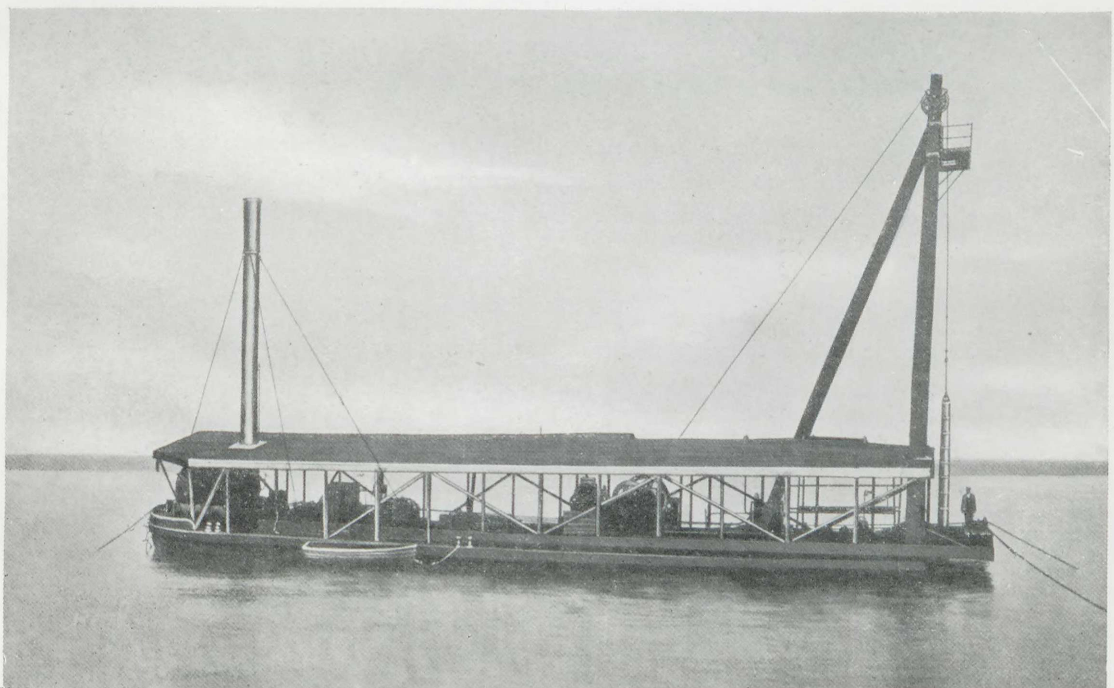


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Photo No. 56.

Barge fitted with Rock Cutting Plant complete.

(3) Depth of water at high and low tide.

(4) Finished depth at high water required to be made.

(5) A chart shewing the situation and formation of the rock, etc.

Cost per cubic yard.

The expense per cubic yard of average rock broken ready for convenient dredging may be estimated correctly for usual local conditions by the following rule, viz.:—

A *Single Cutter* machine will break up per day of ten hours in average rock *one hundred cubic yards* for:—

(*a*) One ton of coal for one cutter; one and a half tons for two cutters, per day of ten working hours.

(*b*) The wages of four men on a one-cutter plant; six men on a two-cutter plant. Skilled labour is not required.

(*c*) The cost of oil, stores, and repairs does not exceed the outlay for coal and wages.

Results.

The Average Result from many works in hard rock is *two cubic feet* of rock broken *per blow—i.e.*, broken to the most suitable size for dredging with a bucket-dredger, which is more efficient than the grab-dredger, because the jaws of the latter do not close readily owing to the frictional resistance of the stones. In most works 150 blows per hour are delivered on an average. This is equal to, say, ten cubic yards per working hour for a single-cutter machine. *The output of a double-cutter plant is about one-half more than that of a single-cutter machine.*

Feed Water for the Boiler. The consumption of *fresh water* is about five times the weight of the coal used. *Sea water* may be used provided there is a fireman on board the vessel who understands the working of a marine boiler with *salt water*.

An Example of work done.

The following is an example of work accomplished by a single-cutter plant in connection with the deepening of the Manchester Ship Canal from 26ft. to 28ft.

Average quantity (over a period of ten months) of rock broken up per month	6,403 cubic yards.
Average cost of breaking	8.94d. per cubic yard.
Minimum quantity of rock broken per month	5,622 cubic yards.
Maximum quantity of rock broken per month	10,180 cubic yards.

The cutter has worked on double shift regularly, and the average cost of working in this manner has been £240 per month, made up as follows :—

	£
Wages	108
Coals and stores	27
Repairs and renewals, including new ropes and repairs to needle	105
	£240

Rate of advance per day.

The rate of advance of the rock-cutter averages 36ft. per diem, the bottom width of the canal being 120ft. Nature of rock : Sandstone of varying degrees of hardness.

Relative merits of light and heavy cutters.

It is found more efficient to have a heavy cutter falling through a short distance than a light cutter dropped from a greater height. For instance a 5-ton cutter, given a 20-feet drop, would give a striking energy of 100 foot-tons. A 10-ton cutter dropped from a height of 10 feet, although not increasing the energy, would prove much more effective in rock-cutting. In the former case the action would be the making of fissures and the breaking of the material into large cubes, whereas in the latter the effect would be to pulverise the material ready for dredging.

The weight of the cutter varies with the hardness of the materials. The 15-ton cutter with a 10-feet drop has been found satisfactory in breaking up granite. On moderately hard rock in shallow water, a 6-ton cutter gives fair results.

Pitch of holes for the blows.

The pitch of the holes for the blows is usually 3 to 4 feet in the case of sandstone, but in extremely hard rock it is as close as 2 feet 6 inches.

Cost of Plant.

The approximate cost of a single rock-cutter plant, with barge complete, for a depth of 50 feet, would be from £5,000 to £6,000, the actual price depending on the conditions, which vary with the locality.

Double and treble cutter plants are more expensive in proportion, and are not so often used as the single-cutter machine.

SUBMARINE MINES FOR HARBOUR DEFENCE, &c.

Submarine Mines are used both in defensive and offensive submarine warfare.

The Science of Submarine Warfare.

The science of defensive submarine warfare, as applied to the defence of harbours, consists of the arrangement of stationary mines moored in such positions and so interspaced as to practically prevent the possibility of a hostile vessel forcing a passage into a harbour without striking or coming within the destructive area of one or more of the mines.

The Explosive used.

Guncotton is the explosive now almost universally employed for submarine mining work. The great safety with which it can be stored and manipulated in the wet state, and the important fact that it can be and is employed in the wet state as an explosive, together with its insensitivity to sympathetic explosion when neighbouring mines are fired, constitute its chief merits. By the new process of compression, blocks of guncotton can be produced mechanically true, and of a size and weight practically unlimited, at the same time a perfectly uniform density is ensured throughout the block, with exact regulation and uniform distribution of the percentage of moisture. These points are of the highest importance in this description of charge, and for this reason, guncotton, as before stated, is almost exclusively employed.

Method of Exploding Mines.

The mines are exploded by the detonation of fulminate of mercury in conjunction with small priming charges of dry guncotton, the fuses containing the fulminate being usually fired by electricity either from the shore or from a battery in the mine itself.

Descriptions of Mines.

The mines cases are usually made of mild steel in a spherical or cylindrical form; these shapes (especially the spherical) having been found by experiment to be the most capable of withstanding external pressure, and to offer the least resistance to tidal currents; they are, therefore, the least liable to be affected by countermining, *i.e.*, destruction through the explosion of neighbouring charges, or to be dragged from their moorings. The cases are made as a rule of mild steel in various sizes for different charges, and the following are a few of the latest and most approved forms:—

The spherical case shown in Fig. 1 is used as a small buoyant mine, containing a charge of 50 lbs. of guncotton, against boats or other small craft, or it may be employed as a ground mine, for which purpose it is provided with a cement lining and made to contain a 250 lbs. charge. It is also used as a case to contain the circuit closing arrangement over a ground or buoyant mine, which is required to fire on contact, but where the charge is placed at too great a depth for a passing vessel to strike the mine itself.

The spherical case shown in Fig. 2 is made to contain a 100 lbs. charge as a buoyant mine or with a cement lining a charge of 500 lbs. as a ground mine.

This form of mine is very suitable for the defence of a harbour. With the 500 lbs. charge it can be moored at the bottom in the centre of the defence, forming a fairway for the passage of friendly traffic in times of peace, and arranged to fire by observation from the shore; with the 100 lbs. charge it can be moored as a buoyant mine on the sides of such fairway or channel, and arranged to fire either on contact with a ship or by observation from shore.

Where the depth of water is too great to admit of the mine being moored at the bottom, similar cases of larger diameter, and containing 500 lbs. of guncotton, are used as buoyant mines, as shown in Fig. 4.

Illustrations reproduced by courtesy of Messrs. SIEMENS BROS. & Co., Ltd.

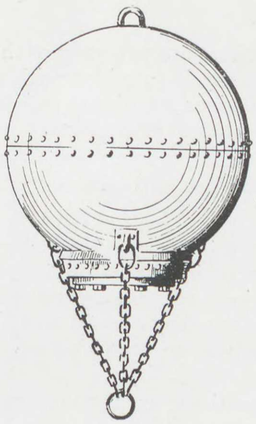

FIG. 1.

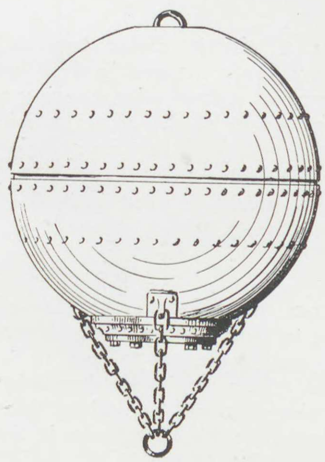

FIG. 2.

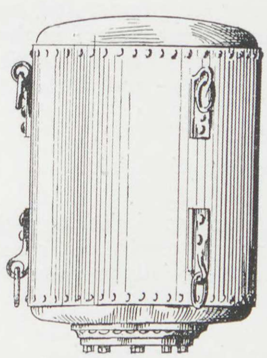

FIG. 3.

FIG. 4.

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Reproduced by courtesy of Messrs. Siemens Bros., Ltd.

In Fig. 3 is shown a cylindrical case for a ground mine. There are two sizes of this mine in general use, *i.e.*, 500 lbs. and 250 lbs. The inside of each case is provided with a lining of cement, which forms a charge chamber for the guncotton, and gives additional weight, tending to prevent the mine from rolling about after having been placed in position.

Cylindrical mines are also used as buoyant mines, chiefly for offensive purposes, and contain charges of either 76 lbs. or 500 lbs.

The 76 lbs. mine may be used either as an electro-contact mine to fire from shore, or as an electro-mechanical mine to be fired from a battery contained in the mine itself. This latter system is, however, objectionable, inasmuch that the mines are dangerous to prepare and lay out, and when laid are dangerous alike to friend and foe; they should never be used except, perhaps, as offensive mines for such purposes as blockading an enemy's port.

The 500 lbs. mine is intended for use in offensive operations as a countermine, but may also be used as an observation mine to fire from the shore.

The following is a brief description of the method of mooring the foregoing mines under the various conditions in which they are likely to be employed.

Method of Mooring Mines.

Fig. 4 shows a 500 lbs. buoyant mine moored under a circuit closer case. This method of mooring is resorted to when it is required to place large charges in deep water. The mine is moored to a cast-iron sinker, or anchor, by means of a steel wire mooring rope, and the circuit closer case is secured to the upper attachment chain of the mine sufficiently near the surface to be struck by a passing vessel.

In moderate depths a smaller case, with a cement lining, would be used instead of the buoyant case; the mine would be at the bottom, as seen in Fig. 5, which shows a ground mine moored under a circuit closer case.

If it be desired to defend a fairway through a defence with buoyant contact mines, these should be moored "Dormant," *i.e.*, kept moored close to their sinkers at the bottom in order to avoid injury by friendly traffic in time of peace, and arranged to rise to within striking distance of the surface when an attack is expected. Such a mine is shown in Fig. 6. The device for holding the mine down consists of a gripping box and exploding link containing a small explosive charge. The circuit is so arranged that this charge can be fired at will from the shore, thus breaking the link and allowing the mine to rise to the full extent of its mooring rope, the length of which has been previously adjusted to ensure the mine floating at the required depth.

Fig. 7 shows a cylindrical mine moored as a buoyant mine, and arranged to fire on contact with a hostile ship. This class of mine is usually arranged in groups, and may receive the firing current either from the shore or from a submarine battery moored in the mine field in the centre of a group; or, to further economise cable, the battery can be contained in the mine itself, but, as before stated, this latter method is objectionable, and attended with danger to those employed in preparing and laying.

Fig. 8 shows a line of countermines in the position they occupy when laid.

Counter-mining.

Countermining is an operation carried out usually for the purpose of clearing a channel through an enemy's submarine defence for the passage of attacking vessels. It consists of dropping a number of mines, usually twelve, automatically from a specially prepared countermining launch.

The 500 lbs. cylindrical buoyant mine is usually employed in this operation.

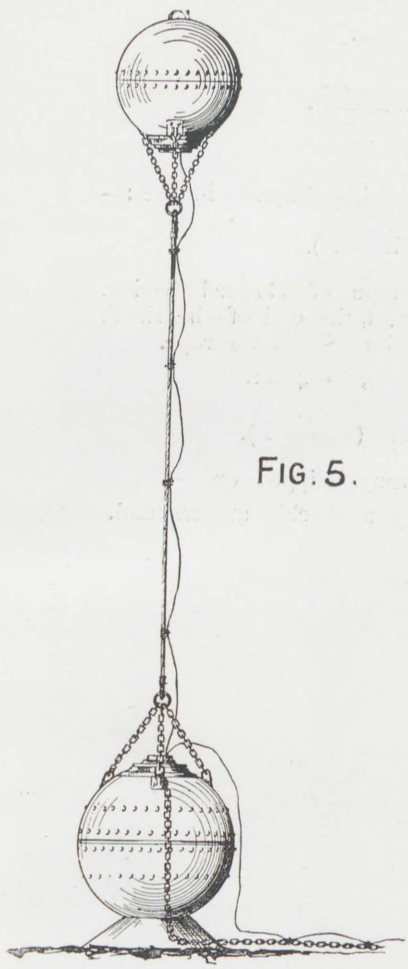

FIG. 5.

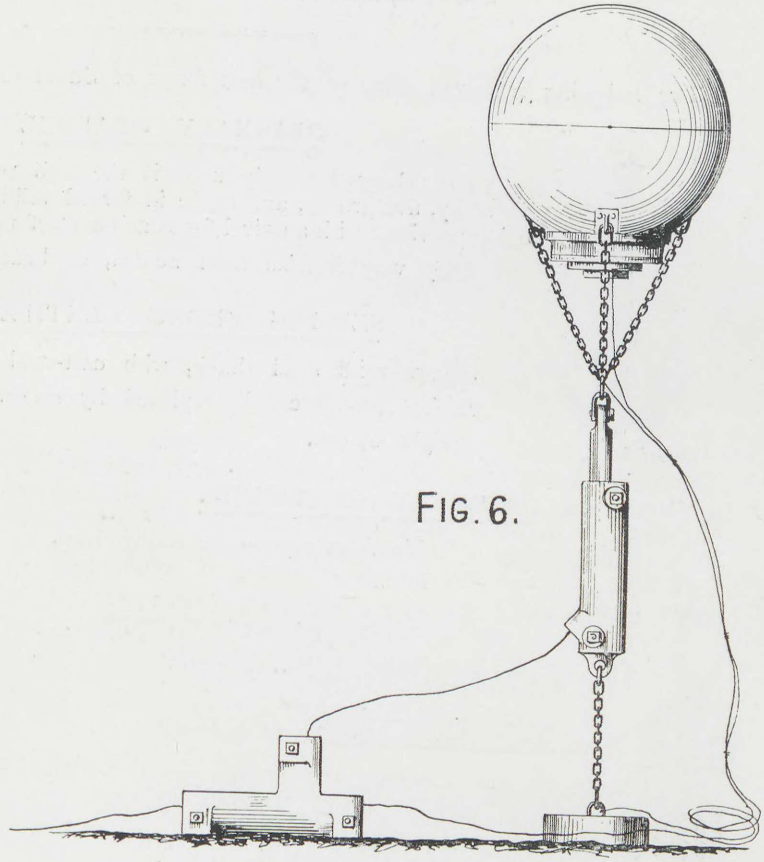

FIG. 6.

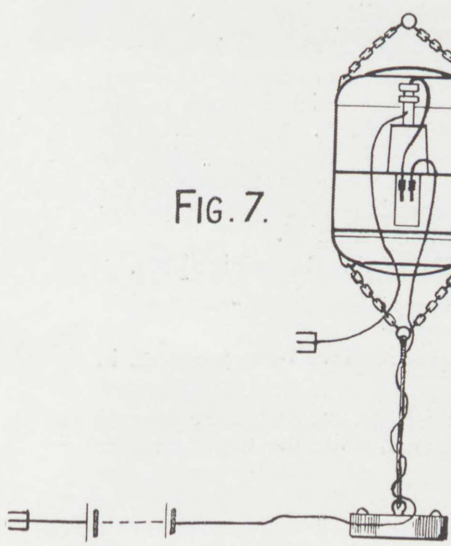

FIG. 7.

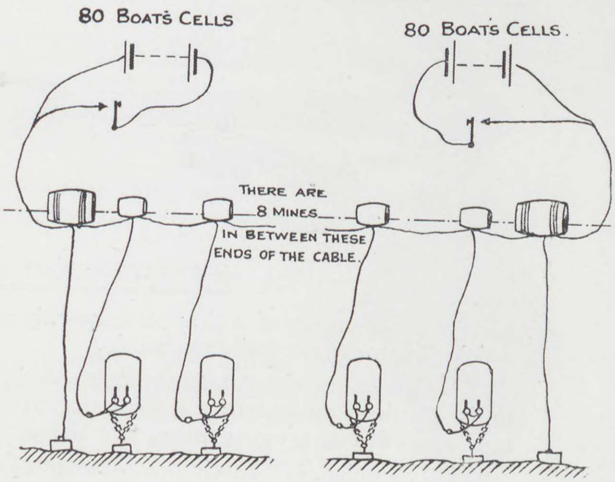

FIG. 8.

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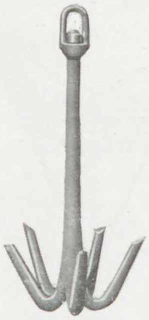
SUBMARINE CABLE GRAPNELS.

The following represent some of the best forms of Submarine Cable Grapnels in use :—



Copyright. **A.**

ORDINARY GRAPNEL (Photo A).

The Grapnel mostly used is the ordinary type of Grapnel having, generally, five prongs, and made in forged mild steel, the end of the shank being provided with a swivel for attachment of the Grapnel chain or rope.

They vary in size from 20 lbs., for boats' use, to 4 cwt.

SLIDING PRONG CENTIPEDE (Photo B).

Square mild steel shank, with cast-steel prongs slipped on.

Broken prongs can be replaced by removing a shackle at one end.

Weight $2\frac{3}{4}$ cwt.

ORDINARY CENTIPEDE.

This consists of a shank of square or round iron, through which double prongs of round or square iron are fitted.

Broken prongs are easily replaced in this pattern.

The weights vary from 20 lbs. to 2 cwt.

COLE'S CENTIPEDE (Photo D).

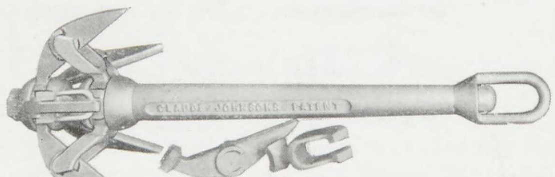
Made of steel castings, the prongs being bolted on so that they may be easily renewed in case of breakage.

The weight of this Centipede is $1\frac{1}{2}$ cwt.

Copyright. **B.**

D.

CLAUDE JOHNSON'S RENEWABLE SECTION GRAPNEL (Photo E).



Copyright. **E.**

The feature of this Grapnel is that any part can be replaced or renewed by simply removing one nut which is fitted to the lower end of the shank. A great advantage of this Grapnel is that long prongs for working in muddy or sandy bottoms can be quickly inserted in place of the short prongs used for ordinary working.

The weight of this Grapnel is $2\frac{1}{2}$ cwt.

RENEWABLE PRONG GRAPNEL.

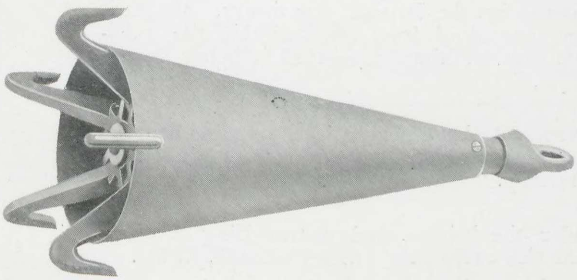
As the prongs of a Grapnel frequently get broken, many forms have been produced in which the prongs are easily renewable.

One of the oldest patterns is the Madge Grapnel, in which the five prongs are secured to the shank by means of a clamping ring and nut at the lower end, while the upper ends of the prongs fit into a recess turned in a shank.

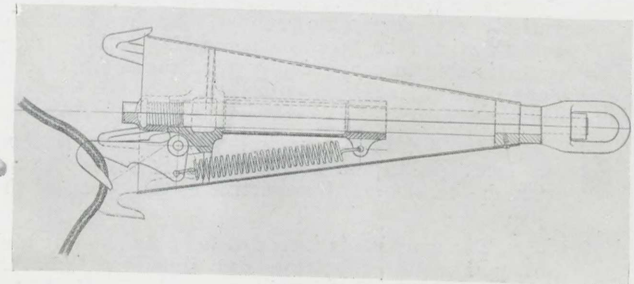
The weight of this Grapnel is about $2\frac{1}{2}$ cwt.

ROCK GRAPNELS (Photos F and G).

For working over rocky bottoms, where the prongs are likely to catch projecting rocks and get broken, Mr. Claude Johnson devised a grapnel in which the prongs are held in their working position by strong springs, the points of the prongs projecting slightly beyond the edge of a conical shield, and arranged in such manner that, should a point hook on to a rock, the body of the grapnel, with its shield, is automatically carried towards the rock, and so releases the prong, which practically recedes under the shield. The weight of the Grapnel is $3\frac{1}{4}$ cwt.



Copyright. F.



Copyright. G.

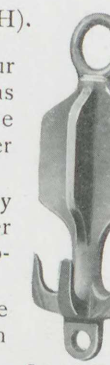
Another form of Rock Grapnel frequently used is the Dutton Grapnel, or "Umbrella" Grapnel, as it is sometimes called. This has five fixed prongs, which are protected (except for a small projecting portion at the points) by a conical corrugated shield, light flat springs being arranged to cover the opening between the shield and the point of the prong, so that after a cable is hooked there is no fear of it getting away. Weight 3 cwt.

MURPHY PATENT GRAPNELS (Photo H).

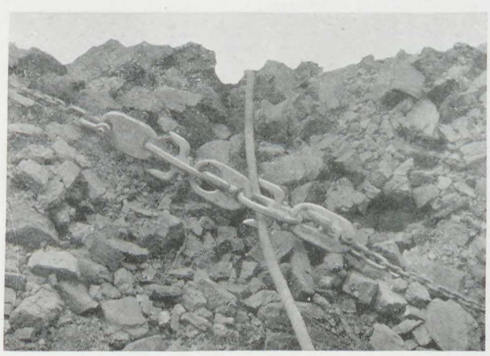
A complete Grapnel consists of about four sections, shackled together. Each section has five prongs, which are protected by wings in the same plane, so as to make it trail easily over rocky bottoms.

The sections being short, the Grapnel is very flexible, and consequently searches well over rocky ground, and the wings are a great protection against the prongs getting broken.

These Grapnels are made in four sizes, the sections weighing 20, 45, 58 and 85 lbs. each respectively.



Copyright. H.



Copyright. I.

RENNIE'S PATENT GRAPNEL (Photo I).

This Grapnel consists of four or five sections linked together.

Each section is in the form of a large link similar to the links of a chain.

Each link is provided with two prongs, and when fitted together the edges of the links protect the succeeding prongs.

The links being short, the grapnel is very flexible, and being made of mild steel the grapnel is practically unbreakable, but the prongs are arranged so that they may be easily replaced should it be necessary.

These Grapnels are made in several sizes, weighing from $12\frac{1}{2}$ lbs. to 450 lbs. per set.

MUD GRAPNELS (Photo J).

For working in muddy or sandy bottoms, Grapnels with long prongs are necessary to reach deep into the mud without the shank becoming embedded.

The common practice is to use a grapnel similar to the ordinary Grapnel, but with longer prongs. Mr. Claude Johnson, however, has patented a Mud Grapnel which is constructed of steel plates, the web being a diamond-shaped plate arranged to glide over the surface of the mud while the prongs, which are at right angles to the web, search down into the mud. Weight 4 cwt.

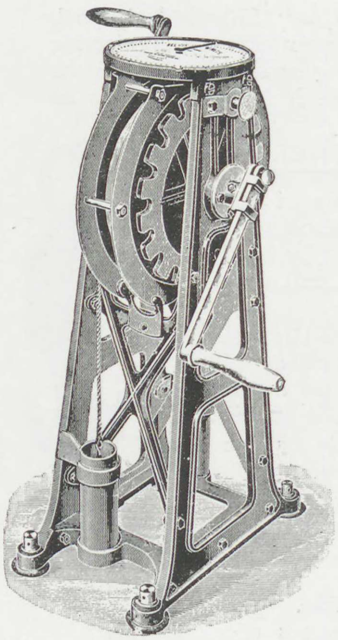
Copyright. J.

DEEP SEA SOUNDING MACHINES.

The advantages of this latest form of Lord Kelvin's Sounding Machine, which is of an entirely new design throughout, and has been adopted by the British Admiralty, are that soundings can be taken from the Navigating Bridge instead of from aft, and that the navigator is able to conveniently read the depth of each cast for himself, instead of being dependent upon a message conveyed from aft.

Another advantage is that it becomes unnecessary to have a man in the chains heaving the lead. With the new machine it is possible to obtain Soundings much more rapidly than with the hand lead, irrespective of the speed of the ship.

The machine is intended to be fixed on or under the bridge, and a travelling fair-lead pulley is mounted upon a spar rigged out from the side of the ship. (See Photos K, L, M).



Copyright.

Photo K.
Deep Sea Sounding Machine.

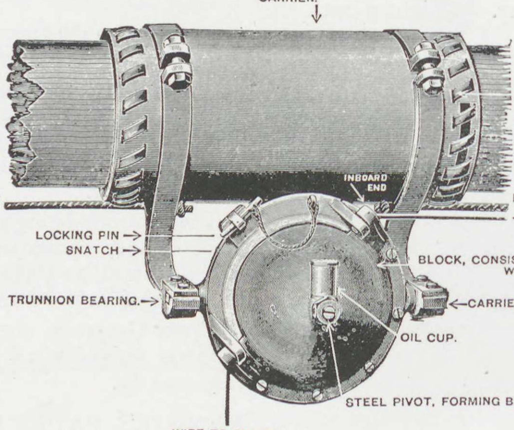


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Photo M.
Enlarged View of Carrier and Fairlead.

The dial showing the amount of wire run out is very much larger than formerly, and the divisions are consequently larger and more open. The dial is fixed ON TOP of the Machine, so that, if the machine is fixed below the bridge, the dial can be read conveniently from above. The dial indicates accurately the exact length of wire out, and the figures are bold and clear to facilitate reading.

While the depth may be ascertained in the usual way by means of the Depth Recorder or the Chemical Tubes, it is intended that with the new Machine, the depth may be readily ascertained from the length of wire out. Tables are prepared showing the depth indicated for each fathom of wire run out with the vessel travelling at all the varying speeds. Consequently, when taking a sounding, and the vessel's rate of speed at that moment being known, the corresponding DEPTH for any length of wire can be INSTANTLY ASCERTAINED, THE MOMENT THE LEAD TOUCHES BOTTOM, by inspection of the following tables.

SPEED AND DEPTH TABLE.*

MACHINE, Kelvin's Mark IV.
SINKER, Kelvin's M.C.I. with lead core, weight 24 lbs. Plaited Hemp Line, 12 ft. long.
WIRE, Seven Strand.
AUTOMATIC BRAKE WEIGHT, 6 lbs.
Wire led through Kelvin's carrier and block.
GUARD TUBE, Seized on 3 ft. above eye of sinker.

APPROXIMATE VERTICAL DEPTH.	FATHOMS OF WIRE RUN OUT.				
	SPEED IN KNOTS.				
	6	8	10	12	13
5 Fathoms ..	6½	7½	9½	10½	14
6 ,, ..	7½	9	11½	13	16
7 ,, ..	9	10½	13½	15	18
8 ,, ..	10½	12	15	17	20
9 ,, ..	11½	14	16½	19	22
10 ,, ..	13	15½	18½	21½	24
11 ,, ..	14½	16½	20	23	26
12 ,, ..	15½	18	21½	25	28
13 ,, ..	17	19½	23	27	30
14 ,, ..	18	21½	25	28½	32
15 ,, ..	19½	23	26½	30½	34
16 ,, ..	20½	24½	28	32½	36
17 ,, ..	22	26	30	34½	38
18 ,, ..	23	27½	31½	36½	40
19 ,, ..	24½	29	33½	38½	42
20 ,, ..	26	30½	35	40½	44
21 ,, ..	27½	32	37	42½	46
22 ,, ..	28½	33½	39	45	48
23 ,, ..	30	35	41	46½	50
24 ,, ..	31	36½	42½	49	52

APPROXIMATE VERTICAL DEPTH.	FATHOMS OF WIRE RUN OUT.				
	SPEED IN KNOTS.				
	6	8	10	12	13
25 Fathoms ..	32½	38	45	51	54½
26 ,, ..	33½	39½	46½	53	56½
27 ,, ..	35	41	48½	55½	58½
28 ,, ..	36	42½	50	57½	61
29 ,, ..	37	43½	52	60	63
30 ,, ..	38½	45	53½	62	65
31 ,, ..	40	46½	55½	64½	
32 ,, ..	41	48	57	67	
33 ,, ..	42½	49½	59	69	
34 ,, ..	43½	51	60½	71½	
35 ,, ..	45	52½	62½	74	
36 ,, ..	46	54			
37 ,, ..	47½	55½			
38 ,, ..	48½	57			
39 ,, ..	50	58½			
40 ,, ..	51	60			
41 ,, ..	52½				
42 ,, ..	54				
43 ,, ..	55				
44 ,, ..	56½				
45 ,, ..	58				

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It may be added that the proportion of wire to depth differs not only with the speed of the ship but also with the roughness of the sea, and with the depth itself.

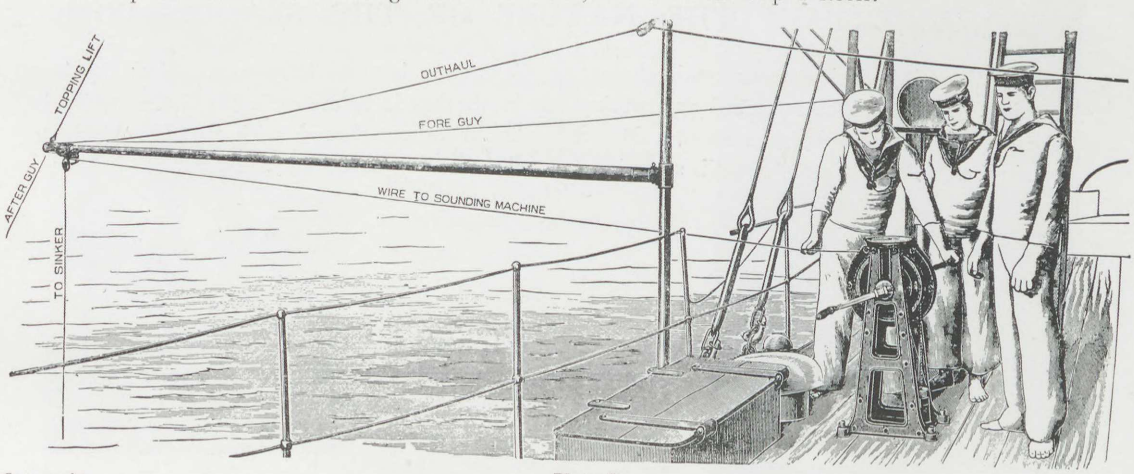

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Photo L.
Illustration of Method of Working Sounding Machine.

THE DEPTH RECORDER.

The Depth-Recorder is shown at N. As the sinker descends, the increased pressure forces the piston D up into the tube, while the spiral spring pulls the piston back. The amount that the piston is forced up against the action of the spiral spring depends on the depth. To record the depth the marker C is used. As the Recorder goes down, the marker is pushed along the piston. When the Recorder is brought up to the surface of the water, the piston comes back to its original position, but the marker remains at the place on the scale to which it was pushed, and shows the depth to which the Recorder has been. The depth is read off by the marker.

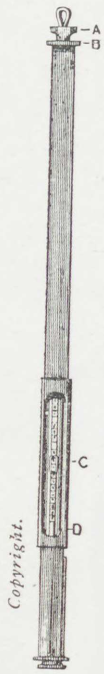


Photo N.
Depth Recorder.

CHEMICAL TUBES.

When Chemical Tubes are being used instead of the Depth Recorder, one of the brass guard tubes is lashed to the rope between the wire and the sinker, about 3 feet from the end of the wire. Before taking a cast the officer, or leading hand, places a glass tube, with the open end down, in the guard tube, and puts the cap on. When the guard tube is brought on board, care should be taken to keep it right side up. If it is turned on its side, or upside down, the water will run up the glass tube and produce a bad mark. The officer takes out the glass tube, and applies it to the scale with the closed end against the brass plate at the top of the scale. He reads off the number of fathoms shown on the scale by the lowest part of the red coating. This, without correction, will be the depth accurately enough if the barometer be at anything from 28¾ to 29½ inches.

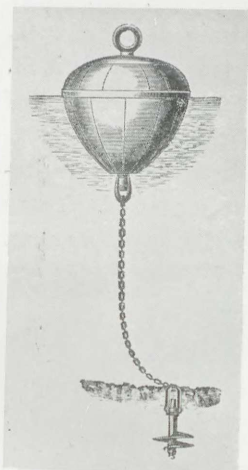
If the	Barometer	stands	at	29¾	add	one	fathom	in 40.
,,	,,	,,	,,	30	,,	,,	,,	30.
,,	,,	,,	,,	30½	,,	,,	,,	20.
,,	,,	,,	,,	31	,,	,,	,,	15.

TO ASCERTAIN THE NATURE OF THE SEA BOTTOM.

When it is desired to ascertain the nature of the sea bottom, hard soap makes the best arming. It should be squeezed and worked up in the hands before using. If the cavity in the bottom of the sinker has smooth sides they should be roughened with a cold chisel, to retain the arming when the vessel is steaming fast, otherwise it will be washed out.

MOORINGS AND MOORING BUOYS, Etc.

Photo O illustrates the standard type of Mooring Buoy in general use, and Q the Trinity pattern Conical Beacon Buoy, with their respective screw moorings. Photo P shows a Mooring Buoy of the Drum type.


Copyright.
Photo O.


Copyright.
Photo P.

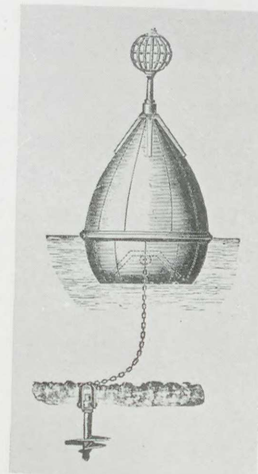
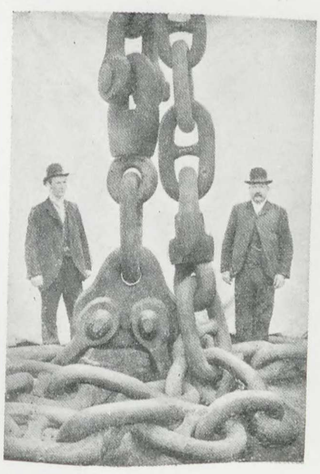
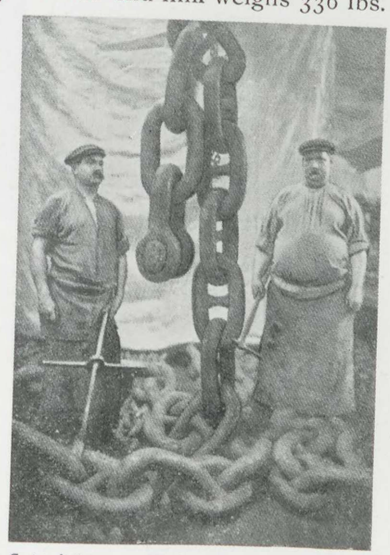

Copyright.
Photo Q.

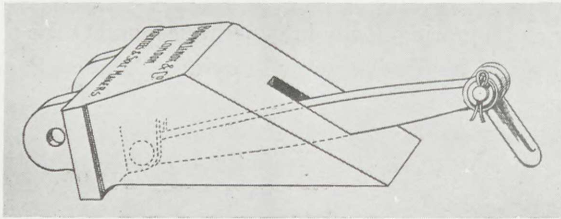
Photo R shows part of the huge mooring cables made by Messrs. Brown, Lenox & Co., Ltd., for the leviathan Cunarders "Mauritania" and "Lusitania." The links in buoy pendant are in $4\frac{1}{4}$ and $5\frac{3}{8}$ inch diameter iron respectively. Each end link weighs 336 lbs. and each common link 243 lbs. The swivel connection weighs 4,485 lbs. and each shackel 711 lbs. The total weight of the moorings is over 200 tons. Each of the patent link mooring anchors (photo T) weighs 12 tons.


Copyright. **Photo R.**

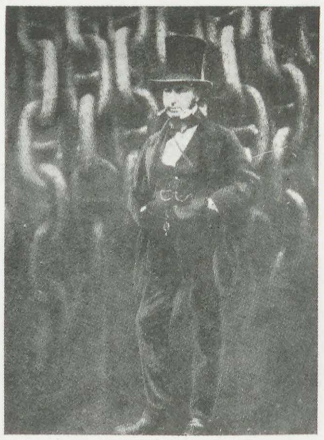
The chain cable weighs, with shackles, about 130 tons, the total length being 1,900 feet. The links are of $3\frac{3}{4}$-inch diameter iron at


Copyright. **Photo. S.**

the smallest part, and 22¼ inches in length. Each joining shackle weighs 4½ cwts. and the end or anchor shackles 7½ cwt. each. At the end of the cable swivel pieces are inserted, each weighing 13½ cwts. The end links on the swivel pieces are of 4¾-inch diameter iron, and the swivel alone weighs 6¼ cwt. Tests were made on three links at Lloyd's Proving House, and, under the Admiralty strain of 198.8 tons, each link elongated nearly ¼ inch. The Statutory breaking stress of 255.7 tons was then applied, the result being a further elongation of the links by ¾ inch. An attempt to test the three links to destruction failed to break the links, notwithstanding that the full power of the testing machine (350 tons) was applied. There was no sign of fracture or defect of any kind, although the load was nearly 90 per cent. above the Admiralty stress.



Copyright. **Photo T.**

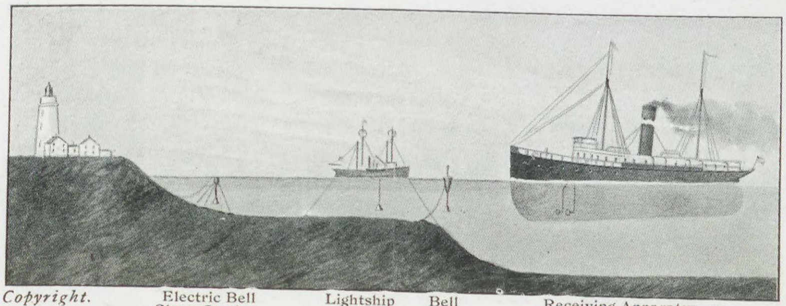


Copyright. **Photo U.**

Photo of the eminent Civil Engineer, Brunel, with the 2⅞-inch cable for the "Great Eastern," manufactured by Messrs. Brown, Lenox & Co., in 1855.

SUBMARINE SIGNALLING APPARATUS.

When it is remembered that sound travels more than four times as fast in water as in air,* and that in water it is not subject to the same possible obstructions and variations as it is in air, it will be readily understood how much more effective and reliable is submarine than aerial signalling under certain conditions.



TYPES OF SUBMARINE SIGNALS.

Reproduced by courtesy of The Submarine Signal Co.

General View of the Submarine Sound Signalling System, showing its different applications.

The conception of the Submarine Fog Signalling Bell is probably due to the scientist, Colladon, who, in his experiments on Lake Geneva, in 1826, had a bell weighing 150 lbs. suspended 5ft. under water from the side of a boat and struck by a hammer attached to the end of a lever. Stationed in another boat, he listened for the bell sounds propagated beneath the surface, which were conveyed from the water by a cylindrical tube of tin some 9ft. long and 6in. in diameter. One end of this tube terminated in an orifice for insertion in the ear, and the other was spread out somewhat in the form of a spoon, with its orifice closed by an elliptical plate of tin about two square feet in area. By attaching a suitable weight to the lower end of the tube it was easily retained in a vertical position, with about four-fifths of its length submerged, its plate being turned toward the boat carrying the bell. With this simple apparatus, Colladon was able to hear, with perfect distinctness, the blows of the hammer on the bell across the widest part of Lake Geneva, when the calculated distance between the two boats was not less than eight miles. Small progress, however, seems to have been made in the art of under water signalling until the year 1900, when Mr. A. T. Mundy, an American, turned his attention to the subject, and with the aid of expert assistants succeeded, after innumerable experiments, in producing a system which made it possible to strike a note on a bell under water at regular intervals, and to enable the navigator of a ship travelling at high speed to receive the sounds twelve to fifteen miles from their source without leaving his wheel-house.

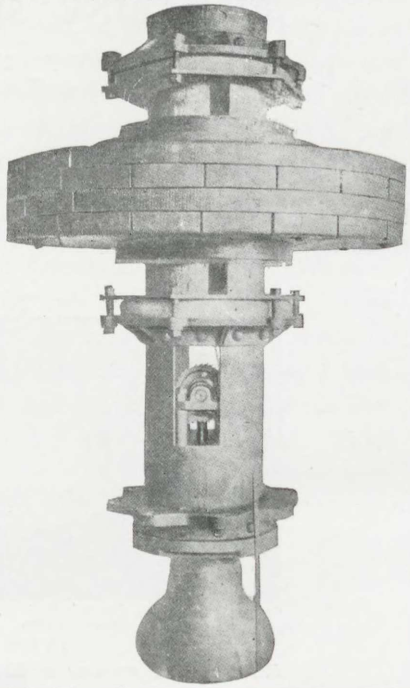
Submarine Signalling Apparatus consists of two main parts: (1) the SENDING APPARATUS, which for all practical purposes, is confined to BELLS; and (2) the RECEIVING APPARATUS.

* In air the velocity is 1,100 ft. per second, and in water 4,700ft. per second.

SUBMARINE SIGNALLING APPARATUS.

Copyright.

Direction-Indicator and Receiving Telephone.



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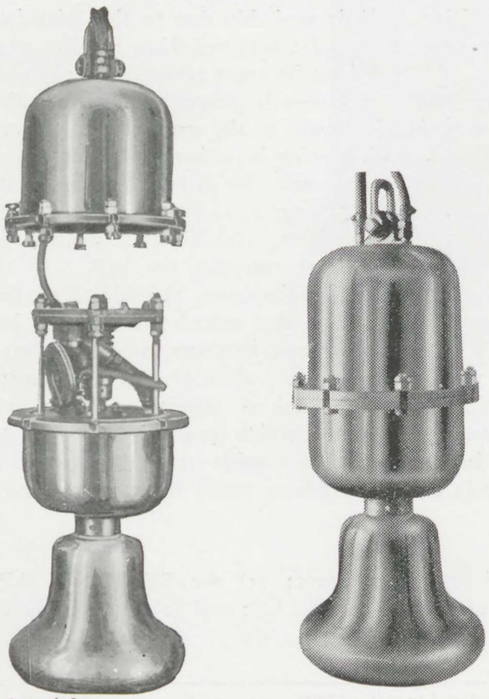
Submarine Signal Buoy Apparatus for attaching to Bell Buoys.



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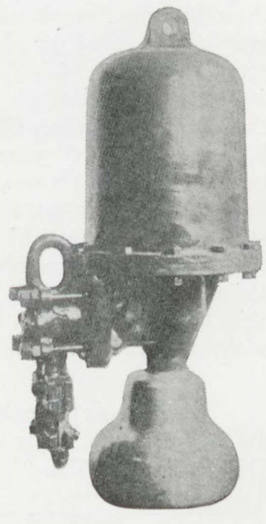
Lightship Bell attached to case (open and closed) containing Striking Mechanism operated by Compressed Air.



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Electrically operated Bell with Cable Connections.

The BELL EQUIPMENT is of four kinds: (*a*) *The Electrical Shore Station,* consisting of a BELL, weighing about 2 cwt., fixed to a tripod 21 feet high, resting on the sea bed, and connected with Lighthouse or Shore Station by suitable electric cable. (*b*) *Light Vessel Equipment.* This is a pneumatic bell similar in shape and form to that of the electrical bell, but worked by compressed air, and is lowered into the water from the vessel at periods of fog, and ringing usually a number of times corresponding to the number of the Light Vessel as registered by the Government to which it belongs. (*c*) *Bell Buoy.* This mechanism is pendant from any deep-sea 10ft. buoy, and is automatic in action, the power being conveyed from the under connection between the buoy and the flotation of a sea anchor fixed thereunder. (*d*) *Hand Bell.* This can be lowered from any pier or jetty, and is worked by hand power.

(*a*) Is specially adapted for rocky coasts. Its radius of sound is reliable up to ten to fifteen miles, and it has been reported at eighteen miles or more. (*b*) is mostly operated on Light Vessels, and has been largely adopted by the United States Government, and is now being installed by the Trinity House. (*c*) A third application of the submarine signal is made by suspending a submarine bell from an ordinary gas or other buoy, and striking it by a mechanism which is worked by the vertical motion of the buoy caused by the action of the waves. The bell in this case is hung about 16ft. below the surface of the water. The difference in movement between the buoy and a sea anchor suspended below it operates the mechanism. (*d*) This is especially for use by those shipping lines, such as cross-channel boats, whose voyages are between ports not far distant, and to whom it is of great value as a time-saver.

The RECEIVING APPARATUS can best be described as the "ears" of a ship. It consists of two tanks about 22in. square, filled with sea water, fastened securely against the side of the skin of the ship, below the water line—one on the port and another on the starboard side, placed at a certain distance from the bow; this distance is varied according to the shape of each individual ship. Within each box are suspended two specially designed microphones, wholly immersed, and telephone wires are carried from each microphone to an indicator box situated on the bridge, pilot house, or other convenient spot for the navigator. On this box are suspended telephonic ear-pieces or receivers, enabling two observers to listen simultaneously. By the simple movement of a switch, the listener can locate the sound and determine whether it is coming from the port or starboard side. As a provision against accident, a second set of microphones, placed in each tank, can be brought into action by moving another switch.

The above are the usual forms in which the apparatus is made use of. It is also largely used by the navies of the world for intercommunication between ships, more especially as it is at present the only known method of communicating with a submarine after she has left the surface, and it is of frequent value for communication between ships of a squadron, whose Marconi is out of action, where the Admiral of such squadron is using his wireless for communication with headquarters, in which case any form of lighting signal is impossible for fear of betraying the position of the squadron to the enemy.

From the humanitarian and economic points of view there can be but one opinion as to the advantages of Submarine Signalling Apparatus, for there is no doubt that it has been instrumental in saving many lives and much property.

SALVAGE OPERATIONS.

It is computed that the value of vessels and cargoes annually lost on the British Coast alone exceeds £9,000,000 sterling.

SALVAGE PLANT AND DIVERS.

This should in all cases be of the best and most powerful description, fit to cope with vessels of various sizes that may have to be dealt with. We recommend the following as a complete and perfect salvage plant and *personnel*:—

(1) SKILLED and WELL-TRIED DIVERS, preferably SHIPS' CARPENTERS and BOILER-MAKERS—sober and reliable men—with proper equipment of DIVING APPARATUS. Ship's crew to include MEN CAPABLE OF DEALING WITH HEAVY LIFTS, PURCHASES, etc.

(2) PONTOONS.—In some cases considerable BUOYANCY can be gained by attaching PONTOONS (CAMELS) to the sunken vessel, these being constructed either of iron or steel plates, or of timber.

WATER-TIGHT BARRELS, placed in the holds of small wrecks, have also proved of great service. STRONG RUBBER AND CANVAS AIR-BAGS have also been successfully used in the same way, these being placed in the vessel's hold, or secured to the vessel outside, and then inflated with air forced down by pumps through a tube attached to the bags, thus displacing the water.

(3) At least three 12-in. CENTRIFUGAL PUMPS,* each capable of discharging 150,000 gallons of water per hour; two 10in. PORTABLE PUMPS,† each of a capacity of, say, 60,000 gallons an hour; BOILERS; FLEXIBLE INDIA-RUBBER SUCTION HOSE, with suitable COUPLINGS, FOOT VALVES and GRATINGS; DISCHARGE PIPES, etc.

(4) Special STEEL WIRE ROPES, from 6in. to 9in. in circumference, and Chain Cables, for slinging, lifting, and hauling purposes; a stock of screws, 7 feet to 8 feet long by 3 inches in diameter; LEAK STOPPERS.

(These latter are of simple construction, viz.:—To a bar of iron slit through half its length there is jointed in the middle a screwed spindle, half the length of which lies flush in the slit in the bar, the remaining portion forming a handle. If the apparatus is taken in hand with the tip of the thumb on the slit end of the bar, all will be in a straight line, but if the bar is thrust forward through a hole, at the same time removing the tip of the thumb, the bar will immediately adjust itself across the hole on the other side, and afford a certain and secure purchase, forming, in fact, the head of a **T**-*headed bolt. A washer-plate to cover the whole of the wound can then be slipped upon the shanked or screwed spindle, and secured to the side of the ship by a tightly screwed-up nut. This washer, or patch plate, can be faced with layers of thick felt, so as to embed any jagged edges or irregularities through the bulging of the wound, and so make a water-tight patch.)*

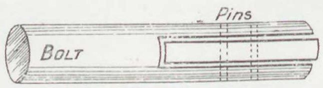


Fig. No. 57.

Another form of leak-stopper is the "Douglas," a sort of "umbrella" arrangement, which, being used from inside a ship, is passed through the hole, and then the "umbrella" is expanded and drawn up tightly against the outside of the skin of the vessel. They are made for hulls ranging from $\frac{1}{16}$ in. to 6in. thick.

* For capacities of various sizes of Centrifugal Pumps, see page 96.

† Driven by steam, electric or oil motor.

(5) BATTERIES (preferably of the "Twist" type, which are capable of firing either high or low tension detonators) and INSULATED WIRES with DETONATORS for firing charges of dynamite, or other suitable explosives under water.

(6) SUBMARINE ELECTRIC LAMPS, for under-water use, and POWERFUL ARC LAMPS FOR SURFACE OPERATIONS AT NIGHT.

(7) STEAM WINCHES for working heavy loads cargo; SLINGS; PURCHASES, etc., for heaving off ships.

(8) A stock of QUICK-SETTING CEMENT ("MEDINA") and BRICKS should be kept on board the salvage vessel; in certain cases few better plans can be adopted for stopping up holes. This method was employed when raising H.M.S. *Sultan*.

(9) A supply of DYNAMITE, or "TONITE" OR OTHER EXPLOSIVE, suitable for submarine work, with waterproof bags or tin canisters for holding the charges (or "Tonite" can be had made up in water-tight cartridges ready for use).*

(10) PNEUMATIC ROCK DRILLS, DRILLS FOR DRILLING IRON OR STEEL, AUGERS for boring timber, with AIR COMPRESSORS for working same, and also for forcing water out of pontoons, etc.

(11) HULKS, each having a d.w. capacity of 500 or 600 tons, and fitted with steam winches or cranes, are also of great service, particularly in the case of deep-water wrecks.

(12) A good supply of TIMBER and WROUGHT-IRON, for making special bolts, etc.

METHODS EMPLOYED.

It is not possible to lay down any hard and fast rule for the carrying out of salvage operations, the *modus operandi* depending so much upon the depth of water and position in which the wrecked vessel is lying, her tonnage, and the nature and extent of the damage. Invariably, however, the first step to take is to send down Divers to survey the vessel and make a thorough examination with a view to ascertaining the extent of the damage. The Divers having given an accurate report, the next thing to be done is to map out a plan of operations, taking into consideration the nature of appliances at hand, tides, weather, etc.

CENTRIFUGAL PUMPING MACHINERY FOR SHALLOW WATER SALVAGE.

Where the depth of water to be dealt with does not exceed 30ft., Centrifugal Pumps are the most effectual appliances to use. Divers should be sent down to clear away any obstacles that might impede the operations, to remove the cargo if necessary, to stop up holes and repair the damage to the vessel's hull, and to batten down openings and strengthen the decks preparatory to fixing the suction pipes from the Salvage Pumps.

LIFTING CRAFT, PONTOONS, WIRE ROPES, ETC., FOR DEEP WATER SALVAGE.

In cases where the vessel is sunk so deep as to make the use of pumping machinery ineffectual, the salvors will have to resort to lifting vessels, or large pontoons, moored over the wreck.

A method often employed where there is a rise and fall of tide is to have two or more hulks braced together by baulks of timber, and having sufficient combined buoyancy to allow a good margin over and above the dead weight to be lifted, moored over the wreck; wire ropes are then attached to, or placed under, the vessel by the Divers, and carried up over sheaves on the lifting hulks. At the rise of tide the wreck is lifted off the bottom, and the hulks are then towed into shallower water, the slack of the ropes being taken up, and the operation repeated until the vessel is left high and dry.

* See notes on Explosives, page 99.

Deep Water Salvage. Where there is no rise and fall of tide, and where pumping machinery could not be successfully used, the plan is to sling the wreck by means of wire hawsers led up to two hulks moored over the sunken vessel, and which generally have water pumped into them in order to sink them as far as possible consistent with safety. In some cases pontoons are then attached to the sides of the sunken vessel (these pontoons are sunk by letting water into them, which is expelled by means of a powerful air pump when they are placed in position by the Divers). When all is secure the hulks are pumped out and the water expelled from the pontoons simultaneously. By this means a good strain is secured, and the wreck is lifted off the bottom, and can then be towed into shallower water. Instead of hulks, on several occasions large pontoons alone have been successfully used in the raising of sunken vessels. These pontoons are constructed of timber or of steel plates, and are divided into compartments, which can be filled with water to sink them as far as possible with safety, or pumped out, as desired, the lifting being done pretty much in the same manner as in the case of the hulks described above.

Passing wire ropes under vessels. In cases where it is found expedient to take wire ropes right round the hulls of smaller vessels, the readiest method of passing them under the keel is to use a hose-pipe, one end of which is connected to a pump, the other end being directed under the keel to force a channel through the sand, etc. With a good pressure this device will be found more expeditious than the old system of pricking a way under the keel and passing a small pilot chain through to make way for the larger lifting hawser.

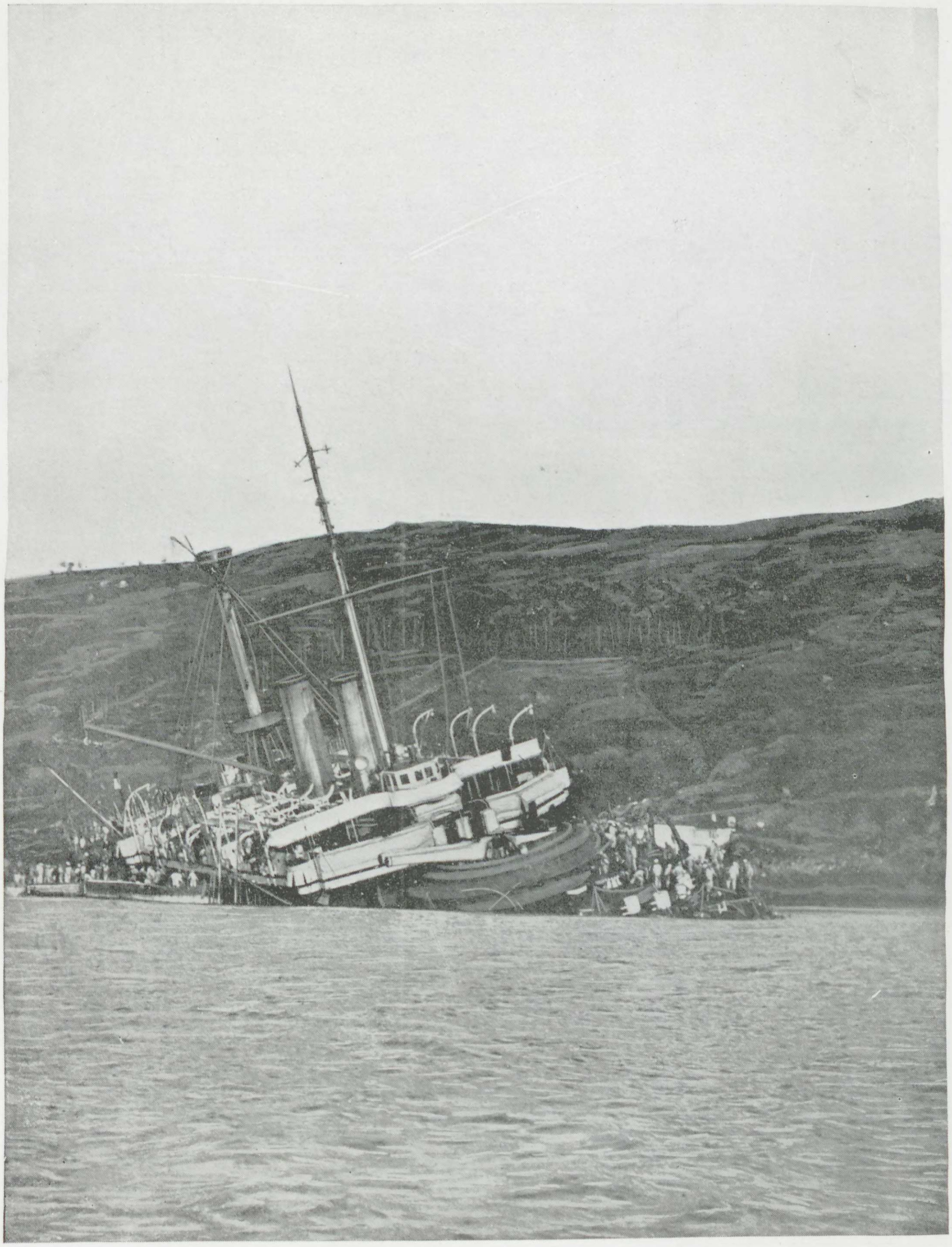
The following are a few examples of successful ship-raising operations carried out with the aid of Centrifugal Pumping Engines and Divers:—

H.M.S. "Sultan." H.M.S. *Sultan,* sunk between Malta and Gozo, and raised by Messrs. Baghino Brothers, of Genoa. In this case it was found necessary to blow away projections of rock by means of small charges of dynamite, which had to be carefully used in order to avoid further damaging the vessel. All holes and apertures were then stopped up by means of timber, bricks and a special cement (*Medina*), which has the properties of setting quickly and adhering to iron; the suction pipes from the Salvage Pumps were then introduced into the wreck by the divers, and Pumping commenced.

H.M.S. "Howe." H.M.S. *Howe,* 10,300 tons, 11,500 h.p., length 325ft., breadth 68ft., depth 26ft., four 67-ton guns, stranded on Pereiro Reef, entrance to Ferrol, Spain, 2nd November, 1892. The *Howe* listed over to starboard 20 degrees, and at high water her fore-deck was entirely covered. Projections of the rock on which she stranded penetrated right through her double bottom, and had to be carefully blasted away by small charges of dynamite. A large shield was constructed and fixed over the damaged parts by Divers, and the vessel was then pumped out. Before she could be floated, however, it was found necessary to blast away the rocks (about 400 cubic feet) all round her, which was done by means of charges of dynamite, a rock drill, driven by compressed air, being used for boring the holes for the charges. The *Howe* was floated by the Neptune Salvage Company, of Stockholm, who, without doubt, possess the most powerful and complete salvage plant in the world. The operations were carried out under the superintendence of Capt. Edlind. This Company, since its formation, has undertaken over 1,500 different salvage operations, representing a value, in its damaged condition, of over £6,000,000 sterling. (See photo, page 131.)

S.S "Utopia." S.S. *Utopia,* sunk off Gibraltar in about 50ft. of water, had a coffer-dam attached to her gunwales by Divers, and was then pumped out and floated.

S.S. "Argus." S.S. *Argus,* sunk at Birkenhead, had a wooden coffer-dam built on to her deck, and the holes in her side, caused by the collision, were patched up by Divers. Salvage pumps were then used to pump out the water in the vessel's hold, and she was ultimately floated and towed into a safe place. The salvors of this vessel and of the S.S. *Utopia* were the East Coast Salvage Company, of Leith (Mr. T. N. Armit, Superintendent). Somewhat similar methods were employed in the case of the S.S. *Kottingham,* also raised by Mr. Armit (see page 139).



Copyright. **Photo No. 57.**

H.M. Battleship "Howe" on the Rocks, near Ferrol, Spain.

Floated by the Neptune Salvage Company of Stockholm (*see page 130*).

THE SALVAGE OF H.M.S. "GLADIATOR."

By the Liverpool Salvage Association.

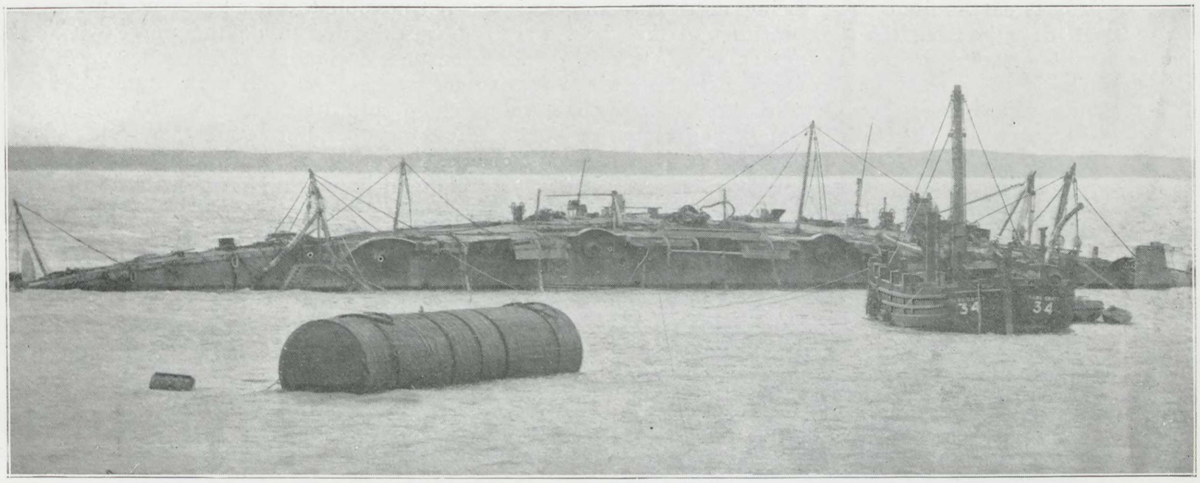
H.M.S. "Gladiator."

This cruiser, 320ft. long, 57½ft. broad, displacement 5,750 tons, collided with the American liner *St. Paul* in the Solent, off Yarmouth, Isle of Wight, during a blizzard on the 25th April, 1908. The *Gladiator* was struck on the broadside at an acute angle a little forward of the after gun sponsons, ripping the shell plating from top to bottom of the moulded structure. The bow of the *St. Paul* was ultimately wedged in behind the sponson and the gun pedestal, and when she got clear again she carried part of the *Gladiator's* armour deck plating embedded in her bow. After the cruiser had been beached, the divers found that about 50ft. in length of her side plating, including the framing and part of the deck beams and bunker division walls, had been stripped off, and that the interior was open to the sea from the top of the gunwale down to within 3in. of the bilge keel, two of the three boiler rooms being in communication with the sea.

Copyright **Photo No. 58.**

ONE OF THE DIVERS ABOUT TO DESCEND

When the Liverpool Salvage Association's staff and plant reached the scene of the disaster, the *Gladiator* was lying with a list to starboard (the damaged side) of 93 deg., and with her deck towards the shore, only the port side of the vessel being visible at high water. The bed of sand and small stones on which she rested was smooth and very hard. The beach shelved quickly, and the first operation was to bring the vessel nearer inshore to prevent her from slipping into deeper water. In addition to occasional bad weather, the salvors had to contend with a strong ebb tide, the current across the bow being often 8 knots at the ebb of spring tide, heavy eddies being formed; therefore the time for diving was limited. The guns with their shields, weighing nearly 15 tons apiece, were first removed. Then the funnels, ventilators, boats, davits and other fittings were salved,



Copyright

Photo No. 59.

Position of the Vessel after she had been dismantled.

submarine pneumatic tools being used for cutting away the funnel casings, etc. All openings were made watertight by wooden covers secured by hook bolts. After this work had been completed, it was found that the part torn away by the *St. Paul* had folded down on the port side, having no doubt turned over as the ship heeled on her damaged side. In order to avoid further damaging the vessel, it was decided to remove this ragged structure, this being done with "Gelignite." The vessel was now ready to be hauled into shallower water. Five river gun-boats with very heavy moorings, in view of the strong currents, each boat carrying steam-driven centrifugal pumps, sizes 5in. to 12in., were moored "bows on" to the wreck. The suction pipes of the pumps having been placed by divers, two steel-plates pontoons, or "camels," each 50ft. long by 10ft. in diameter (having about 100 tons buoyancy), sheathed with wood, the ends being protected by collision mats, were secured to the vessel for the purpose of increasing her buoyancy. The pontoons, made with coned ends, were fitted with valves for the admission of water when it was desired to sink them, and also with valves, connected to air compressors by means of flexible tubes, to admit air for the expulsion of the water when the pontoons were required to be refloated. The cylinders had external 10in. channel stiffeners fitted circumferentially, and these were also used for taking the wire ropes by which the pontoons were connected to the wreck.

For securing the pontoons, steel bits or bollards were bolted down on the port side of the ship—*i.e.*, the side which lay above the water level. Over a teak backing a steel plate was fastened on the outer skin-plating, and behind it hard wood blocks were fitted between the frames, with a heavy steel plate connecting these blocks together. The bolts passed completely through the bollards and other parts, and were secured inside by divers. Around the channels on the external surface of the cylinders a 6in. wire-rope strap was wound, one eye being wove through the other. A special shackle was also devised for enabling the wire rope to be disconnected readily. The shackle was made up of two plates, so that the outer one could be removed to free the rope. The vessel was slung to the pontoon by means of a 9in. cable. One end was shackled to the strop round the cylinder, the other end being towed under the *Gladiator* by the *Ranger* (one of the Liverpool Salvage Association's vessels), and made fast to the bollards on the port side of the wreck. The buoyancy of the pontoon, when pumped out, thus tended to pull the ship over in the upright position. But the idea at this stage was merely to ease the ship in order to facilitate the operation of hauling her inshore.

Great hauling power being necessary, and, as it was not possible to execute a powerful pull directly from the tugs working in the shoal water, it was decided to do the work by means of heavy steam capstans on shore. Chain cables were passed through the bow hawse pipes of the wreck, and connected by 8in. wire ropes to the shackles on the shore station. These were passed through a 100-ton leading block, to which in turn were shackled 100-ton wire purchases, the falls being taken to the capstans. Pumping operations were then commenced, but in consequence of the great damage amidships, it was considered impracticable to pump out the two damaged boiler rooms. This first pumping operation resulted in the vessel altering her angle of heel by 10 deg., and she was considerably eased up from the bed by the pontoons. The capstans were started, and the attendant tugs were utilised as far

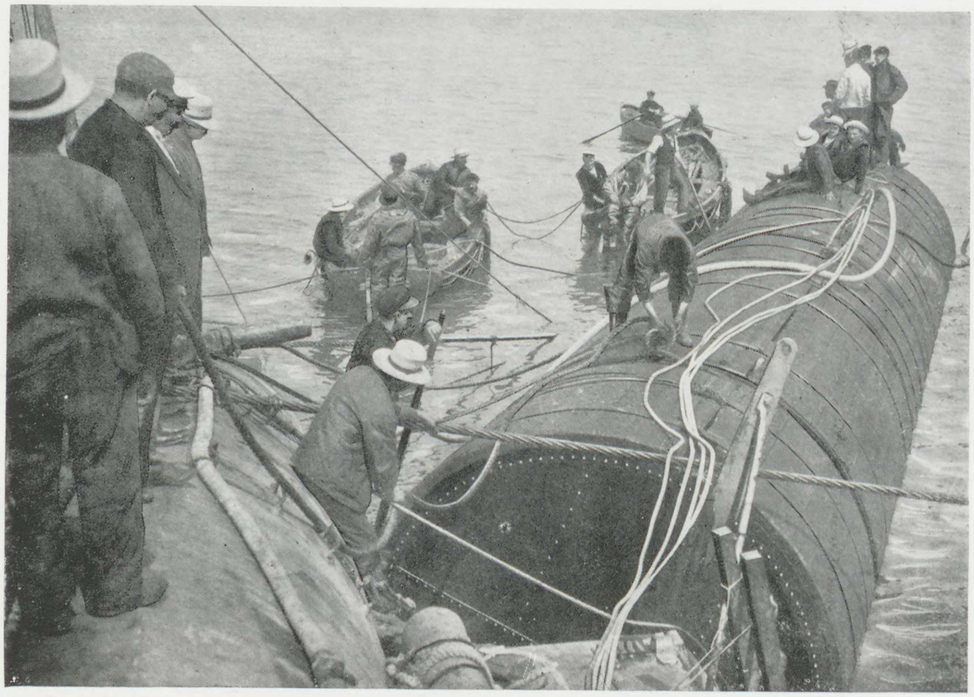


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Photo No. 60.

One of the Steel Pontoons being placed in position.

as possible. After the vessel had been moved about 6ft. shorewards, she was brought up owing to the forward bridge, which projected beyond the tumble-home of the hull, cutting into the sea-bed. The velocity of the tide being so great, it was decided not to continue the operation, but the vessel had already been swung parallel with the shore. The forward bridge was removed, the pumps were restarted, and the capstans and tugs succeeded in moving the ship a further 30ft. inshore. It was then decided to proceed with the work of uprighting the vessel.

Five additional cylinders had in the meantime been constructed, each of these later ones being divided into three compartments. The sizes of the seven cylinders used were: one 75ft. by 12ft. dia.; two 40ft. by 12ft.; two 50ft. by 10ft.; and two 50ft. by 12ft. The five first mentioned were arranged on the starboard side, the largest being placed alongside the damaged boiler rooms. The remaining two cylinders (50ft. by 12ft.) were placed on the port side, the object of these latter being to prevent the vessel from turning over on that side after reaching the vertical position. These two pontoons were secured by wire ropes toggled at their lower ends through holes cut in the bilge keel, the length of rope being so adjusted that when the vessel came into the upright position, it was taut, thus the cylinders floating along the port side would resist any tendency to list to port. On the port side of the vessel two heavy tripods (one abreast of each mast) were erected. These were secured into angle-iron collars fitted on the outer skin-plating, with backing similar to that adopted in the case of the bollards already described. But in this case only the angle-iron collars were secured.

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Photo No. 61.

One of the Pontoons being sunk.

The tripod legs were not fixed, the object of this being to allow of their falling away when the vessel righted. Fitted at the top of each tripod was a heavy casting taking a 6in. wire rope, one end passing to the masthead, the other end being carried to a salvage steamer anchored about 50 fathoms seaward, and moored by a 7-ton stern anchor. The wire rope was led through a large leading block on the bows of two of the salvage vessels to a 50-ton purchase, extending the whole length of the deck of the salvage steamer. Heavy winches thus exerted a strong pull on the masts, utilising the tripods as a fulcrum. 280 tons of pig-iron were placed on the port bilge-keel to assist in the righting of the vessel. As a safeguard against any tendency of the vessel to slip into deeper water, 6in. wire ropes were taken from the mastheads to the shore, and there secured to purchases worked from the capstans, so that they could be made taut or let out as required. These preparations having been completed, the cylinders were placed in position and partly sunk, the two salvage vessels with their leverage appliances were in readiness, and the steamers with their centrifugal pumps were brought into position close to the ship. The pumps were started, and for some time pumped about 6,000 tons of water per hour from the forward and aft compartments, No. 1 boiler room, and the engine room. To get the best results out of the pumps, the steamers carrying them were brought right over the pontoons, which were sunk for this purpose; but when the pumps had gained headway, the vessels were moved back. The water being forced out of them by compressed air at a pressure of about 20lbs. per square inch, the pontoons were floated, and their buoyancy, com-

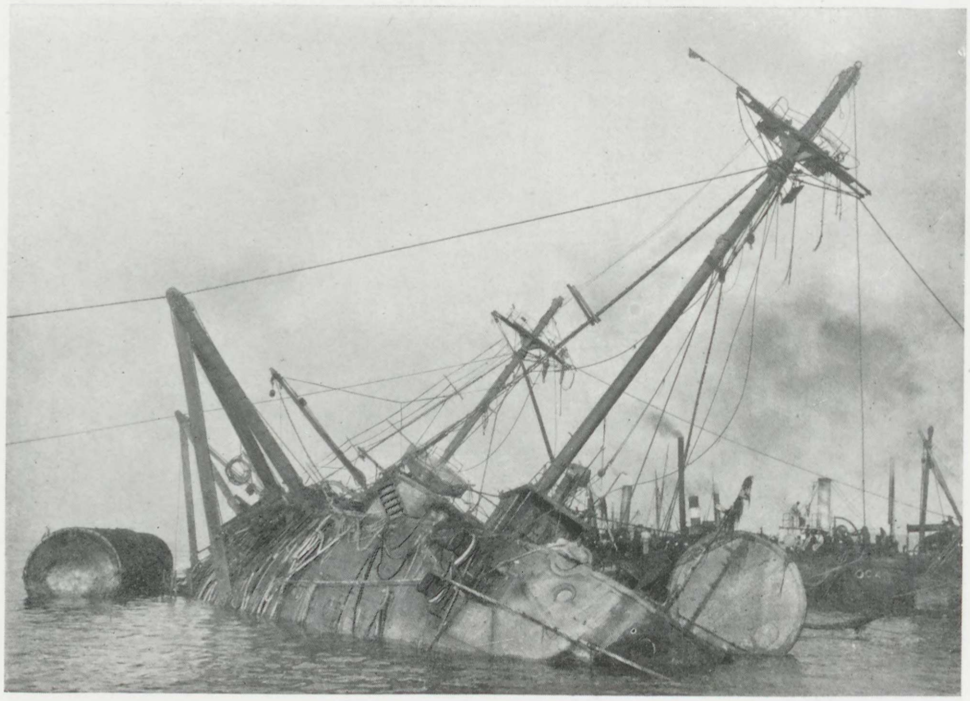

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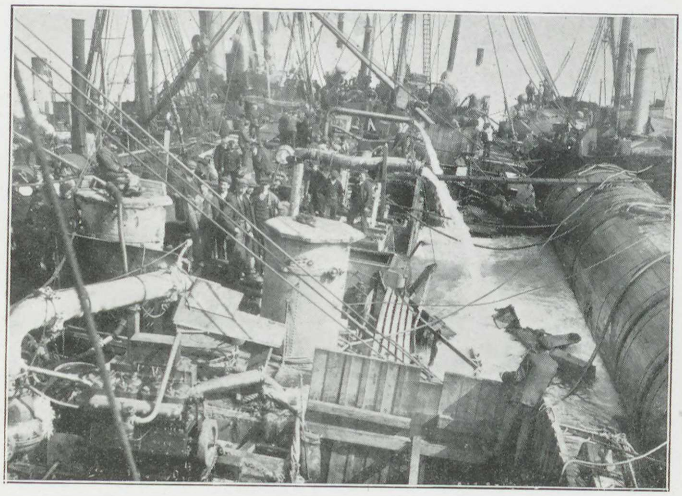
Photo No. 62.

The Ship righting. The tripods are clearly shown.

bined with the salvage vessels' pull on the cruiser's mastheads through the tripods, and assisted by the 280 tons of counterpoise weight already described, caused the *Gladiator* to steadily rise towards the vertical. The simultaneous working of all these devices proved most successful, the ship ultimately righting from 70 deg. to 7 deg. to starboard.

Owing to the small fall of the tides and to the limited freeboard, the upper deck was dry only on the port side, the starboard side being several feet under water. It was thus impossible for the pumps to make much headway towards floating the ship, and it was therefore decided to build cofferdams to enclose the whole of the after upper deck, and to construct similar ones between the deck casings over the three boiler uptakes and the engine-hatch. Thus a wooden wall was built almost right fore and aft on the starboard side. This made it possible to place pumps on the boat deck and to remove the water inside the coffer-dams to the upper-deck level, and afterwards several pumps were placed on this level to give them greater power in working the lower compartments. At the final, or completely successful, attempt to float the vessel, all available pumps were at work. On the starboard side three pontoons (50ft., 40ft. and 75ft.) were left in position, the two bow pontoons having been removed to allow one of the salvage boats to get alongside. The larger pontoon was placed opposite the damaged shell-plating. Another of the salvage steamers took up her



Copyright. **Photo No. 63.**

CENTRIFUGAL PUMPS AT WORK.

position on the port side of the cruiser, and there were also the two check-pontoons, one of them partly filled with water to counteract the starboard heel (6 deg.) of the ship. In this way, with the pumps kept going at their fullest capacity, with a salvage steamer on either bow, each vessel having round it a steel-wire strap, connected by cable to masthead tackle to assist in keeping the vessel upright, the *Gladiator* was towed into Portsmouth Dockyard. Thus ended one of the most difficult salvage operations ever undertaken. The work was carried out under the supervision of Captain Fred Young, of the Liverpool Salvage Association, who had as his assistants Captains Williams and Wilson. The pontoons and other special appliances were constructed by the Naval Authorities at Portsmouth Dockyard.

A very full account of these operations appeared in ENGINEERING, *9th October*, 1908.

H.M.S. "GLADIATOR."

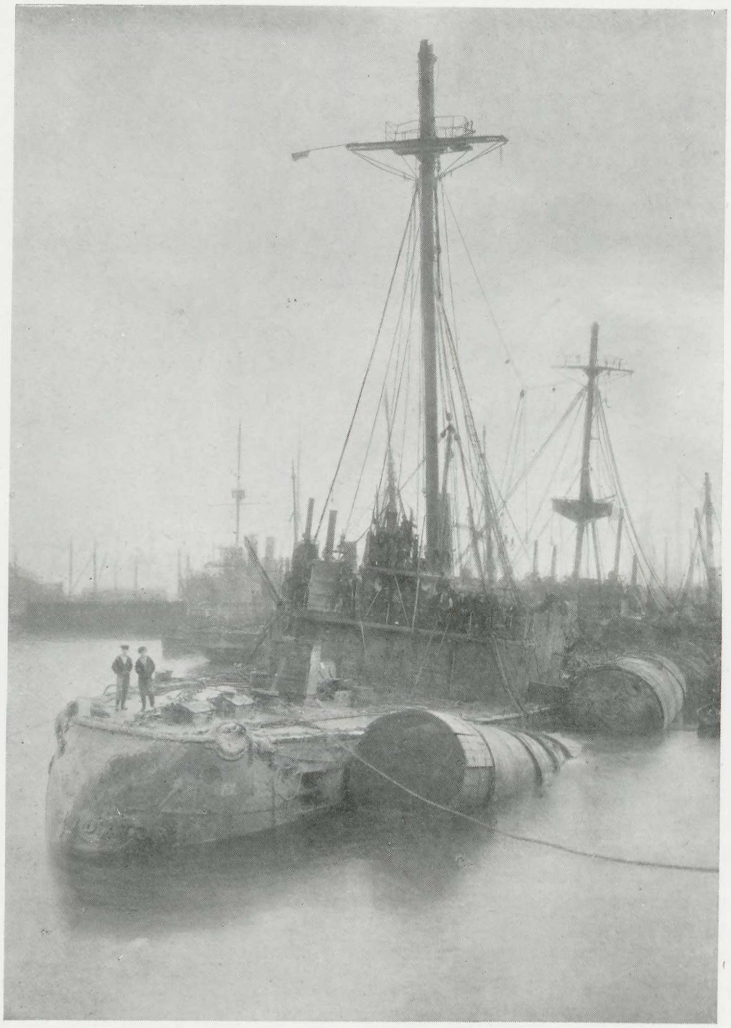


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Photo No. 64.

The Vessel afloat. Two of the Pontoons alongside.

SALVAGE OF S.S. "KOTTINGHAM."

(See description, page 140.)

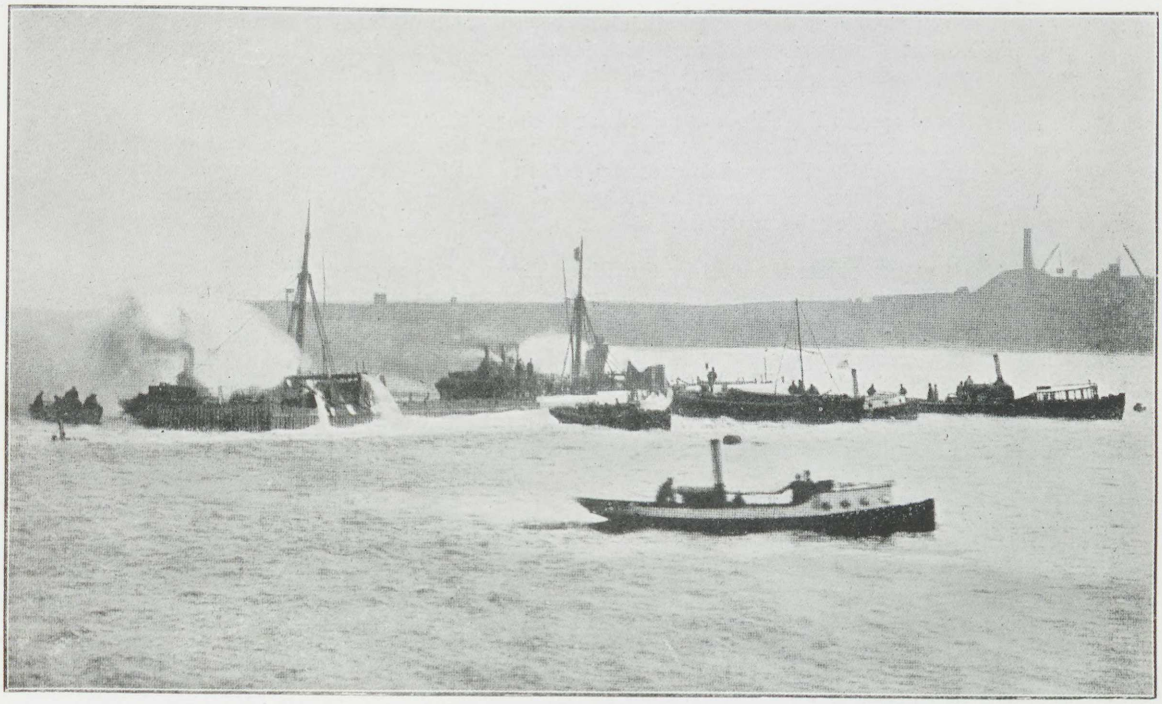

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Photo No. 65.
Pumping Operations.

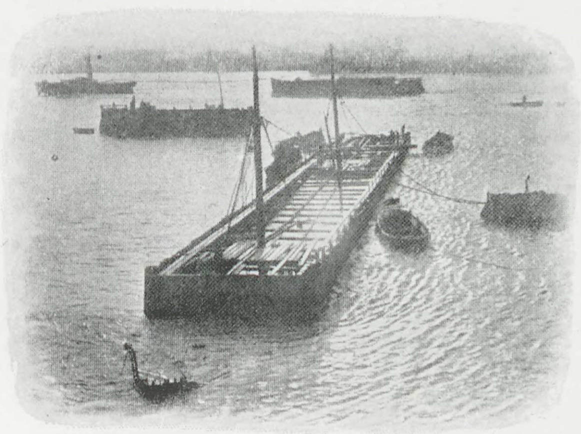

Photo No. 66.
Ready for Raising.

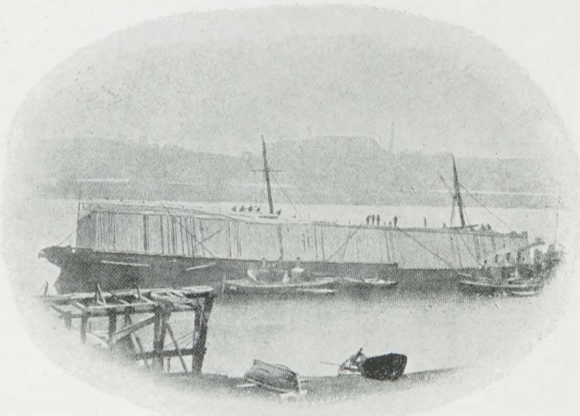

Photo No. 67.
Beached.

S.S. "Kottingham."

The photographs on the preceding page give a good idea of one of the methods employed in the raising of sunken vessels. The s.s. *Kottingham* had gone down in the fairway of the busy waters of the Tyne, and the East Coast Salvage Company, of Leith, were called in to remove the serious obstruction to navigation.

A WOODEN COFFER-DAM was built and attached to the sides of the vessel, the hull being meanwhile made watertight, and the Centrifugal Pumping Engines were set to work to pump out the water enclosed within the walls of the coffer-dam and the hull of the ship.

By these means the ship was raised, and after being drawn in towards the bank, she was beached at Jarrow. The larger photograph shows the pumping operations, the volume of water delivered by the Pumps being amply demonstrated. The two smaller photographs are views of the vessel before and after raising, and show the way in which the coffer-dam was used and the extent of the structure.

Thames Conservancy Lifting Lighters.

The LIFTING LIGHTERS used by the River Thames Conservancy Board have done excellent work. These lighters are built on a system of construction similar to that applied to ordinary dredgers, having an arrangement of watertight compartments running the whole length and breadth of the vessels.

A well, or open space, is provided through the centre of the lighter, 60ft. long, 2ft. in breadth at the bottom, and 1ft. 6in. at the top. At the top ends of the well, stiff athwart-ship bulkheads are placed, making the foremost and after compartments perfectly watertight. The sides of the well are plated in similar manner to the ordinary side plating, and six watertight compartments are formed on each side of the well before the fore and after bulkheads.

Other arrangements are made to ensure great strength in construction, with the result that ample longitudinal and vertical rigidity is provided to withstand very heavy lifting strains, leaving at the same time sufficient surplus buoyancy to lift 400 tons with each lighter.

Russian Ironclad "Vladimir."

Colonel Gowan, who cleared the harbour of Sebastopol of the wrecks which had purposely been sunk by the Russians during the Crimean War, successfully raised the *Vladimir*, a large ship, which, being filled with mud, weighed about 5,000 tons. For this operation he constructed four large PONTOONS or CAISSONS, each about 100ft. long, 65ft. wide, and 22ft. deep. At each end of the pontoons were fixed two wheels on iron pedestals, over which lifting chains passed. The pontoons being constructed in watertight compartments, water was let into the after compartment to counterpoise the lifting weight. On each pontoon was fixed a portable steam-engine of 15 horse-power, to work the powerful centrifugal pumps and the winches. The chains were of 2½in. best quality iron. Some difficulty was experienced at first in passing these chains under the keel of the wreck, but by means of a scraper, which was pulled backwards and forwards, a passage, or channel, was made, through which was passed a light chain, to which a heavier chain was attached, and which was brought into position by these means.*

S.S. "Prince Consort," H.M.S. "Partridge," etc.

Many other means of raising vessels have been adopted with success. Where the vessel is very small, it may be filled with empty watertight casks, which will be almost sufficient of themselves to raise it in many cases. Air bags or indiarubber pontoons have been successfully used in many instances, both when introduced into the hold or when attached to the sides of a wreck. The *Prince Consort* paddle-steamer, of 607 tons gross register, was in this way raised some years ago at Aberdeen, the deadweight lift being about 560 tons. Of smaller vessels raised by these means may be mentioned the brig *Ridesdale*, 170 tons, sunk off Calshot Castle; H.M.S. *Partridge*, of 180 tons; and the brig *Dauntless*, of 179 tons.

S.S. "Wolf."

Passing to accounts of the methods by which some notable lifts have been made, one of the earliest cases of the raising of an iron ship was that of the *Wolf*, a paddle-steamer, 243ft. long, by 27ft. beam, and 13ft. 8in. in depth.

* For description of another plan, see page 130.

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THE WRECK OF THE BATTLESHIP "ROYAL GEORGE," 104 Guns, sunk at Spithead, 1782.
Divers worked at the wreck, recovering guns, etc., during six Summers, 1839 to 1844 inclusive.

This vessel was run into and sunk in Belfast Lough, in about 45ft. of water, and ten miles from the shore. An examination of the wreck showed her to be embedded in clay, and the rise and fall of the tide being only about 9ft. at springs and 8ft. at neaps, there was very little assistance to be looked for in that direction. Messrs. Harland and Wolff, of Belfast, who undertook to raise her, had previously been engaged in raising the *Earl of Dublin*, and the pontoons used for that vessel, six in number, and having a combined buoyancy of 500 tons, were fortunately available. In addition to these, two larger pontoons, each 70ft. long by 12ft. wide by 9ft. deep, each containing 7,560 cubic feet, and each having a displacement of 216 tons, were constructed. Each of these pontoons was divided into six watertight compartments, so that each or all of them could be filled with water or pumped out as desired. Thus the lifting power employed had a buoyancy equal to about 932 tons, the deadweight to be lifted being estimated at about 850 tons.

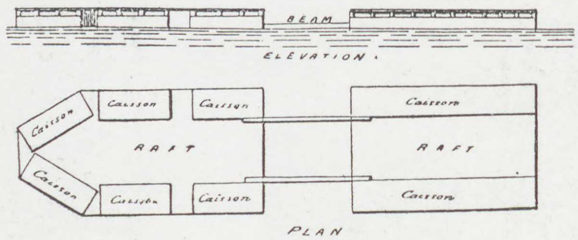


Fig. No. 68.

The six smaller pontoons, or caissons, were placed together and rafted over at the head of the sunken ship, and a similar raft or floor was constructed upon the two larger pontoons, which were floated to the after end of the wreck. These two rafts were afterwards connected by two stout beams fore and aft, binding the whole of the pontoons into one floating platform of the size of the vessel below. Cross logs or joists had been laid across the pontoons in such a manner as to correspond in position with the side ports of the wreck, through which holes the lifting chains were afterwards passed by the divers. Of the ports there were twenty-five on each side, so that each had to bear a strain of about 17 tons. In each of the angles formed by the projecting ends of the joists and the sides of the pontoons was fitted a box bracket of wrought iron, carrying a hexagonal cast-iron sheave about 10in. diameter, grooved for the links of the lifting chains, which were of 1½in. diameter, and the links 10½in. long, over all.

On the top of each joist, two screws, each 5ft., 3in. diameter, and of ¾in. pitch, were fixed, one on each side, by which to tighten or take in the lengths of the chains. The lower ends of the chains were fitted with hooks to take hold of the vessel through the side-lights.

About 200 men were employed at first in putting the pontoons into place, putting down the cross-joints, or flooring, etc., and afterwards about 100 men to work the screws, etc. On taking in the chains by means of the screws and pulleys, the wreck was lifted and carried about 6ft. on the first day, but a nasty sea springing up, two of the lifting chains gave way, letting the fore ends of the two forward pontoons burst up, and breaking three of the cross-joints and the top of the starboard pontoon, whilst the port pontoon was bent in by the extra strain thus brought upon it. This necessitated the filling of the fore-compartments of each of the forward tanks to relieve the strain on the bows, whilst the divers went below to re-couple the chains. Other trifling difficulties occurred on the following day, but the wreck was continually moved for short distances and grounded, until, on the thirty-fifth day, the wreck was towed into Abercorn Basin. The number of tides in which the vessel was actually moved was fifteen; the other tides were employed in putting right the various little mishaps that occurred. The wreck, 850 tons in weight, had been lifted 45ft. and towed ten miles, the total cost of the operations being about £6,000.

ACCOUNT OF A SUCCESSFUL DEEP-WATER SALVAGE OPERATION OF FORTY YEARS AGO.

S.S. "Taranaki."

The screw steamer *Taranaki*, 229 tons, lost in Queen Charlotte's Sound, New Zealand, was raised from a depth of 105ft. by means of four pontoons. The wreck lay in 105ft. at high water, in a sheltered position at Bowden's Bay in the sound. The bottom, where it lay, had a rise of 6ft. in the vessel's length, and went on at this slope ahead for about 60ft., when it rose suddenly up a steep bank, inclining with a rise of 30ft. in the length of the vessel (some 190ft.). This bank got still steeper near its summit, and had over it a depth of water of 21ft. at high tide. The depth then increased to 24ft., and then shoaled very gradually towards the shore for 600ft. This bank added much to the difficulty of raising the wreck. The range of tide is small, at springs being 4ft. 6in., and at neaps 2ft. 6in. Two Divers were employed, and an average of fifty-four men worked during the operations. The weight to be raised was approximately 400 tons. The floating power provided was four timber pontoons of the following dimensions: Two of them were 95ft. long on deck and 91ft. on bottom; the other two were 85ft. long on deck and 91ft. on bottom; all four were 14ft. wide on deck, and 12ft. 6in. on bottom, and their depth was 8ft. They had three watertight bulkheads in each, and had valves in bottom, and pumps. They were built of kahikatea, or New Zealand white pine, at Picton. The bottoms, sides and decks of the pontoons were formed of 2½in. planking; the side and floor timbers, which measured 8in. by 6in., being placed 2ft. apart, while the deck beams, which measured 7in. by 7in., were placed 4ft. apart. The deck was further stiffened by a 6in. by 5in. longitudinal stringer placed beneath the deck beams, and supported by 5in. by 4in. upright posts interposed at intervals between it and the keelson. The scantling of the latter was 8in. by 6in., and that of the bilge pieces 9in. by 6in., whilst at the corners formed by the junction of the sides with the deck and bottom were placed covering planks measuring 14in. by 8in. and 14in. by 6in. respectively.

They were moored two on each side over the wreck; and across them, and extending over the wreck, lay twenty-two beams of the same timber as the pontoons. Each beam was of two pieces, each 18ft. by 9in., and placed on edge 5in. apart, and bolted together. The lifting rods were forty-four in number, half on each side of the sunken vessel; they were of round iron 1¼in. diameter, in long links 12ft. long, coupled by short double links. The top link was divided into three, the uppermost of which was double, composed of two bars, each 4in. by ⅝in., and pierced with 1½in. holes, 4½in. apart. This was the fleeting link used for adjustment of length of lifting rod. As the vessel rose, the links, as required, were taken out by the Divers. The top of the fleeting link was attached to the lifting screw, which was of 2⅜in. iron, and screwed for a length of 2ft. 3½in., with four threads to an inch. A nut on this was worked by two or sometimes three men with a lever 5ft. long, of 1½in. iron, with an eye fitting over the nut. The nut bore on an iron washer, resting on a hard wood block, lying on the cross beam. To allow for oscillation of the rod, the washer was composed of two parts; the upper of wrought iron, was rounded at the bottom and fitted in a turned, rounded recess in the lower part, which was of cast iron.

Counterbalance weights poised the rod when adjusting or fleeting the screw. These hung over sheaves in the cross beams betweenthe pontoons. At the bottom of each rod was a strong wrought-iron hook, to take hold of the portholes or side lights. This hook was of 3¾in. by 1in. iron, thickened where it took hold of the plate of the wreck to 2½in. An ingenious stop or catch took hold of the lower edge of the porthole, and prevented the hook from falling out. This was attached to the hook by two pinching screws, and was adjusted by the Diver after the hook was placed. It was found to act well. An open iron cage was let down for the Divers to stand in, and adjusted from the pontoons to the position wished. In lifting the wreck all the screws on one side were raised 1ft., or half the lift; then those on the other side taken up 2ft., or the full lift, and then the remaining foot of lift on the first side taken up. In fleeting, four screws were fleeting at once, one in each pontoon at alternate ends.

The pontoons were moved in position, and all the rods fixed and gear ready. On the 7th of August, when the first lift was made by letting water into the pontoons, and pumping out as the tide rose, having first screwed down tight, she started out of the mud with a sudden lift of 6in. This day they got a lift of 5ft., and hauled ahead 50ft. After getting her to the slope of the bank before mentioned, it was found that when allowed to rest on the ground she slipped back, owing to the rise, the bow being 30ft. higher than the stern; so after this time they had to lift by the screws, and keep her carried from the pontoons. They lifted at each lift rather more at the stern than at the bow, so as to get her again on level keel, and also hauled the stern side-on to the bank. They went on lifting the fore end about 3ft. and the after end 4ft. on the days they worked the screws, till the 21st of September, when she floated over the bank, and went some 300ft. ahead towards the shore.

On the 22nd the rail was up to the cross logs, which were then packed up, and by the 26th of September, 1869, the leaks and portholes were stopped up, and the *Taranaki* pumped out. She was found to have a rent in a plate 3ft. long by 1in. wide, and near it a hole 3in. diameter, with a piece of rock in it; both these were in the engine-room compartment. She had sunk by the stern seven hours after she struck. The fore compartment seems to have remained tight, as the deck beams and fore-hatches were forced in by the pressure of water when she went down. The boiler was also much damaged by the upper part being collapsed. She had been down over thirteen months in $17\frac{1}{2}$ fathoms of water, and the upper decks were completly worm-eaten by the boring-worm. The hull was coated with barnacles and shelly incrustation, but the engines were uninjured, and the bearings were bright and clean. The cast-iron work was unhurt, the wrought-iron starting gear tarnished, but not so as to damage it; one of the cylinders was full of water, the other empty. The cargo was sadly deteriorated. She had been raised 92ft., nearly all by the screws. Her hull was reported quite sound, and she was refitted and repaired at Wellington. The total cost was close upon £3,000.

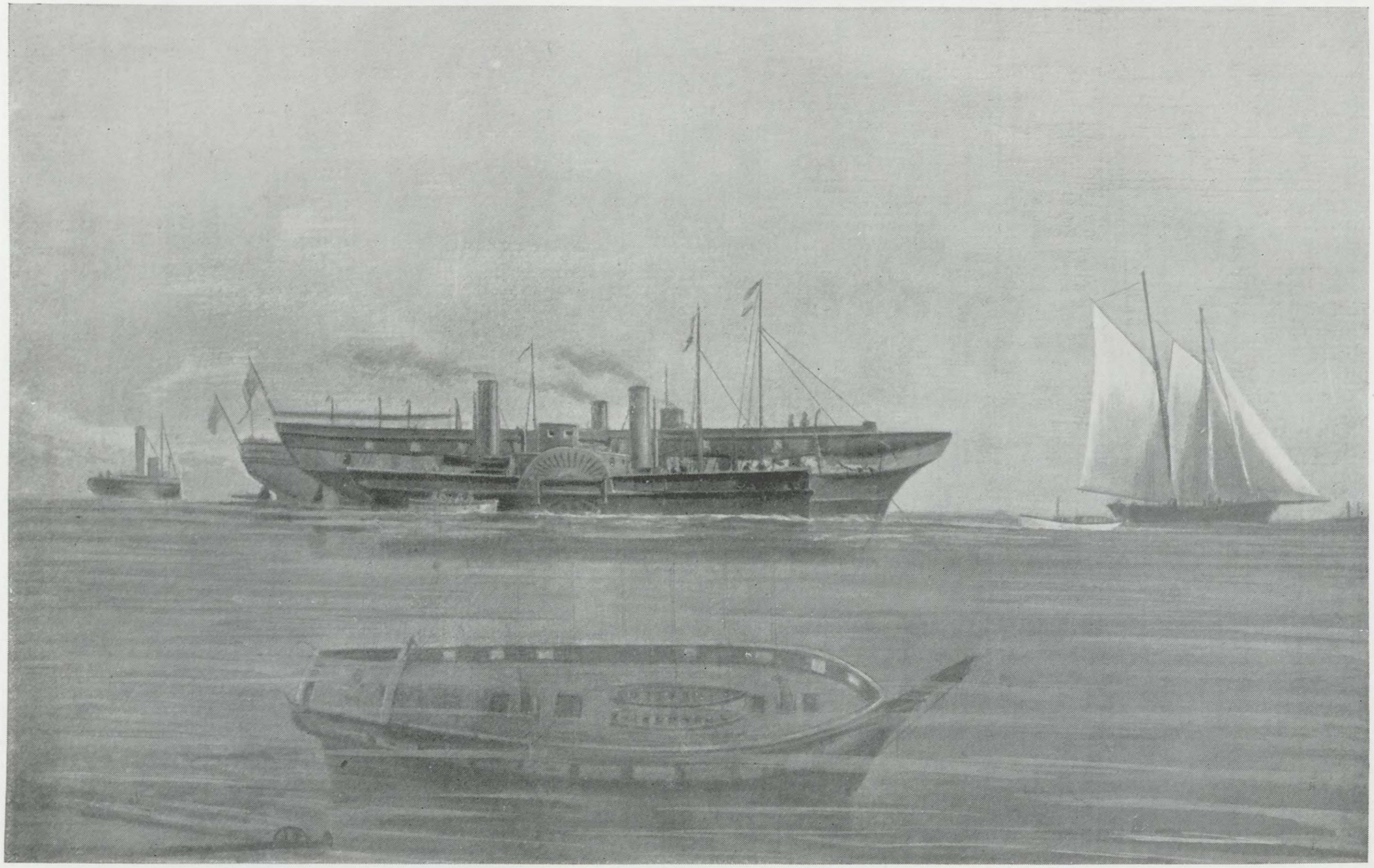
"Locksley Hall."

The "Locksley Hall," sunk in the River Mersey.—This iron ship, 227ft. in length, 1,356 tons gross, was sunk by falling foul of the bows of a steamer lying at anchor, and was a source of danger to passing vessels. The Mersey Dock and Harbour Board proposed to disperse the wreck by means of explosives, but the Mersey railway authorities objected to this being done, the wreck being in proximity to their newly constructed tunnel, which it was thought the use of explosives might injure. A syndicate undertook to lift the vessel and carry it into shallow water for the sum of £15,000. The dead-weight of the wreck was calculated at about 1,000 tons, and the weight of the cargo at about 1,400 tons. Some of the latter had been already recovered, and it was estimated, therefore, that the total weight to be raised was about 1,800 tons. Four hulks were purchased, each capable of lifting 500 tons, leaving a margin of 200 tons buoyancy for contingencies. The ropes used were of flexible steel wire, 9in. and 7in. diameter.

The lifting ropes were placed under the wreck by a sawing kind of operation, conducted from two tugs, the bearing surfaces of the hulks being protected by rubbing pieces of timber faced with plate iron. At the first lift, the hulks, rising with the tide, lifted the wreck, and were towed into shallower water. The work was finished in six weeks from the signing of the contract.

German Ironclad "Grosser Kurfurst."

An interesting case was that of the *Grosser Kurfurst*, a German war vessel, sunk near Dover by collision with the *Konig Wilhelm* in the year 1880. An attempt to raise this vessel was made by a London Wrecking Company. The general features of the plan proposed by the Company's experts were approved by the Admiralty on behalf of the German Government, and there is but little doubt that the vessel would have been raised had not the Company itself gone into liquidation. The *Grosser Kurfurst* was sunk in twenty fathoms in the stream of the tide, and right in the fairway of the channel. She was turned completely over, keel uppeımost, but was found to be holed in one place only, on the port quarter below her armour plating. This hole was covered by an iron shield, on the rim of which a hollow channel iron was riveted. An indiarubber hose pipe capable of withstanding a very high pressure, was packed into this channel, and as soon as the shield had been firmly fixed



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No. 69.

H.M.S. "EURYDICE."

(*See page 146.*)

into its place water was forced into the hose so as to fill up all the irregularities between the shield and the skin of the vessel, and to form a watertight joint. Wire cables were then stretched along the vessel's keel, and fastened with chains at the bow and stern. The stays from her ports on either side were brought across the fore and aft wire cables every 10ft. along the length of the ship, and were securely fastened where they crossed.

It was then proposed to apply 1,000 tons of lifting power on these cables by attaching sunken flexible pontoons to them, and then pumping the pontoons full of air. This was intended only as a steadying power to prevent the vessel from turning over when lifted. These preparations being completed, the vessel herself was to have been pumped full of air, thereby getting her full displacement, and plans for towing her to a safe place and there turning her upright had been prepared. The plan, however, was never completed. The shield was fixed and a number of lines placed in position to guide the descent of the pontoons, and one of the pontoons had been actually attached to the ship; but the Company had to cease operations for want of funds. Thus a very interesting salvage case, which gave promise of being entirely successful, had to be abandoned just when the most difficult part of the work had been practically completed.

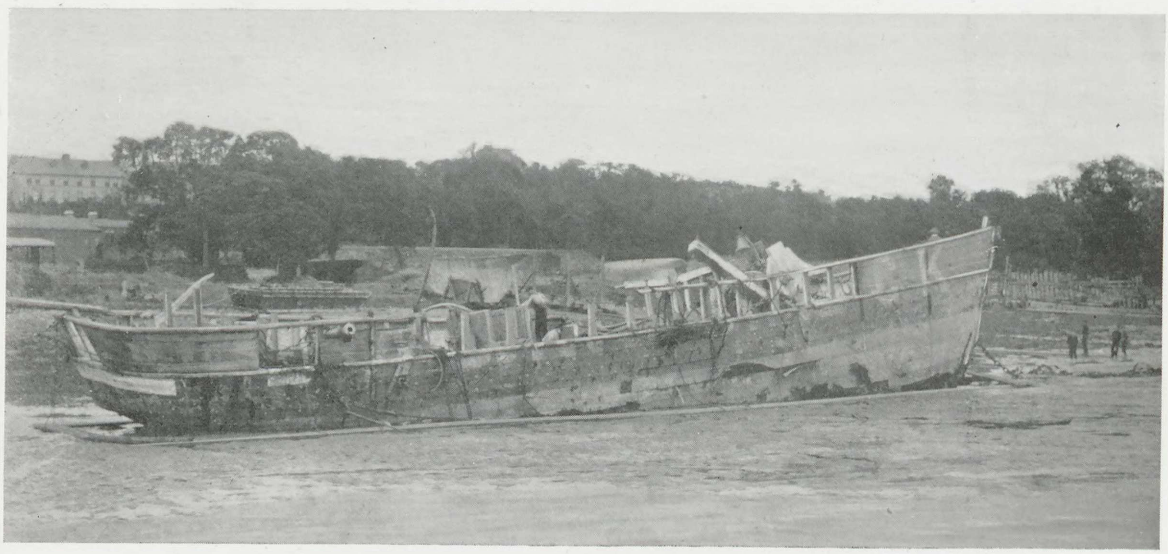
H.M.S. "Eurydice."

H.M.S. *Eurydice,* sunk off the Isle of Wight, was raised by having oak toggles placed inside each porthole, and to which were attached wire hawsers carried up to two lifting frigates, which were moored over the wreck. Siebe, Gorman and Co. had eight divers working in conjunction with the Admiralty divers at the wreck, which lay in 15 fathoms=90ft. of water, and the entire operations were carried out without a single accident, although the vessel was lying in a very exposed position. (See photo, page 145.)

Lightship "Puffin."

The *Puffin* was a composite lightship stationed at Daunt's Rock, off Cork Harbour. During a severe gale on 8th October, 1896, she disappeared with all hands, being found a few days later sunk at her moorings in 15 fathoms, low water.

After some months, the Irish Lights Commissioners contracted with Messrs. T. Ensor and Son, Queenstown, for her recovery. This, owing to the very exposed position and strong tides, was a difficult work; even in summer very few days could be worked, and these only during *slack tide.*



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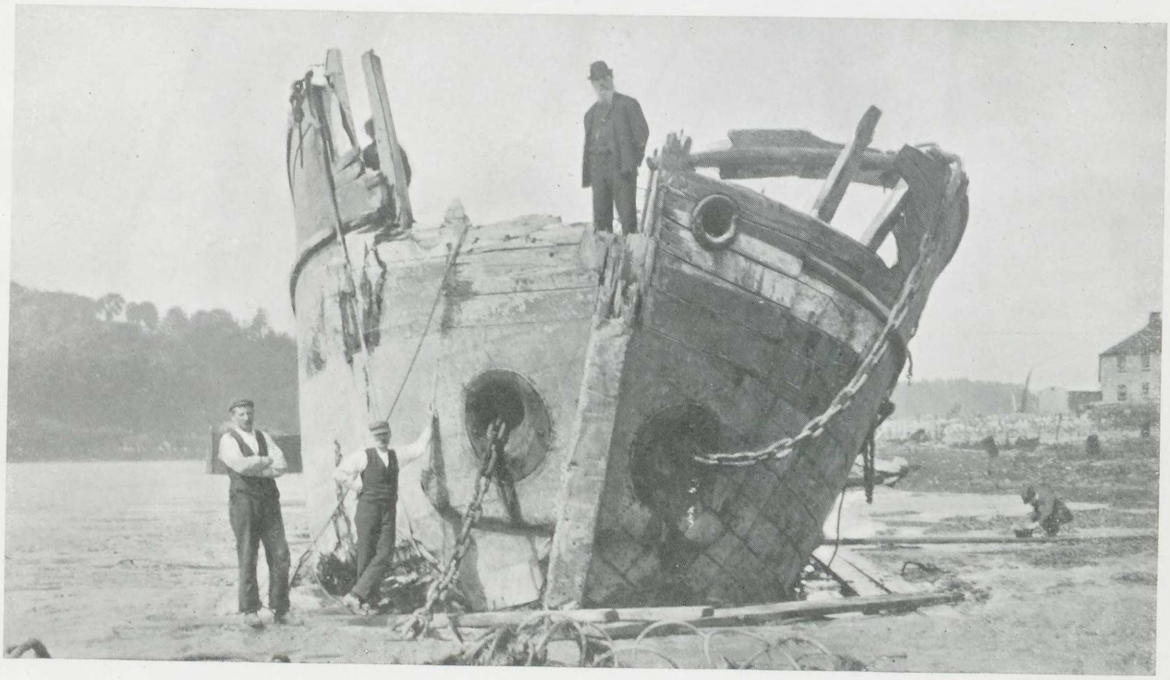
THE "PUFFIN" BEACHED.

When the slinging was complete, the lifting hulk was moored over the wreck, and her six wire purchases were lowered down and shackled on by the Divers to the slings already attached to the ship. The wreck was then hove up and towed towards the harbour. The first lift got the *Puffin* into eight fathoms=48ft., and the second took her right into the harbour, nearly six miles from where she first lay.

While lying on the sea-bed during the winter, the bottom of the wreck was all ground away, so that when lifted she presented the appearance seen in the photos, which show the *Puffin* lying on the beach near Queenstown. The entire operation of lifting the *Puffin* was under the personal supervision of Mr. H. T. Ensor, who also surveyed the wreck, when first located, for the Irish Lights Commissioners.



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ALL THAT WAS LEFT OF HER. ("Puffin.")
It will be seen that her bottom was ground completely away.

TWO INTERESTING SALVAGE CASES.

We give on pages 148 and 149 photos of two very interesting Salvage Cases which were entrusted to the East Coast Salvage Co., Ltd., of Leith, and which were brought to a successful conclusion.

It is nearly 30 years since Mr. Armit founded the East Coast Salvage Company, first at Dundee, and over 20 years ago at Leith. His previous experience as a wreck-raiser at home and abroad was extensive, the recovery of the great wreck of the ill-fated Tay Bridge being a prominent feature in his busy life.

The East Coast Salvage Company, Limited, possesses a valuable plant. Their specially built twin screw Salvage Steamer, "*Wrecker*," 451 tons register, is admittedly one of the ablest and most useful Salvage boats in the United Kingdom. Her accommodation for about 40 artificers is greatly admired. In addition to 12 Centrifugal pumps capable of throwing 5,500 tons of water per hour, the Company has six complete outfits of diving gear, with specially built diving boats, pneumatic engines and drilling gear, together with all the paraphernalia of under-water building plant, a method of ship-raising of which Mr. Armit has long been a prominent exponent.

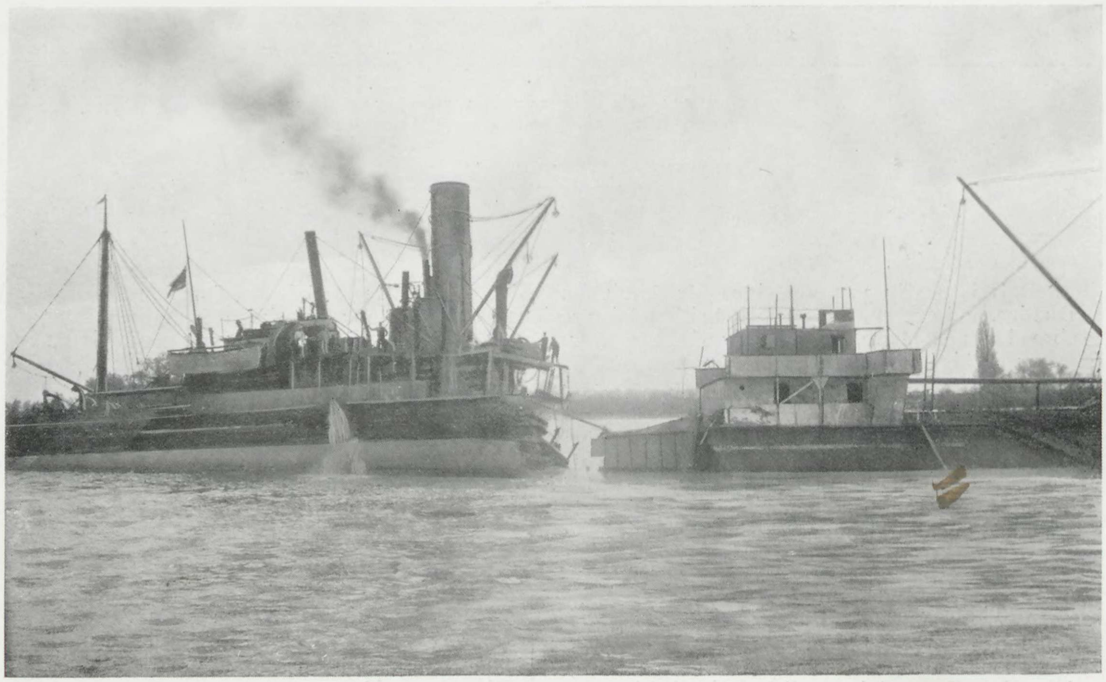
PRINCIPAL SALVAGE ORGANISATIONS IN EUROPE.

The largest Marine Salvage organisations in Europe are the following:—

London Salvage Association, London.
Liverpool Salvage Association, Liverpool.
The East Coast Salvage Co., Ltd., Leith.
The British Marine Salvage Co., Ltd., Glasgow.
The "Neptune" Salvage Co., Stockholm.
The Svitzer Salvage Co., Copenhagen.
Mr. Henry Ensor, Queenstown.

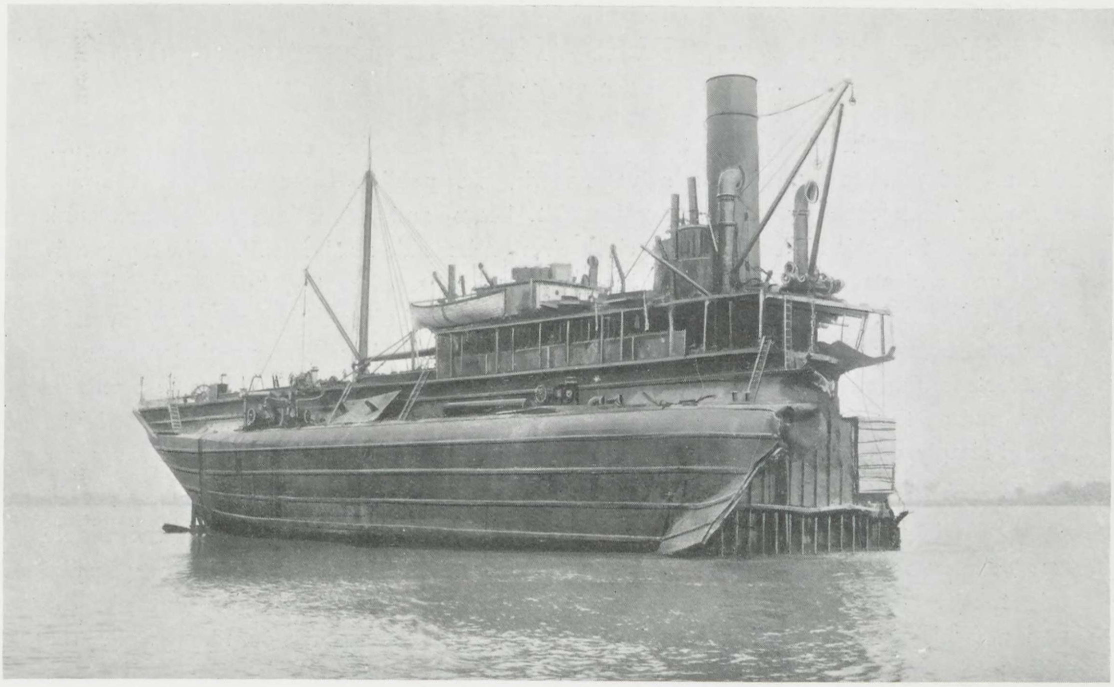
Copyright. Photo No. 70.

S.S. ANGLIA, Cable Steamer, ashore, County Down, Ireland, 1907.
Floated by the East Coast Salvage Co., Ltd., Leith.



Copyright. Photo No. 71.

S.S. MONTGOMERY, sunk and broken in two, River Garonne.
Floated by the East Coast Salvage Co., Ltd., Leith.



Copyright.

Photo No. 72.

S.S. "MONTGOMERY," after end floated.
Raised by the East Coast Salvage Co., Ltd.. Leith

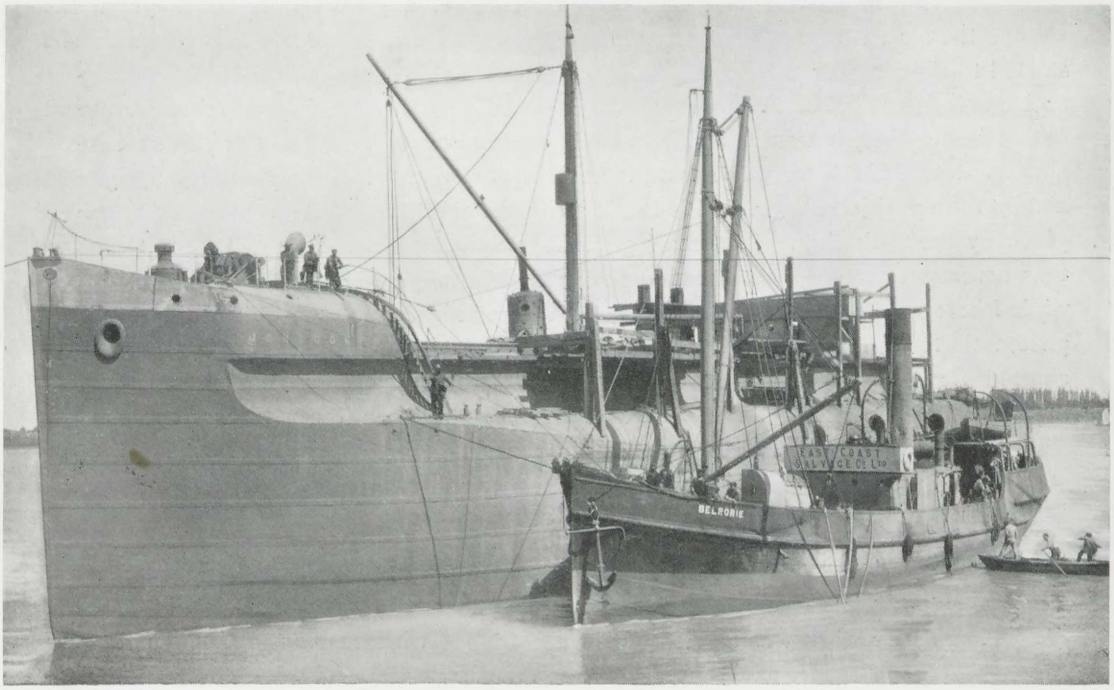


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Photo No. 73.

S.S. "MONTGOMERY," fore end floated.

Salvage of the s.s. "FLESWICK" by Compressed Air.

(See page 151.)

To show the great advantage which, under favourable circumstances, attends the use of compressed air for salvage work, we publish three views of the s.s. *Fleswick*. This steamer, 180ft. long by 28ft. beam, and laden with coals, was sunk by collision in Cork Harbour, going right over on her side as she sank. She lay nearly right across a strong tide, with her bow in about 26ft. of water, her stern being in about 40ft. L.W. spring tides. Photo 74 shows the ship before lifting on a very low tide. The contract for raising this ship was given to Messrs. Thos. Ensor and Son, salvage contractors, Queenstown. The nett underwater weight to be handled was just on 600 tons, and as the contractors judged that to sling the ship with wires and lift with hulks would simply wreck the entire upper works of the ship, they decided to try air for lifting her, and also to assist in turning her over.

Having covered the two hatchways about 28ft. by 15ft. each down to the middle line with plates, and stopped up ventilators, etc., on the starboard side, it was possible to get some 400 tons of air lift in the holds. The engine and boiler space down to the casing (which was not good enough to hold air) gave another 60 tons, while the after-peak and cabins gave about 40 tons. Owing to the small amount of air space aft, it was found necessary to put a hulk right aft to assist, and the wire from this hulk crushing the main rail and bulwarks, caused the only damage done to the ship in lifting.

Heaving-in plant having been rigged on shore, a good strain was kept on the ship as the air went into her, and when nearly full of air, to middle line forward, she started to slide in over the mud. Photo 75 shows the ship at about half-flood. It may be noticed that the excess of air over weight forward has lifted her bow some 3ft. more out of water than it was at low water. The ship having been brought into sufficiently shallow water, her stern was hauled in to bring her parallel to the shore for uprighting and into the position shown by Photo 76. With the exception of the 20 tons or so of lift given by the hulk right aft, the air gave all the lifting power required to shift the 600 tons actual weight from the position shown in Photo 74 to that shown in Photo 76, while Photo 75 shows all the plant used. Two small air compressors intended for driving pneumatic tools, and having a united capacity of about 200 cub. feet free air per minute, sufficed for the job, the large compressor specially rigged for this job never being used at all. The use of air in this case not only reduced the risk of breaking the ship in two where the collision had cut into her funnel, but entirely avoided the destruction of bulwarks and deck structures which must have followed had wires been used to handle the weight.

Compressors delivering about 210 cubic feet of air per minute were found sufficient for the job.

The entire work was carried out in accordance with the plans and under the personal supervision of Mr. H. T. Ensor.

S.S. "FLESWICK." *(See description, page 150.)*

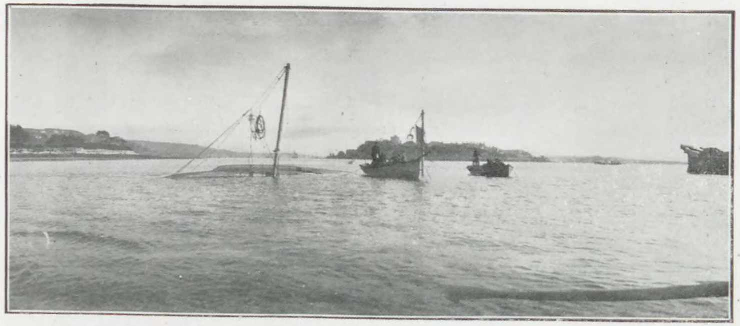

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Photo No. 74.

Before lifting, looking from mastheads towards deck. Low water.

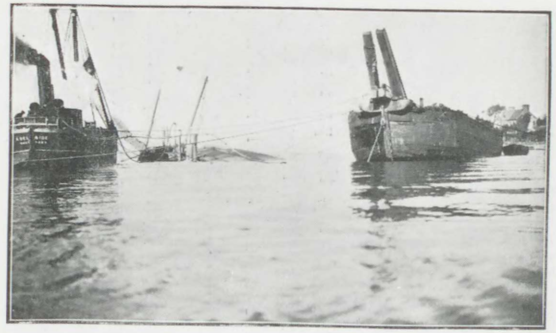

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Photo No. 75.

Last lift. Ship being hauled in aft into position for uprighting. Taken about half flood.

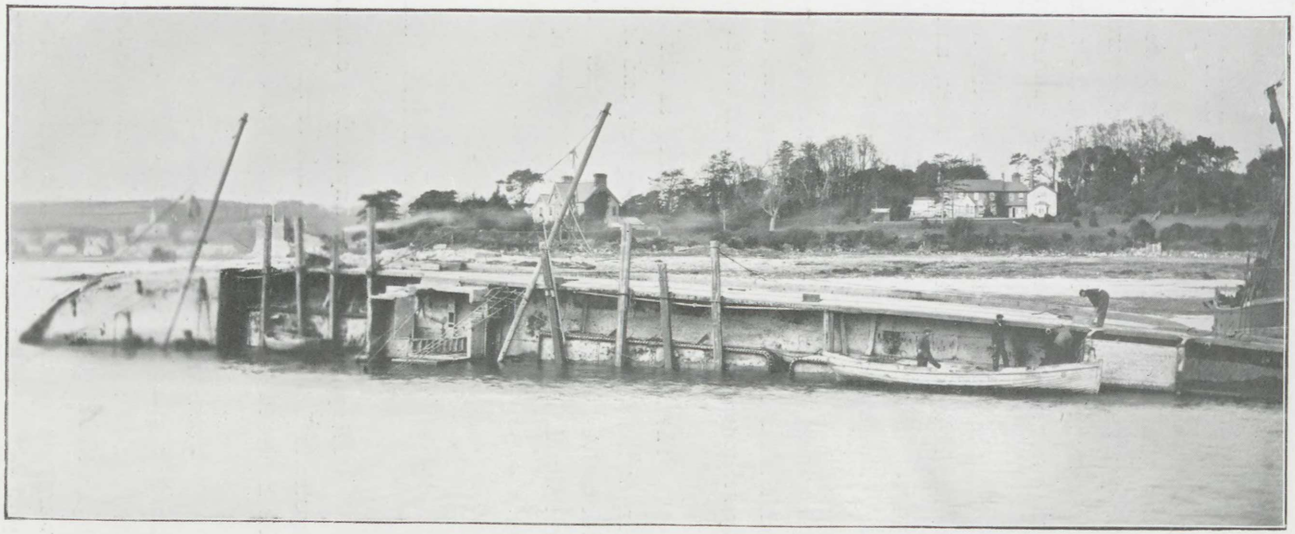

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Photo No. 76.

After last lift. Low water view of deck, showing plates on after-hatch and hook-bolts securing same to coamings.

SUBMARINE COMMERCIAL INDUSTRIES.

PEARL, SPONGE, CORAL AND AMBER FISHERIES.

The pearl fisheries of Australia have developed greatly during the past twenty-five years, until at the present time several thousands of men, with from 800 to 900 luggers are engaged in the industry, the annual yield of Mother-o'-Pearl shell alone being valued at considerably over a quarter of a million pounds sterling.

The principal fisheries are on the north-west and north-east coasts, Broome, W.A., being the centre of the former, and Thursday Island, Torres Straits, of the latter. There are smaller fisheries with stations respectively at Onslow, Shark's Bay and Cossack on the West Coast, and Port Darwin in the Northern Territory.

The luggers are of 10 to 12 tons, each carrying one Japanese or Manila diver, with a mixed crew of four or five, and are worked in groups of six to eight attended by schooners of 60 to 120 tons, from which the luggers are provisioned weekly.

The Pearl Oyster (classified as the *Avicula Margaritifera*) is an oyster slightly larger than the European congener, and is valuable for the pearl it bears, the shells themselves being of no commercial value. These are found more or less in all parts of the world, but principally on the Coasts of Ceylon, Western Australia, Panama, and some parts of Mexico and California.

THE PEARL.

The pearl is really a tiny nucleus coated with films of carbonate of lime. The oyster is well provided with this secretion, with which it lines its shell, and which, in its hardened state with which we are familiar, is called nacre, or mother-of-pearl.

Now, the oyster is extremely sensitive to irritation, and the tiniest grain of sand or other foreign particle that may find its way into the valves causes the mollusc to exude its secretion and cover the intruding particle with layer upon layer till it is as smooth as the inside of the shell itself. Similarly, when a "borer" worm or other prey of the oyster has succeeded in boring through the shell, the mollusc will plug up the hole with nacre, continuing to spread layer upon layer until the aperture is made impregnable. If now we opened the shells, we should find a pearl adhering to one of them.

But the more valuable pearl is that which is found loose inside the mantle of the oyster, or perhaps but very slightly attached to it. Sometimes one of the ova is lifeless, and is not exuded with the rest at spawning time. Although infertile, it is still supplied with nutriment from the parent body, and gradually increases in size. It then hardens, and so becoming a source of irritation, the mollusc covers it with nacre, and thus a pearl—perhaps of great price—is formed.

The pear-shaped pearl acquires its form through the connecting link or pedicel between the stranded ovum and the body being also coated with nacre.

Amongst the Chinese and Japanese very clever methods have been used for compelling the oysters to produce pearls. Several of the live shells are collected and put in a pond of clear sea water. A wedge of steel is slipped into the open lips (oysters live with their lips open) to prevent them shutting, then a small hole is drilled through the shell from the inside; a small mother-of-pearl button is fixed into this hole, with a round knob projecting inside the shell; the steel wedge is then removed from the lips, which quickly come together, and the mollusc inside soon feels this uncomfortable button pressing into its body. Squirting from one of the cells in its mantle the liquid nacre over the button, it gradually lessens the uneven inside surface, and so produces a pearl over the button.

Month by month the shell is examined until at length a pearl is formed over the intruded button. When it is ready the oyster is destroyed, the pearl is cut out of the shell and set in some ornament where the artificial foundation can be hidden in the setting, and only the perfect top of an apparently perfect pearl is shewn.

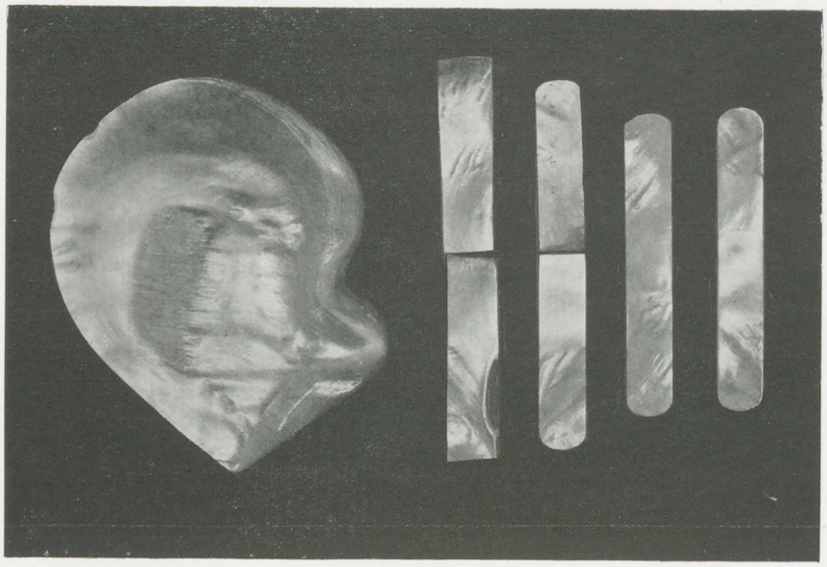
Photo No. 78.

Pearling Lugger.

(Western Australia.)

The Mother-o'-Pearl Oyster (*Maleagrina Margaritifera*) produces the largest pearls, but is mainly valuable for the shells, a single pair often weighing, when cleaned and dried, as much as 14 lbs. These abound all over the Northern Coast of Australia, Western Australia, the Eastern Archipelago, Lower Burmah, New Guinea and the South Pacific Islands.

The shells obtained are classified into four qualities: Young shells, known to the trade as "chicken shell," which are the most valuable, and average about 4,000 to the ton; "ordinary sound" quality, from 600 to 1,200 to the ton; and "wormy"—*i.e.*, worm-eaten and old—also 600 to 1,200 to the ton.



Copyright. **Photo No. 79.**

Shewing the various stages in the manufacture of a Mother-o'-Pearl Paper Knife, from the rough shell to the finished article.

It is calculated that the annual take of a single boat is seven tons, of which five tons cover the outlay, and two tons may be reckoned as clear profit. The value per ton has a wide range, varying according to the state of the home market, and may be estimated at from £60 to £200. Most of the pearls taken are of poor quality and comparatively valueless, but occasionally gems are found realising as much as £1,000, although some years ago a pair of Drop Pearls fetched over £15,000, another £5,000, whilst the famous Southern Cross Pearl realised over £15,000. Coarse ones of extraordinary size are sometimes obtained.

NATURAL (NAKED) DIVING.

The most important Pearl Fisheries employing the naked diver to-day are in Ceylon and the Persian Gulf, where many thousand persons are dependent upon the industry for their livelihood. These men frequently remain below the surface for two minutes at a stretch.

In the case of the Ceylon fisheries, the oysters brought up are divided into three equal heaps, one of which goes to the Government, one to the divers, and one to the company owning the boats, etc.

SCOTTISH PEARL FISHERIES.

It may not be generally known that pearl fishing was carried on over a century ago off the coast of Scotland, considerably over a hundred thousand pounds' worth of pearls being sent to France between the years 1760 and 1800 alone. A revival of the industry has been talked about in quite recent years. We believe the business is still carried on in a perfunctory sort of way by local fishermen.

SPONGE DIVING.

Huxley says that the sponge is "a kind of sub-aqueous city, wherein the people are arranged about the streets and roads in such a manner that each can easily appropriate his food from the water as it passes along."

It is a skeleton or flexible frame inhabited by animals of almost the lowest form of zoological life (protozoa)—a jelly-like, glutinous mass which separates from the skeleton when squeezed.

The chief Sponge Fisheries are in the Mediterranean where the divers, mostly of Greek nationality, all use diving apparatus. There are other fisheries in the Gulf of Florida, in Cuba, the West India Islands, and on the North African Coast. Some of these employ a certain number of naked divers, but in most cases diving apparatus is used. As in the case of the Australian Mother-o'-Pearl Shell, the best specimens of sponge are to be found in deep water, the shallow water fisheries having become practically exhausted through over-fishing.

Besides helmet and natural diving, there are two other methods of sponge fishing, viz., by dredging and harpooning. The former is usually adopted where the water is too deep for divers. The harpoon is merely an iron fork fixed to a long handle. When a patch is sighted, the harpooners dexterously cut and stab till the sponge is released from the rocks to which it has grown.

By means of a simple contrivance, those in the sponge fishing vessels are able to survey the sea bed for patches of sponge. In clear water it is possible to see to a depth of nearly thirty fathoms with this device. It consists merely of a copper or zinc cylinder from two to four feet long by about twelve inches in diameter, treated inside with lamp-black, a circular glass being fitted at one end and a pair of handles at the other end. The searcher pushes the cylinder about a foot under water, puts his head into the open end, and as the vessel moves along he looks out for fruitful ground.

INTERNAL STRUCTURE OF SPONGE.

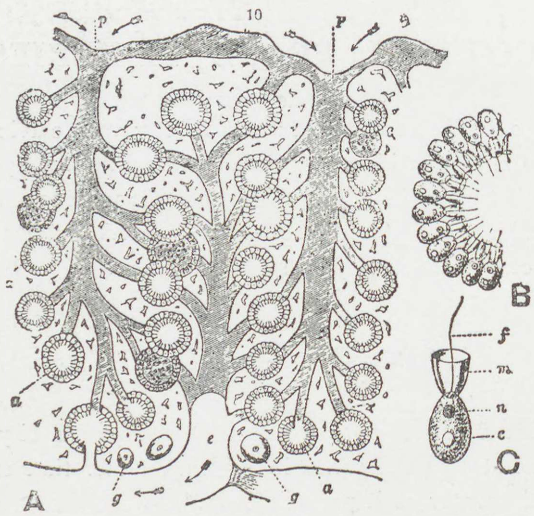
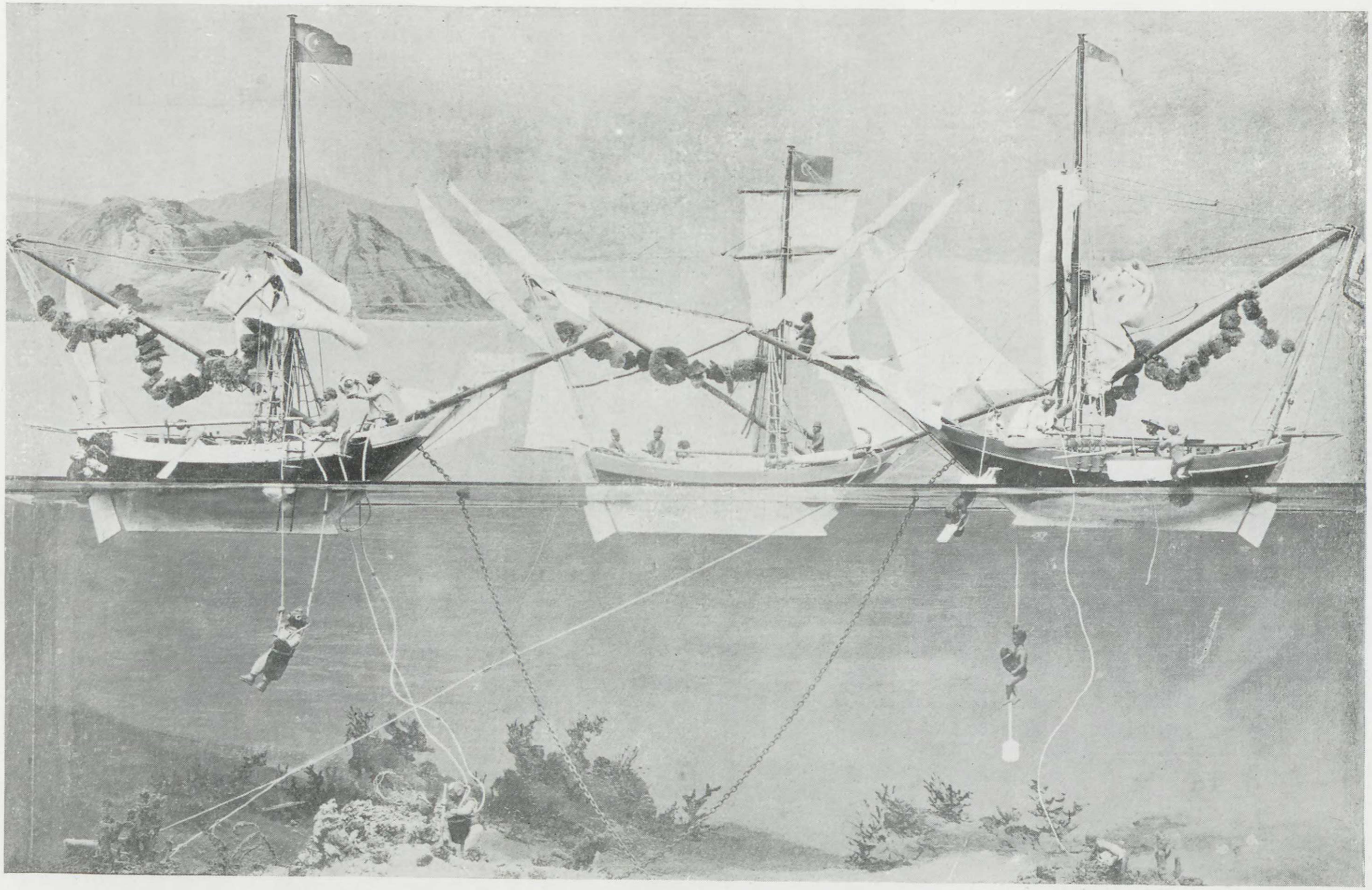


Fig. No. 80.

A, Vertical section of outer layer magnified 75 times; *p*, pores or openings of canals for conducting water which flows to *a* sacs; *e*, canal for expulsion of water; *g*, early stages of spores; *B*, sac, transversely divided, 800 diameters, showing sponge particles with cilia; *C*, sponge particles highly magnified; *f*, cilium; *m*, collar; *n*, nucleus; *c*, contractile vesicle.

SPONGE DIVING.



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No. 81.

This picture shows the Helmet diver and the naked diver at work.

HISTORICAL.—THE EVOLUTION OF THE DIVING DRESS AND DIVING BELL.*

Unassisted or Natural Diving.

The earliest record of the art of diving having been practised for a purpose of utility occurs in that part of Homer's *Iliad* in which he compares the fall of Hector's charioteer to the action of a diver. Thus it would seem that the art was known approximately eleven centuries before the Christian era. Thucydides is the first to mention the employment of divers for mechanical work under water. He relates that divers were employed during the defence of Syracuse (B.C. 215-212) to saw down the barriers which had been constructed below the surface of the water with the object of obstructing and damaging any Grecian war vessels which might attempt to enter the harbour. At the siege of Tyre (333 B.C.), too, divers were ordered by Alexander the Great to impede or destroy the submarine defences of the besieged as they were erected. The purpose of these obstructions was analagous to that of the submarine mine of to-day.

Fig. No. 28

The employment of divers for the salvage of sunken property is first mentioned by Livy, who records that in the reign of Persius considerable treasure was recovered from the sea. By a law of the Rhodians, their divers were allowed a proportion of the value recovered, varying with the risk incurred, or the depth from which the treasure was salved. For instance, if the diver raised it from a depth of eight cubits (12ft.) he received one third for himself; if from sixteen cubits (24ft.) one half; but upon goods lost near the shore, and recovered from a depth of two cubits (36in.) his share was only one tenth.

In passing, we must not forget the well-known case of the piscatorial contest between Antony and Cleopatra. Antony, wishing to prove his skill as an angler before the object of his adoration, sent down a diver secretly with a fish previously caught to attach it to his hook. The trick was speedily discovered by Cleopatra, who despatched another diver to fix a *salted* fish on the hook.

These are examples of unassisted diving as practised by the Ancients. Their primitive method, however, is still in vogue in some parts of the world—notably in the Ceylon Pearl Fisheries and in the Mediterranean Sponge Fisheries, and it may, therefore, be as well to mention the system adopted by the natural, or naked diver of to-day.

The volume and power of respiration of the lungs vary in different individuals, some persons being able to hold their breath longer than others, so that it naturally follows that one man may be able to stay longer under water than another. The longest time that a natural diver has been known to remain beneath the surface is about two minutes. Some pearl and sponge divers rub their bodies with oil, and put wool, saturated with oil, in their ears. Others hold in their mouth a piece of sponge soaked in oil, which they renew every time they descend. It is doubtful, however, whether these expedients are beneficial. The men who dive in this primitive fashion take with them a flat stone with a hole in the centre; to this is attached a rope, which is secured

* Copyright by R. H. DAVIS in the U.S.A.

to the diving boat and serves to guide them to particular spots below. When the diver reaches the sea bottom he tears off as much sponge within reach as possible, or picks up pearl shells, as the case may be, and then pulls the rope to indicate to the man in the boat that he wishes to be hauled up. But so exhausting is the work, and so severe the strain on the system, that, after a number of dives in deep water, the men often become insensible, and blood sometimes bursts from nose, ears and mouth.

Early Diving Appliances.

The earliest mention of any appliance for assisting divers occurs in the works of Aristotle, who speaks of a sort of "vessel for enabling men to remain some time under water." It is also recorded that Alexander the Great made a descent into the sea in a machine called a *Colympha,* which had the power of keeping a man dry, and at the same time of admitting light. Pliny also speaks of divers engaged in the strategy of ancient warfare, who drew air through a tube, one end of which they carried in their mouths, whilst the other end was made to float on the surface of the water. Roger Bacon (A.D. 1240), too, is supposed to have invented a contrivance for enabling men to work under water; and in Vegetius's *De Re Militari* (editions of 1511 and 1532—the latter in the British Museum), is an engraving (reproduced on page 158) representing a diver wearing a tight-fitting helmet to which is attached a long leathern pipe leading to the surface, where its open end is kept afloat by means of a bladder. This method of obtaining air during subaqueous operations was probably suggested by the action of the elephant when swimming; the pachyderm instinctively elevates his trunk so that the end of it is above the surface of the water, and thus he is enabled to take in fresh air at every inspiration.

Lorini's Apparatus.

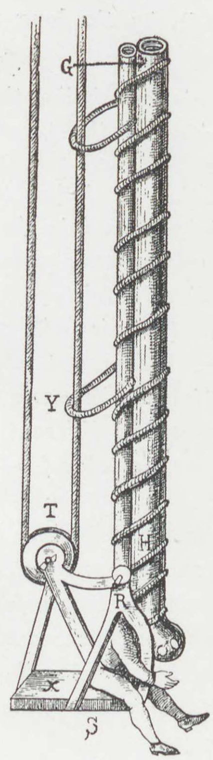


Fig. No. 83.

Lorini, an Italian, about the year 1609 designed a diving apparatus of which the following is a translation of his original description:—

The instrument is intended to be made with a leather tube, with an internal stiffening framework of iron hoops, and rods placed longitudinally, as shown by "G—H," which tube should be of a length equalling the depth of water. This tube is lashed and tied by a rope to the spar "R—P," while at the bottom, at the end R, the iron stay-hoop "R—S" is fitted, and a weight of lead or stone "S" attached thereto, upon which a man can sit astride, who should have a dress of goat-skin (like that which is used for oil-pipes), the sleeves of the dress being tied up at the wrists, as is done with the sleeves of a suit of armour, and at the thighs it should fit tight, so that no water can intrude, but he should have his head in the small air chamber at the lower end of the tube, where there are glasses through which he can see and have daylight.

And as he is to have his hands free outside he will be able to do any work he likes, and by speaking to the attendant at the upper orifice "O—P" he can report what comes to his hands.

Borellus' Apparatus. The next illustration is worthy of special note inasmuch that the apparatus depicted therein aims at the renewal of the air and the separation of the exhaled from the inspiratory air. This apparatus was designed by Borellus, and the following description is taken from his work "*De Motu Animalium,*" Rome, 1682 :—

Make a vessel, or iron or tin hollow body, as shown in "M—H," 2 feet in diameter, which can be put over the head "A" of a man like a helmet, so that the head is enclosed as in a chamber, and which fits accurately upon the shoulders, nape of the neck and chest, the metal neck being tied fast with cords, and the man being dressed in a dress of buckskin; thus a man equipped in this way will be able to live under water for some hours, free and unimpeded, the air enclosed in the metal vessel "M—H" being, so to speak, renewed from time to time, as will be shown later on.

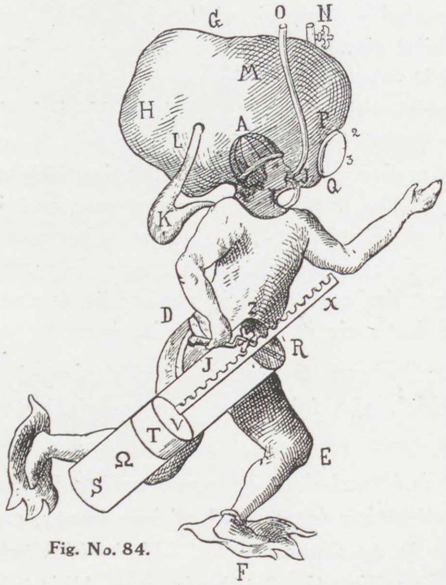


Fig. No. 84.

You must make a curved metal tube "J K L," 3 feet long, to which at the central lowermost curve a leather sac is attached, and the tube must also have, from the outside, two orifices or nozzles "J—L," which, within the hollow vessel, surround the head, in order that air can be inhaled through the anterior orifice "J" and exhaled through the posterior orifice "L." By this device two advantages are afforded. Firstly, the air, which is inhaled from the tube, is rendered fresh and good again by the surrounding water (as also all the air contained in the whole vessel), by the long travel through the tube "J K L."

Secondly, the exhaled air, on inhaling through the narrow neck at the orifice of the tube "J," passes out, not through the nose, but through the mouth alone, as experience shows; if then the exhaled air is drawn by the inhalation into the long, curved tube, it must necessarily follow that, through this passage and roundabout way, drops of moisture or vapour will adhere, and trickle down inside the tube, and be collected in the leather sac, just as in a still; hence it comes that the air will go out through the orifice "L," which goes round the curve, and thus become not only fresh but also pure, clear and dry, and therefore the diver will not inhale the warm breath exhaled through mouth and nose, but he will receive and enjoy a quite different, fresh, pure air, and under these circumstances he can breathe quite comfortably for half an hour without danger.

But as nevertheless no one could sustain life unless the air enclosed in the vessel is renewed, it is highly necessary that the vessel "2" should have metal tubes "N—O," with closed cock, so that in case of necessity, on coming to the surface, one can exhale through one pipe "P—O" and draw in fresh air through the other tube "N," and, after closing the cocks, redescend. Besides, the metal vessel or body put over the head must have, in front, as shown, "2—3," a hole into which plate glass, fused on, is inserted, so that the diver may be able to see.

The cylinder "S—J," girded to the loins, serves for the purpose of compressing air within it, by means of the piston "T" worked by rackwork—thus increasing the specific gravity of the diver so that he can ascend or go down at will.

Lethbridge's Apparatus.

John Lethbridge, a Devonshire man, in the year 1715 contrived "a watertight case for enclosing the person." The following is Lethbridge's own account of his invention :—

Necessity is the parent of invention, and being, in the year 1715, quite reduced, and having a large family, my thoughts turned upon some extraordinary method to retrieve my misfortunes, and was prepossessed that it might be practicable to contrive a machine to recover wrecks lost in the sea. The first step I took towards it was, going into a hogshead (upon land), bunged up tight, where I stayed half an hour, without communication of air. Then I made a trench near a well at the bottom of my orchard in this place, in order to convey a sufficient quantity of water to cover the hogshead, and then tried how long I could live under water without air-pipes, or communication of air, and I found I could stay longer under water than upon land.

This experiment being tried, I then began to think of making my engine, which was soon made by a cooper, in Stanhope Street, London, of which I give you the following description:—It is made of wainscot, perfectly rounded, about 6 feet in length, about 2½ feet diameter at the head, and about 18 inches diameter at the foot. It is hooped with iron hoops, without and within, to guard against pressure. There are two holes for the arms, and a glass about 4 inches diameter and 1¼ inches thick to look through, which is fixed on the bottom part, so as to be in a direct line with the eye. Two air-holes upon the upper part, into one of which air is conveyed by a pair of bellows, both which are stopped with plugs immediately before going down to the bottom. At the foot part there is a hole to let out water sometimes. There is a large rope fixed to the back or upper part, by which it is let down, and there is a little line, called the signal line, with which the people above are directed what to do, and under is fixed a piece of timber, as a guard for the glass.

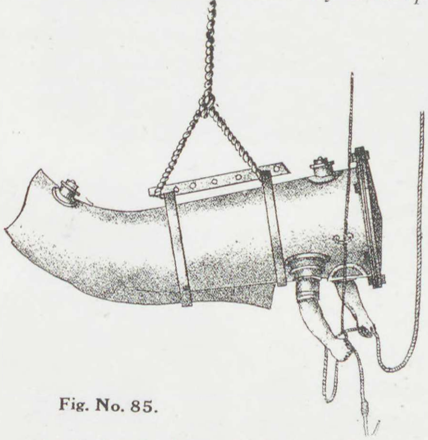


Fig. No. 85.

I go in with my feet foremost, and when my arms are got through the holes, then the head is put on, which is fastened with screws. I lie straight upon my breast, all the time I am in the engine, which hath been many times more than two hours, being frequently refreshed upon the surface by a pair of bellows.

I can move about 12 feet square at the bottom, where I have staid many times thirty-four minutes. I have been 10 fathoms deep many a hundred times, and have been 12 fathoms, but with great difficulty.

Mr. Symons came to the Lizard to see my engine, which he liked so well that he desired to adventure with me on some wrecks near Plymouth, where we adventured together without success.

Kleingert's Apparatus.

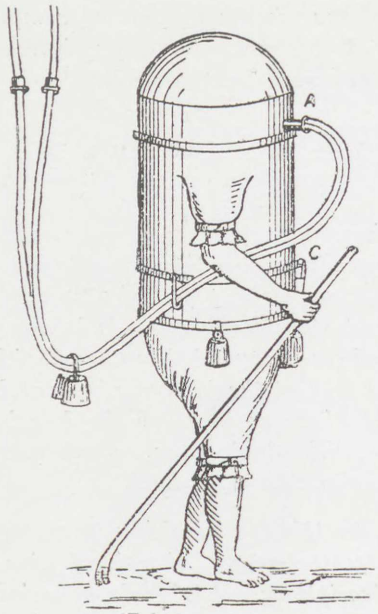


Fig. No. 86

The next contrivance worthy of mention, and most nearly resembling the modern diving dress, was an apparatus invented by Kleingert, of Breslau, in 1798. This consisted of an egg-ended metallic cylinder, enveloping the head and the body to the hips. The diver was encased first of all in a leather jacket having tight-fitting arms, and in leather drawers with tight-fitting legs. To these the cylinder was fastened in such a way as to render the whole equipment air-tight. The air supply was drawn through a pipe which was connected with the mouth of the diver by an ivory mouthpiece, the surface end being held above water after the manner mentioned in Vegetius, *viz.*, by means of a floating bladder attached to it. The foul air escaped through another pipe held in the same way above the surface of the water, inhalation being performed by the mouth and exhalation by the nose, the act of inhalation causing the chest to expand and so to expel the vitiated air through the escape pipe. The diver was weighted when going under water, and when he wished to ascend he released one of his weights, and attached it to a rope which he carried, and it was afterwards hauled up.

But as this apparatus did not permit of descending into deep water, Kleingert subsequently constructed a diving machine in which the diver was provided with an air reservoir, and therefore could continue his stay under water as long as the necessary supply of air for respiration sufficed, which he inhaled under a pressure corresponding to the depth reached by him.

As Fig. 87 shows, the compression of the air corresponding to the existing water pressure is effected by the piston being forced in by the water pressure during the lowering of the apparatus, and the air thus compressed is supplied to the diver, from the reservoir, through a pipe. As will be seen, the diver is surrounded by compressed air everywhere except on his arms and legs; consequently, the whole of his body is subjected everywhere to the same pressure. The head and trunk of the diver are surrounded by cylindrical metallic casings, shutting off the air surrounding his body hermetically against the surrounding water, and from which the arms and legs protrude, through watertight-joint pieces of leather attached to the casing. The capacity of the air reservoir was about 40 cubic feet. A foot-board was fixed to the reservoir on which the diver was stationed.

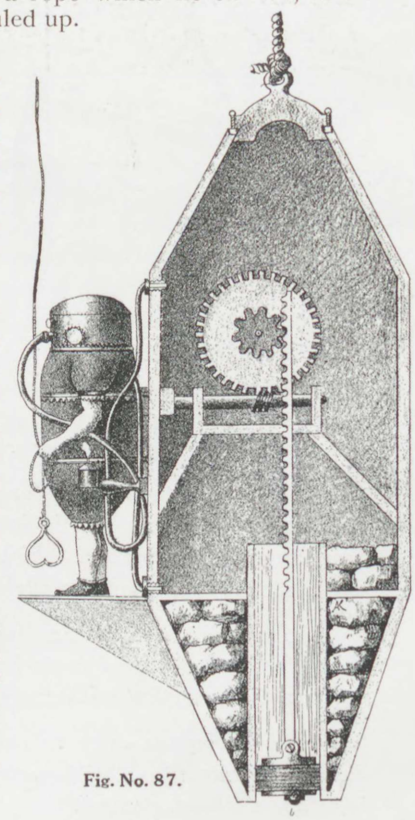
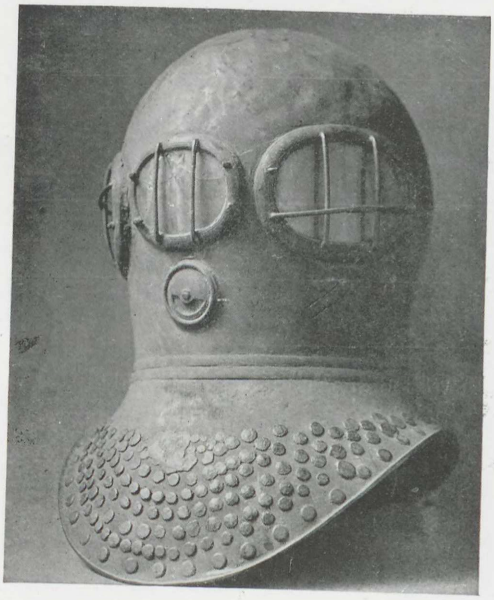


Fig. No. 87.

Siebe's "Open" Dress.

This, or equally cumbersome apparatus, was the only diving gear in use up till 1819, in which year Augustus Siebe invented his "Open" dress, worked in conjunction with an air force pump. This dress consisted of a metal helmet and shoulder plate atached to a water-tight jacket, under which, and fitting closely to the body, were worn trousers, or rather a combination suit reaching to the arm-pits. The helmet was fitted with an air inlet valve, to which one end of a flexible tube was attached, the other end being connected at the surface with a pump which supplied the diver with a constant stream of fresh air. The air, which kept the water well down, forced its way between the jacket and the under-garment, and escaped to the surface on exactly the same principle as that of the diving bell, hence the term "Open" as applied to this dress.



Copyright. **Photo No. 88.**

Although excellent work was accomplished with this dress—work which could not have been attempted before its introduction—it was still far from perfect. It was absolutely necessary for the diver to maintain an upright, or but very slightly stooping, position whilst under water; if he stumbled and fell, the water filled his dress, and, unless quickly brought to the surface, he was in danger of being drowned.

Siebe's "Close" Dress as now universally used.

To overcome this and other defects, Siebe carried out a great number of experiments, extending over several years, which culminated in the introduction, in the year 1837, of his "Close" dress in combination with a helmet fitted with air inlet and regulating outlet valves. This type of apparatus was used in the later stages of the "Royal George" operations, taking the place of the "open" dress which had been in use from the commencement.

Though, of course, great improvements have been introduced since Siebe's death, in 1872, the fact remains that his principle is in universal use to this day. The submarine work which it has been instrumental in accomplishing is incalculable. But some idea of the importance of the invention may be gathered from the fact that diving apparatus on Siebe's principle is universally used to-day in harbour, dock, pier and breakwater construction, in the pearl and sponge fisheries, in recovering sunken ships, cargo and treasure, and that every ship in the British navy and in most foreign navies carries one set or more of diving apparatus, for use in case of emergency—clearing fouled propellers and valves, cleaning and repairing ships' hulls below the water line, and for recovering lost anchors, chains, torpedoes, etc.

Greatest depths attained.

The greatest depth at which useful work has been performed by a diver is 182ft. From this depth a Spanish diver, Angel Erostarbe, recovered £10,000 in silver bars from the wreck of the steamer "Skyro," sunk off Cape Finisterre; Alexandra Lambert succeeded in salving £70,000 from the Spanish mail steamer "Alphonso XII," sunk in 162ft. of water off Las Palmas, Grand Canary; W. Ridyard recovered £50,000 in silver dollars from the "Hamilla Mitchell," sunk off Leuconna Reef, China, in 150ft. There are individual cases where much larger sums have been recovered, but those mentioned are particularly notable by reason of the great depth involved, and stand out as the greatest depths at which good work has been done. Professor

Copyright. **Photo No. 89.**

Dr. J. S. Haldane, F.R.S., and his Colleagues.

J. S Haldane, F.R.S., and his colleagues—Dr. A. E. Boycott, M.D., and Lieut. Damant, R.N.—have proved, however, that it is quite possible to do serious work at a depth of 210ft. and even more, provided that the stage method of decompression, as per pages 47 to 49, be employed. *(See also paragraph 7 of Introduction.)*

The sponge fishers of the Mediterranean work at a maximum depth of about 150ft., and the pearl divers of Australia at 120ft. But submarine operations on the great majority of the harbour and dock works of the world are conducted at a depth of from 30 to 70ft.

Diving Bells.

We are all familiar with the experiment of placing an inverted tumbler in a bowl of water, and seeing the water excluded from the tumbler by the air inside it. Perhaps it was to some such experiment as this that the conception of the diving bell was due. As is well known, the pressure of water increases with the depth. For all practical purposes, this pressure can be taken at four and a quarter pounds to every ten feet. See page 93 for further particulars.

Sink a diving bell to a depth of, say, 33ft., and the air inside it will be compressed to about half its original volume, and the bell itself will be about half filled with water. But keep up a supply of air at a pressure equal to the depth of water at which the bell is submerged, and you will not only keep the water down to the cutting edge, but you will ventilate the bell and make it possible for its occupants to work for hours at a stretch.

Roger Bacon (A.D. 1250).

Tradition gives Roger Bacon (A.D. 1250) the credit for being the originator of the diving bell, but actual records are lost in antiquity.

Of the records preserved to us, probably one of the most trustworthy is an account given in Schott's work, *Technica Curiosa,* printed at Nuremberg in the year 1664, which quoted from one John Taisnier, who was in the service of Charles V. This account describes an experiment which took place at Toledo, Spain, in the year 1538, before the Emperor and some thousands of spectators, when two Greeks descended into the water in a large "kettle," suspended by ropes, with its mouth downwards. The "'kettle' was equipoised by lead fixed round its mouth." The men came up dry, and a lighted candle, which they had taken down with them, was still burning.

Sturmius.

Sturmius, too, in the 16th century, introduced a diving bell, in which he carried a number of bottles of air, which were broken as the air in the bell required revivifying.

Francis Bacon, in the *Novum Organum,* lib. II, makes the following reference to a machine, or reservoir, of air to which labourers upon wrecks might resort whenever they required to take breath:—

"A hollow vessel, made of metal, was let down equally to the surface of the water, and thus carried with it to the bottom of the sea the whole of the air which it contained. It stood upon three feet—like a tripod—which were in length something less than the height of a man, so that the diver, when he was no longer able to contain his breath, could put his head into the vessel and, having filled his lungs again, return to his work."

Dr. E. Halley, F.R.S.

But to Dr. Edmund Halley, secretary of the Royal Society, undoubtedly the honour is due of having invented the first really practical diving bell. This is described in the *Philosophical Transactions*, 1717, in a paper on "The Art of Living Under Water by means of furnishing air at the bottom of the Sea in any ordinary depth." Halley's bell was constructed of wood, covered with lead to give it the necessary sinking weight, and so distributed as to ensure the bell keeping a perpendicular position when in the water. It was in the form of a truncated cone, three feet in diameter at the top, five feet at the bottom, and eight feet high. In the roof a lens was introduced for admitting light, and also a tap to let out the vitiated air. Fresh air was supplied to the bell by means of two lead-lined barrels, each having a bung-hole in the top and bottom. To the hole in the top was fixed a leathern tube, weighted in such manner that it always fell below the lever of the bottom of the barrel so that no air could escape. When, however, the tube was turned up by the attendant in the bell, the pressure of the water rising through the hole in the bottom of the barrel, forced the air through the tube at the top and into the diving bell. These barrels were raised and lowered alternately with such success that Halley says that he, with four others, remained at the bottom of the sea, at a depth of nine to ten fathoms, for an hour and a half at a time without inconvenience of any sort.

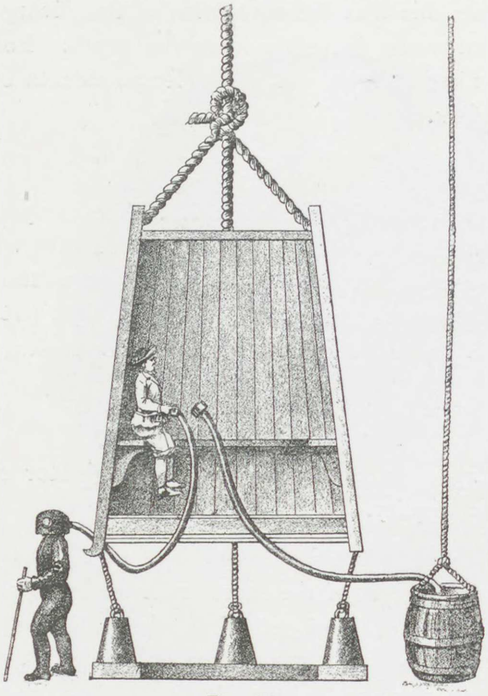


Fig. 90.

Debrell's Submarine Boat.

Robert Boyle, in his *Experiments Physico-Mechanical* (1647), describes a submarine vessel, contrived by one Cornelius Debrell about the year 1620, which was to be rowed and used under water and was actually tried in the river Thames by order of James I. It is said to have succeeded well, carrying twelve rowers besides passengers. Boyle says: "*Debrell conceived that it is not the whole body of the air but a certain spirituous part of it that fits for respiration, so that besides the mechanical contrivances of his boat he had a chemical liquor, the fumes of which, when the vessel containing it was unstopped, would speedily restore to the air, fouled by the respiration, such a portion of vital parts as would make it again fit for that office.*" Boyle assures us that the liquid which was used for restoring the air was discovered by a physician who married Debrell's daughter, and the secret of which Debrell disclosed to only one person, who imparted it to Boyle. The statement seems incredible, but, if true, the secret of the preparation of this wonderful *elixir vitæ* has passed away with Boyle.

Triewald's Bell.

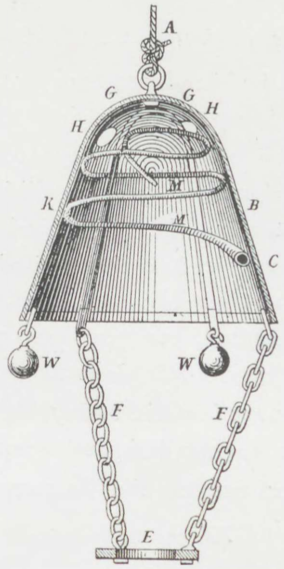


Fig. 91.

In 1728, Martin Triewald, a Swedish military officer, contrived a diving bell of a lighter and less expensive character than Halley's. This bell, as shown in Fig. 91, was made of copper, tinned on the inside, and was sunk by the lead weights (W W) suspended round the mouth. The iron plate (E) on which the diver stood was suspended by chains (F F) at such a distance from the bottom of the bell that, when he stood upright, his head reached just above the water in the bell, where he had the advantage of the coolest air. A spiral tube was fitted, by which a diver inside the bell could inhale the cooler and fresher air at the bottom through a mouthpiece (M). Air was supplied to this bell in the same way as Halley's.

Spalding's Bell.

In 1775, Charles Spalding introduced an improvement on Halley's bell, the object being to make it more portable, safer to handle, and to allow the divers to have control over it. In shape the bell was like Halley's, but the upper part (P) was formed into a separate chamber by the watertight partition (E F). The bell was weighted with slabs of lead (D D) hung from hooks (S S) to keep it perpendicular in the water, but these weights were not sufficient to sink the bell without the addition of the balance weight (W), which was hung from the centre of the bell by pulley blocks, and allowed to reach down some distance below the bottom of the bell. By lowering this weight to the bottom, the bell, being thus relieved of a weight of about 3 cwt., immediately rises, and any strain on the suspension rope, or danger of being capsized by any obstacle in its descent, are thus avoided. By means of cocks (G L), water or air may be admitted to the upper chamber (P), so that the bell may be made to sink or rise in the water at pleasure. As in the case of Halley's bell, fresh air was supplied by lowering barrels. (*See Fig.* 92.)

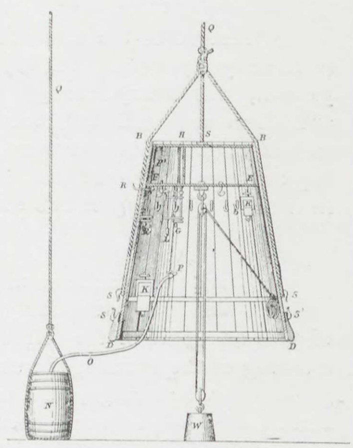


Fig. 92.

Smeaton's First Bell.

John Smeaton in 1788 designed a diving bell for use in repairing the foundations of Hexham Bridge, but instead of weighted barrels, he introduced here for the first time a force pump for supplying the necessary air. This bell was never intended to be wholly submerged, and, as will be seen from the illustration, the pump used for supplying air was fixed on the roof of the bell.

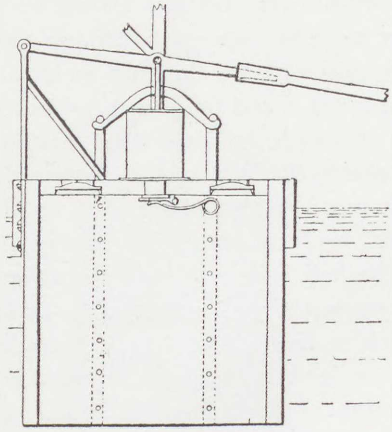


Fig. 94.

To Smeaton, too, we are indebted for the first diving bell plant in the form with which we are familiar to-day, that celebrated engineer having designed a square bell of iron, for use on the Ramsgate Harbour Works in 1790.

The following is Smeaton's own description, taken from his "Historical Report on Ramsgate Harbour," written in 1791 :—

Smeaton's Improved Bell.

"I had scarcely returned from this visitation before a requisition came to desire the expedient I had mentioned might be got ready, and which was done with such expedition that I set forward for Ramsgate the 6th July in order to put it in use; and the 12th I left Ramsgate after a full trial of the Diving Chest, and with the certainty of success.

"Instead of the usual form of a Bell, or of a conical tub of wood sunk by weights (externally applied), this, for convenience, was a square chest of cast iron, which, being 50 cwt., was heavy enough to sink itself; and, being $4\frac{1}{2}$ feet in height, $4\frac{1}{2}$ feet in length, and 3 feet wide, afforded room for two men at a time to work under it. But it was peculiar to this machine that the men therein were supplied with a constant influx of fresh air, without any attention of theirs; that necessary article being amply supplied by a forcing Air Pump, in a boat, upon the water's surface.

"With this machine, which enabled the workmen to stay under water any length of time at pleasure, when the wind was moderate, that the boats could attend, in the course of that and part of the following month, the foundation was cleared; and the tools for levelling of the ground, the same that were originally invented and applied by the late ingenious Mr. Etheridge, were now put in use, under the management of Mr. Cull, the Master Mason, who had formerly been employed in that part of the business, it being the Chairman's wish, as best for the work, that everything should go on in the same method as originally practised. It was computed that about 160 tons of stones had been got up in clearing the foundation, and that about 100 tons thereof had been raised by the Diving Machine, many of above a ton each; but the want of the Machine would doubtless have been the loss of the season."

Fulton's Submarine Vessel.

In 1800, the American, Robert Fulton, who was the first man to introduce steam navigation on the rivers of his native country, made a vessel to enable men to explore the sea bottom. Fulton gave a demonstration with his vessel in the Seine before some members of the French Government,

Payerne's Submarine Vessel.

But probably the first really practicable diving boat was that made by a Frenchman, Dr. Payerne, in 1844. This scientist had long studied the question, but his chief difficulty lay in supplying the occupants of such a boat with fresh air. In 1844, however, he came to the conclusion that it was quite practicable, by chemical means, to restore the purity of the air in the boat without recourse to the atmosphere, and he ultimately built a vessel on this principle, which was employed in the French Government works at Cherbourg.

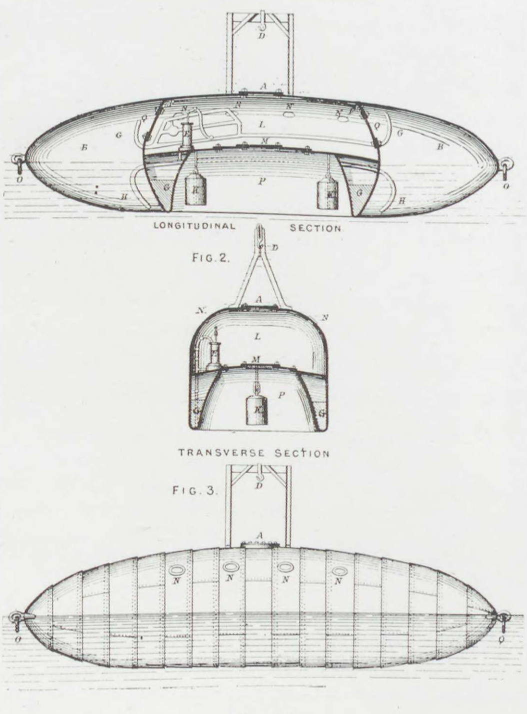


Fig. 93.

Fig. 93 gives a diagram representing the general construction of this machine. It was formed of strong iron plates riveted together in the form shown, with the internal partitions constructed in the same way. A manhole (A) gave entrance to the machine at the top, the cover to which was securely fastened before descending. Light was admitted through strong glass lenses or bull's eyes (N N) inserted in the upper portion of each side of the machine. Mooring rings (O O) were securely fastened at either end, and an iron frame (D) was erected over the manhole (A), on which a pulley could be affixed to facilitate the removal of heavy materials when the machine was at the surface. Internally, the machine was divided into five air-tight and water-tight compartments; the chamber (L) in which the pumps and other requisites for the general management of the machine were placed; the working chamber (P), open at the bottom of the water, and in which the man engaged in the subaqueous work laboured; the ballast chamber (C), in which was placed some 36 tons of iron ballast; and the two air reservoirs or chambers (B B), in which air was compressed by pumping previous to the descent of the machine. A manhole (M) was provided between the chambers (L) and (P), which was securely fastened before opening the manhole (A) on the arrival of the machine at the surface, and was kept open when the men were at work at the bottom. When occasion required, the plates (M M) could also be removed, so as to give more room for conducting the work. Manholes (Q Q) were also provided between the chambers (L) and (B B), to admit of entry to the latter for cleaning and repairs.

The machine was about 43ft. long and 10ft. in depth, and had a total weight of 62 tons, including the ballast and the weights (K K), which weighed together 4 tons, and were used for lowering to the bottom, so as to allow the machine to rise if, in descending, it came in contact with a rock or other obstruction. The usual complement of men was nine, eight engaged in labouring in the work chamber (P), and the ninth in the chamber (L) to purify the air, receive the débris from the men working below, admit fresh air from the chambers (B B), which were necessary every hour, and to attend to the machine. The pump (E) was so arranged with pipes (H G) that the attendant could pump sea water into or out of the chamber (B B) and (C), or pump air from the chamber (B B) into the chamber (L) or (P), and it was also used for filling the chamber (B B) with compressed air when the machine was at the surface. Air cocks (F F) were also provided for supplying the chamber (L) with air from the chambers (B B) so long as the air pressure in the latter was in excess of that in the former. The descent and ascent of the machine was controlled by merely pumping water into the chamber (B B) and (C) when descending, and by pumping it out again for the purpose of ascending, and the machine could be slowly moved about along the bottom by poles used by the men in the work chamber (P). The work done by the machine was paid for by the French Government, according to the quantity of material excavated or masonry laid.

The nine men could excavate somewhat less than one and a-half cubic yards of hard rock in six and a-half hours, besides ascending and descending twice in that time, chiefly to get rid of the débris which they had lifted into the chamber (L), but which might have been much more economically sent to the surface in iron cradles lowered to them for that purpose outside the machine. In general practice, the supply of fresh air was derived entirely from the reservoirs (B B), and the carbonic acid gas exhaled by the occupants, being heavy, fell to the bottom, and, if the machine was being used in running water, was absorbed and carried away by the current; but as a small portion only of the gas would be absorbed in still water, the air was passed through a mixture of lime water with a little potash,* by means of a bellows, the operation being continued for every alternate quarter of an hour. The carbonic acid gas was thus completely absorbed by the lime and the atmosphere purified, so as in all cases to be amply sufficient for the day's work of six and a-half hours.

Payerne and Lamival.

About ten years later, Payerne and his colleague, Lamival, were granted British letters patent for a submarine vessel similar to that already described, but provided with mechanical means of propulsion, and an arrangement for the introduction and discharge of water by means of pumps to enable the vessel to sink or rise in the water as required.

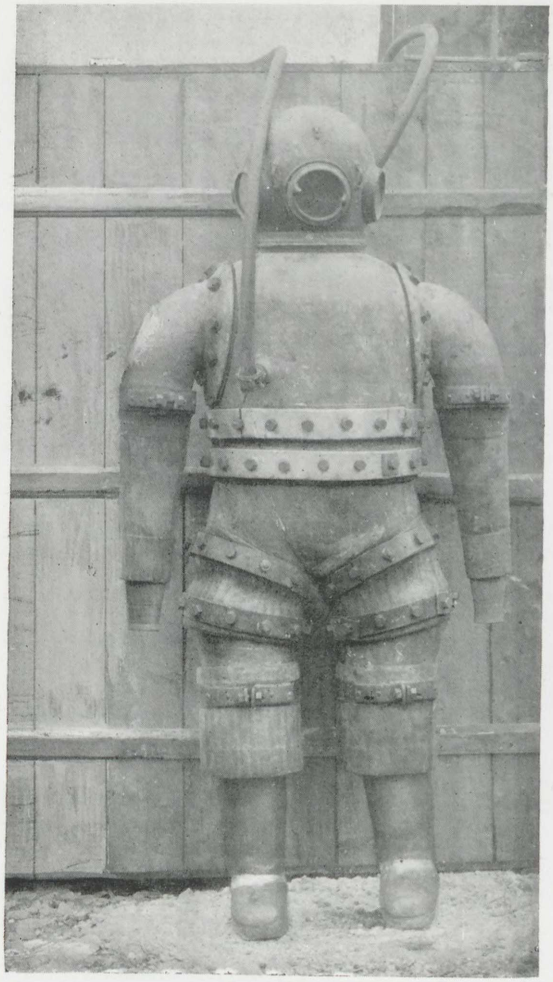
Scott Russell's Boat.

During the Crimean War, the late Scott Russell built a submarine boat called the *Nautilus*, which it was intended to use against the enemy. This vessel was to have been propelled by divers, seated on platforms outside, and obtaining their air supply from compressed air cylinders carried in the vessel. Peace being declared before the final completion of the vessel, the project was abandoned, and she was subsequently broken up.

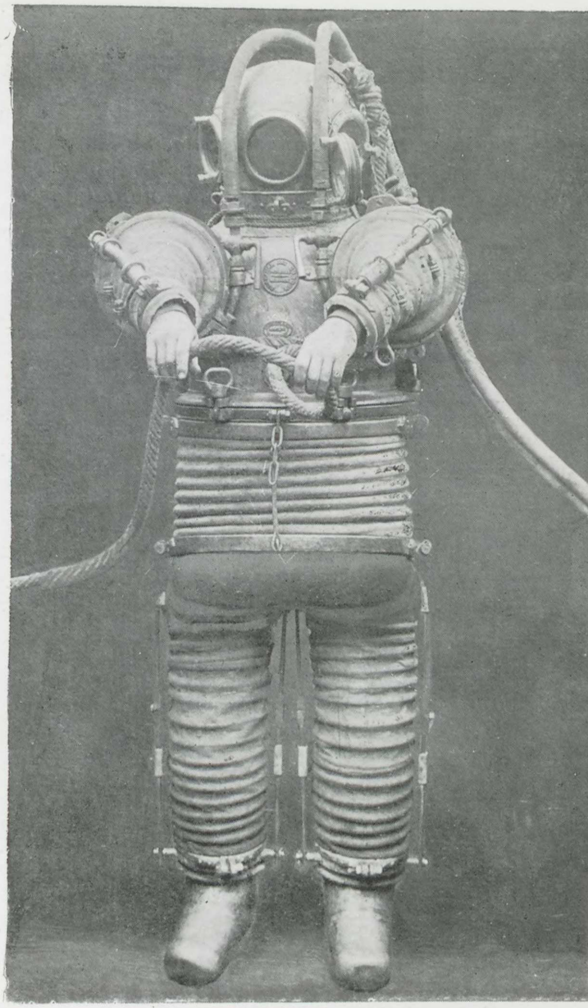
Caissons for Bridge Foundations.

Caissons for securing foundations were first used in this country by Hughes, about sixty years ago, in connection with a bridge over the Medway at Rochester, the depth in this case being about 60 feet. Subsequently Brunel used them for the bridge over the Wye, at Chepstow, and, later, at Saltash, the depth in the latter operations being 87 feet.

* Payerne mentions an alkaline mixture consisting of about 2¼ lbs. of water, ½ lb of lime and 2 oz of potash, and he says that a certain quantity of prepared oxygen may be admitted into the boat.



Copyright. **Photo No. 95.**



Copyright. **Photo No. 96.**

Photos Nos. 95 and 96 illustrate two of the many different forms of diving dresses, which have been designed with a view to their withstanding the water pressure at great depths without a corresponding pressure of air inside to balance, as in the case of the ordinary diving dress. No. 95 is from the designs of a Frenchman; No. 96, which is the more practical, from those of two Australians named Buchanan and Gordon. The latter suit is made in two parts—the *upper* consisting of head and body of stout copper, the arms and *lower* half of the dress (excepting the thigh part, which is also of copper) consisting of a series of special metallic springs, covered inside and out with very strong waterproof material. The arms are fitted with spiral springs, and the legs with jointed supports to prevent the water pressure forcing them upwards. There is also an arrangement by which the suit can be adjusted to the height of the diver. The dress is fitted with two valves—the inlet or air supply valve and the outlet or air escape valve—both being under the control of the diver. To the escape valve is connected a floating pipe, the upper (open) end of which can be submerged to any required depth below the surface, thus allowing the air to escape more freely, and enabling the diver to regulate the air pressure in the dress with greater facility. The weight of the suit is about $3\frac{1}{2}$ cwt.

THE FLOODED SEVERN TUNNEL.

A DIVER'S PLUCKY FEAT.

Any history of the Severn Tunnel would be incomplete without reference to the work done by Mr. H. A. Fleuss and Diver Alexander Lambert when, during its construction, the tunnel was suddenly flooded.

Pumping having been tried without effect, it was resolved to send a diver down, in the ordinary dress, to shut the sluice, but, owing to the fact that he had to drag such a great length of air pipe (over 1,200ft.), the diver experienced great difficulty, and his movements were considerably hampered. Hearing of these difficulties, Mr. Fleuss volunteered, through Siebe, Gorman and Co., to go down with his original self-contained diving apparatus and endeavour to close the iron door in the head-wall, which was something over 1,000ft. from the shaft. He had never had any experience as a diver, and had never done any actual work under water, except to make a few descents to test the apparatus he had invented. On November 3rd, 1880, he left London with his apparatus for Portskewett, and, on arrival the next morning, he was shown drawings, etc., of the shaft and the heading he would have to traverse, but no mention was made to him of the wrecked condition of the workings and the many difficulties to be encountered. He accepted the services of a foreman labourer as his attendant, and, as the ordinary signals used for diving were not suitable in his case, owing to the fact that he used no air pipe, he had to hastily instruct this man in the code that he had adopted. The shaft was about 200ft. deep, in which the water was 40ft. deep, and at 150ft. from the surface was a rough platform about 10ft. above the water. There was a ladder running practically down the centre of the shaft and through a manhole in the platform.

As Lambert was familiar with the workings, Mr. Fleuss asked him to go down first in the ordinary apparatus, and stand at the bottom of the shaft near the entrance to the heading so that he might assist him in detaching his life-line, and also give him some indication of the direction in which to proceed. There were no submarine lamps at that time, and the darkness under water was absolute. Mr. Fleuss went down to the bottom of the ladder, and hung on the last rung with his hands, but could feel no ground, so he let go and dropped some five or six feet; then, taking a couple of steps to the left to clear the ladder with his line, he walked straight forward to the wall of the shaft, then gradually worked his way round to the left until he found the opening to the heading. Reaching across this, he found Lambert waiting for him. No one had told him that the ladder did not reach the bottom, nor was he told that he would have to land upon a staging covering a 7ft. sump. The staging was somewhat broken up, and he frequently found the planks tipping up and giving way beneath him.

Lambert and Fleuss shook hands, and then, as previously arranged, the life-line was detached, and Mr. Fleuss started on his journey up the heading, feeling his way as best he could between the rails. There was a ditch upon each side of the roadway, and sleepers of odd lengths projected partly across these ditches, so it was impossible for him to feel his way along the sides. He also found when standing upright that it was very difficult to know which way he was facing, so he crawled on his hands and knees between the rails. At first there was a considerable depth of soft mud which he could reach down through, and some distance further in there was a big fall, only just leaving room enough to crawl through between this fall and the head-trees. Naturally he got along very slowly, and, after about an hour returned, and, feeling for Lambert, motioned him to refasten his life-line. While this was being done he wondered if his attendant would give him a preliminary pull up so that he could reach the ladder. He gave his four-pull signal, and was very pleased to find that the man above pulled up, and that he pulled plumb with the ladder, so that Mr. Fleuss was able to reach it. Lambert followed, and from what Mr. Fleuss described to him, he was told that he had been up about 300ft. Of course, he meant to have another try, and came up to consider some plan of getting along more quickly. The next time he tried feeling along the rails with a crow-bar, and another time he tried feeling along the sides and roof with a wooden stick. After several attempts, upon each of which he succeeded in getting a little farther up the heading, Lambert came to him and asked to be allowed to put the apparatus on, and to have a lesson in its use. He had an hour or two's successful practice that afternoon, and the next morning, attended by his own special signalman, he went down, taking off his own signal-line at the entrance to the heading. The whole time that he was away, Mr. Fleuss sat on the edge of the manhole counting the minutes, and it was exactly one hour and thirty minutes when Lambert returned to the life-line and signalled to be pulled up. He said that he had been the whole distance, and had shut one of the valves and taken up one rail and partly removed the other from the sill of the door, but that he wanted a shorter crow-bar to complete the work. In the meantime, Mr. Fleuss went to London for more oxygen and caustic soda, and, on his return, Lambert again went up the heading, and succeeded in closing the iron door. This door was set in a 9ft. length of brick heading, 4ft. by 4ft., and before closing the door Lambert had to go right through this heading and close a flap valve at the far end of it. He also had to screw down a 12in. valve on the home side of the door, but, owing to this being fitted with a left-handed thread, he screwed it wide open by mistake, and this, of course, made the time of pumping out longer than it would otherwise have taken.

RELICS FROM THE DEEP.*

A group of relics from the *Royal George*, the salvage operations on which extended over six summers, 1839-1844):—

Silver Dish from Admiral Kempenfeldt's cabin.
Silver Spoon from Admiral Kempenfeldt's cabin.
Clay Pipe.
Silver Shoe Buckle.
Portions of Sword from Admiral Kempenfeldt's cabin.
Wine Bottle with Oyster Shells adhering to it.

Silk Neckerchief. Old Pistol.
A Seaman's Thigh Bone.
Sole of a Shoe, with remains of a Candle.
China Cup. Small Shot.
Copper Rivets and a Medal.
An Officer's Ring taken from his remains.
Narrative of the Loss of the *Royal George*, bound in two pieces of the wood of the vessel.

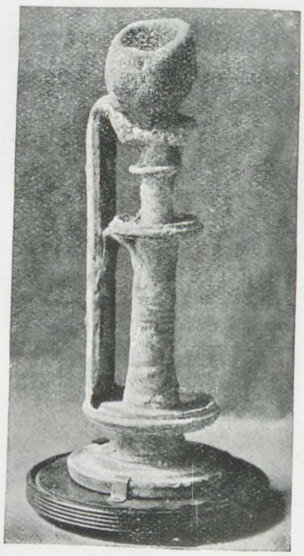


Photo No. 97.

Ancient Greek Lamp, with sponge grown to the oil reservoir, found by a Greek Sponge Diver in 140 ft. of water off Syra. The Lamp is of bronze, and dates 300 years B.C.

Vase, with relics as above, made from portions of the Timber and Guns of H.M.S. *Royal George*, Flagship of Admiral Kempenfeldt, sunk at Spithead in 1782, over 800 lives being lost.

Photo No. 98.

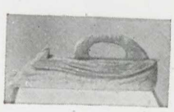


Photo No. 98a.

Carpenter's Plane, found in the wreck of one of the vessels of the Spanish Armada, sunk in Vigo Bay. The difference between the handle and the position of the planing iron of this plane, and of the present-day plane will be apparent.

Officer's Sword from the French Man-of-War *L'Orient*, Admiral's Flagship, which blew up during the fight with Nelson's Ships at the Battle of the Nile, 1st August, 1798; recovered by a Diver in 1890.

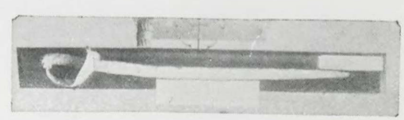


Photo No. 99.

* Most of the relics described are in the possession of Siebe, Gorman & Co., Ltd.

Bottle, with curious deposit of innumerable small shells, found by a Diver in 80 ft. of water off the Danish Coast.

Wheel of a Pulley Block recovered, after being under water 295 years, from the *Mary Rose*, sunk in the reign of Henry VIII.

Photo No. 100.

One of 250,000 Mexican Dollars = 50,000, recovered by Diver Ridyard from the wreck *Hamilla Mitchell*, sunk in 26 fathoms = 156 ft. of water, off the Leuconna Reef, near Shanghai.

One of seven Treasure Chests, each containing Spanish Gold Coin to the value of £10,000 sterling = £70,000 in all, recovered by Messrs Siebe, Gorman and Co.'s Chief Diver, Mr. Alexander Lambert, from the wreck of the Spanish Mail Steamer *Alphonso XII.*, sunk off Point Gando, Grand Canary, in the great depth of 27 fathoms = 162 ft. One of the actual Gold Coins is set in a glass panel fixed outside the Chest.

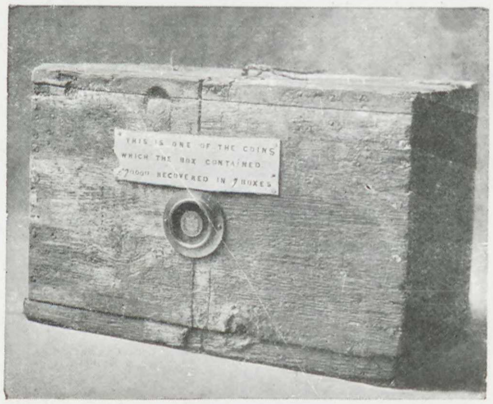
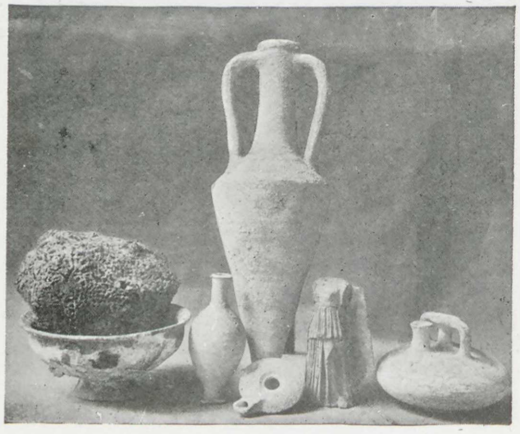


Photo No. 101.

Portions of a Marine's Musket and Carpenter's Mallet, and remains of three Coins recovered, after being 129 years under water, from the wreck of H.M.S. *Edgar*, blown up and sunk off Spithead in 1711.



Group of Water Vessels, one with sponge adhering to it, recovered by Divers from a Submerged Island in the Greek Archipelago.

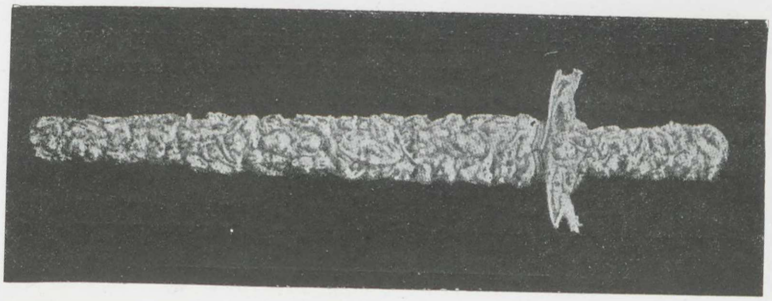
Photo No. 102

Portion of treasure-chamber door of the S.S. *Skyro*, sunk off Cape Finisterre in over 30 fathoms of water.

Roman Tiles found during excavations by divers at Winchester Cathedral.

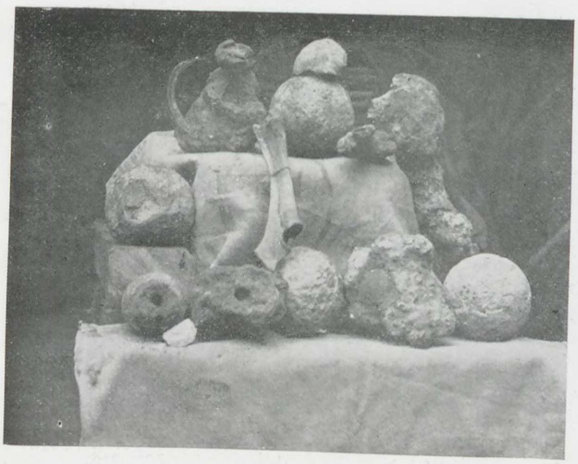
A Horseman's spur, also found during the above operations.

A piece of one of the Beech Logs which formed the original foundations (laid in the year 1085) of Winchester Cathedral.

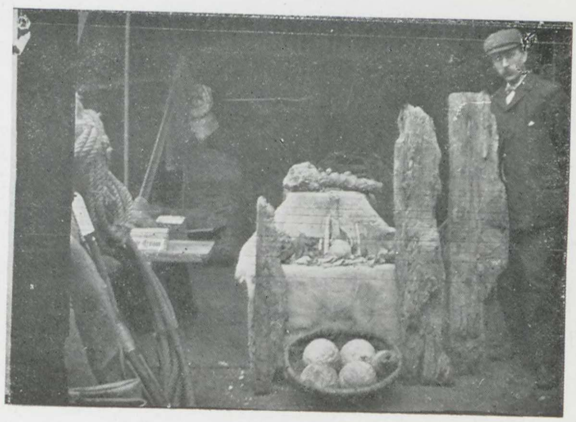


Copyright. **Photo No. 103.**

Hunting Knife, set with diamonds, valued at £7,000, recovered from the *Cadiz*, wrecked between Ushant and Molène, on the French Coast, at a depth of 15 fathoms.



Copyright. **Photo No. 104.**



Copyright. **Photo No. 104a**

The last two photos are of relics recovered during diving operations in Tobermory Bay, Scotland, in connection with the location of the galleon *Florencia*, the flagship of the Florentine squadron, which was sent to assist the Spanish Armada in A.D. 1588, and which was blown up and sunk one night by the Highland chief Donald Glas McLean, who was held captive on board. The *Florencia*, which was built of African oak, and carried 56 guns and a crew of 486, had on board bullion and other treasure of the estimated value of two millions sterling. On board were also a number of priests, and amongst the treasure was a considerable quantity of valuable church ornaments, etc.

Photo 104 *shows encrusted bottles, two scabbards, etc.*

Photo 104A *shows pieces of oak, stone shot in basket, human bones including portion of a skull, small gun, deeply encrusted, etc.*

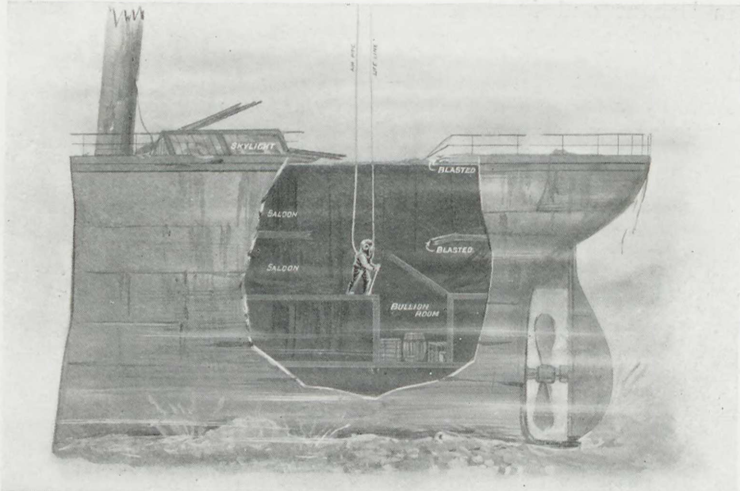
Amongst other relics recovered are a number of silver plates, coins, etc., etc.

In the year 1874 Mr. Gush, a well-known Scottish diver, was engaged by the then Duke of Argyll to look for this wreck, and found, amongst other articles, a small cannon, pistol, coins, etc.; and during the past couple of years Mr. James Gush, of Greenock, has followed in his father's footsteps, working from his own salvage vessel, the *Beamer*.

TREASURE RECOVERY FROM THE DEEP.

£90,000 recovered from the "Alphonso XII."

The treasure seeker's operations, whether on land or under the sea, are usually surrounded with a halo of romance, and without doubt the branch of submarine work which appeals most to the popular imagination is that which is concerned with the recovery of treasure from the deep. Great was the excitement when the chief of the expedition sent out to recover the treasure which went down in the *Alphonso XII.*, in 160ft. of water off Point Gando, Grand Canary, cabled home: "*Lambert has got both scuttles open, and got into the magazines. The boxes of gold are there.*" £90,000 in coin of the Spanish realm, which, before the advent of modern diving appliances would have been irrecoverably lost!



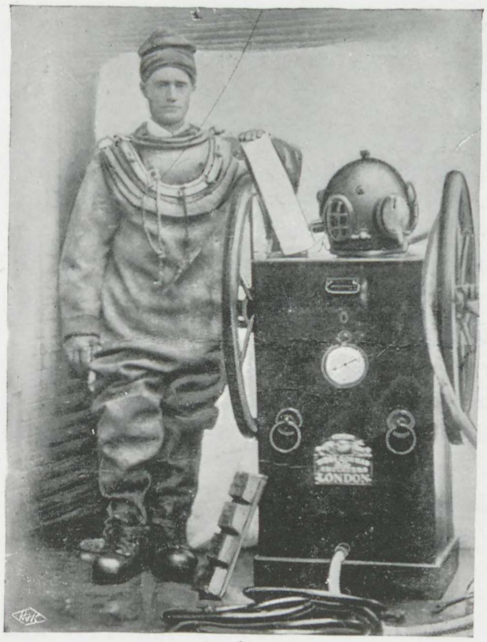
Copyright.

Diver Alexander Lambert forcing his way to the treasure room of the s.s. "Alphonso XII," from which he recovered seven chests containing £70,000 in gold coin. Another diver recovered £20,000.

It was Lambert, too, who saved the situation when the Severn Tunnel was flooded some years ago. A certain door in the drainage tunnel (8ft. by 8ft.) had been inadvertently left open. The door was situated about a quarter of a mile from the shaft, in which the water had risen about 40ft. Equipped in his diving dress, the brave fellow crept through the narrow passage, full of water and floating débris, and succeeded in closing the door. This daring act enabled the pumps to overcome the volume of water, and the work of completing the tunnel proceeded.

£10,000 worth of Bar Silver from the S.S. "Skyro."

Another notable case was the salvage of about £10,000 worth of silver bars from the wreck of the s.s. *Skyro*. This vessel sailed from Cartagena for London with a valuable cargo, including bar silver. Approaching Cape Finisterre in foggy weather, the vessel struck on the Mexiddo Reef, but passed over and went down in deep water within twenty minutes, about two miles off the coast. An expedition went out in the same year (1891), but was unable to secure the treasure, and in 1895 Mr. J. K. Moffat, of Bilbao, entered into negotiations with Lloyd's underwriters, and spent some time in further operations, which had to be suspended owing to bad weather setting in. In 1896 another effort was made with more powerful diving apparatus, and resulted in fifty-nine bars being recovered. The working depth for the Diver was never less than 28½ fathoms, or 171ft., and it frequently exceeded this. To obtain these bars it was found necessary to blow away the deck with dynamite, which the Diver—A. Erostarbe—did only after great difficulty, owing to the boisterous state of the weather. Work had to be suspended in October, but was again resumed in 1897, with the result above reported. When one takes into consideration the wild and exposed position of the wreck, which lies about nine miles south from Cape Finisterre, the strong currents that prevail in the locality, the rough weather that had to be contended with, the fact that the Diver had to use dynamite to effect an entrance into the cabin where the silver bars were stowed, and that the deck was collapsed to within 18in. of the cabin floor, on the starboard side of the silver, some idea of the dangerous nature of the undertaking may be realised. The Diver reported that when he had finished there was no part of the wreck, fore and aft, standing higher than himself, excepting the engines and main boilers; it was just a heap of old iron. To Diver Angel Erostarbe was due the greatest praise for the indomitable pluck he displayed in carrying out this most difficult submarine undertaking.



Copyright.

Photo No. 105.

Erostarbe and two of the silver bars which he recovered from the "Skyro."

£50,000 recovered from "Hamilla Mitchell."

The ship *Hamilla Mitchell* was lost on the Leuconna Rock, near Shanghai, having a heavy cargo in addition to specie valued at £50,000. Lloyd's Agent was instructed by the Underwriters to visit the scene of the wreck, and inform them as to the feasibility of recovering the treasure. His report was that he considered the cargo and treasure irrecoverably lost, as the depth of the water was so great and the position too dangerous for working. Captain Lodge, however, undertook the task, and having consulted Siebe, Gorman and Co. as to the diving gear he should require, they supplied him with a set of their Apparatus specially constructed for deep sea diving, and, having engaged two experienced Divers, Messrs. R. Ridyard and W. Penk, of Liverpool, Captain Lodge left England and duly arrived at Shanghai, where he engaged the pilot cutter *Maggie,* and proceeded in search of the wreck. This operation had to be prosecuted by means of a boat, as the larger vessel could not proceed so close to the high rocks. After a search in different depths, varying from 120ft. to 160ft. of water, the Divers at length found the wreck. The after part containing the treasure had rolled into deep water, 26 fathoms or thereabouts, for it appears that when the *Hamilla Mitchell* struck the rock, she rested on a ledge, but subsequently gales caused her to part amidships, the after part rolling into deep water. After some difficulty Ridyard succeeded in obtaining access to the treasure room, where he found that some of the dollars were lying in heaps, the worms having eaten the wooden boxes so that they were completely riddled. Ridyard made four successful trips, the last of which proved the most advantageous of all, for on that occasion he sent up the contents of sixty-four boxes of treasure. Ridyard being thirsty, W. Penk volunteered to ascend to the top of the island to fetch him some spring water. While filling the bucket he looked round the horizon, and to his astonishment he saw an innumerable quantity of white sails coming from the mainland. He informed Captain Lodge of the circumstance; that gentleman identified them as several hundred piratical junks bearing down upon the island. Orders were therefore given to slip the anchor and chain, but the wind being light they were obliged to make use of oars; and, although in an exhausted condition, Ridyard pulled some time until a breeze sprang up, when they were enabled to make sail, and with the aid of night they reached Shanghai safely, running a very close risk, not only of losing the treasure they had on board, but also their lives. The Shanghai papers blame the authorities for not giving the expedition sufficient protection. The total amount of treasure recovered was £40,000, and but for this *contretemps,* Ridyard would have completed the entire salvage of the treasure. The balance was recovered some time later.

These three operations are particularly notable by reason of the great depths from which the specie was recovered, but much larger sums in specie, etc., have been recovered from vessels sunk in shallower depths, as, for instance, in the cases of the *Malabar* from which bullion to the value of £300,000 was salved; the *Darling Downs,* cargo of wool, etc., valued at £100,000 (of 725 bales all but five were recovered by divers); s.s. *Queen Elizabeth,* cargo and specie valued at £120,000.

THE DIVER'S COMPARATIVE IMMUNITY FROM ACCIDENT.

Considering the conditions under which the diver works, accidents are surprisingly few, and it is the proud boast of Siebe, Gorman and Co., Ld., that, notwithstanding the fact that there are several thousands of divers using their apparatus in various parts of the world, not a single accident attributable in the slightest degree to faulty construction or defective materials has ever occurred. Such accidents as have happened have been due to causes beyond control, and quite unconnected with the diving appliances. Take, for instance, the case of a diver engaged in a salvage operation on the Chilian coast some years ago, who was killed through a heavy box of silver, which he had worked hard to recover, falling out of its sling and crushing him. This was hard luck indeed.

Diver killed with box of silver.

Then there is the case of Diver Pearce, who some years ago was engaged in salving bales of cotton from the s.s. "London." A chain, having at one end of it four sharp-pointed hooks, was let down to the diver, whose duty it was to fix the hooks into the bales which were then hauled to the surface. One morning, Pearce, having fixed the hooks in one of the bales, signalled to those above to try whether the strain would hold. Whilst feeling to ascertain if the bale had started, the hooks, not being sufficiently secured to stand the strain, gave way, and, tearing out of their grip through the packing, one of them caught Pearce in the palm of the hand and dragged him from the bottom of the hold to the upper deck. When brought to the surface, he was in a state of collapse. In three months, however, he was at work again.

Diver hooked up by the hand.

Encounters under water

Of encounters with the denizens of the deep, many tales have been told, some true, the majority fit only to be relegated to the limbo of most "fish" stories.

Octopus.

The most dangerous foe the diver ever meets is the octopus. Once this creature, if of any great size, gets its tentacles, with its countless suckers, fastened to a diver, it is only by almost superhuman effort that he is able to free himself from its terrible grasp. There are cases on record where the struggle has only terminated when both diver and his adversary have been hauled bodily to the surface and on to the deck of the diving vessel, and even then the octopus has fought furiously.

Sharks.

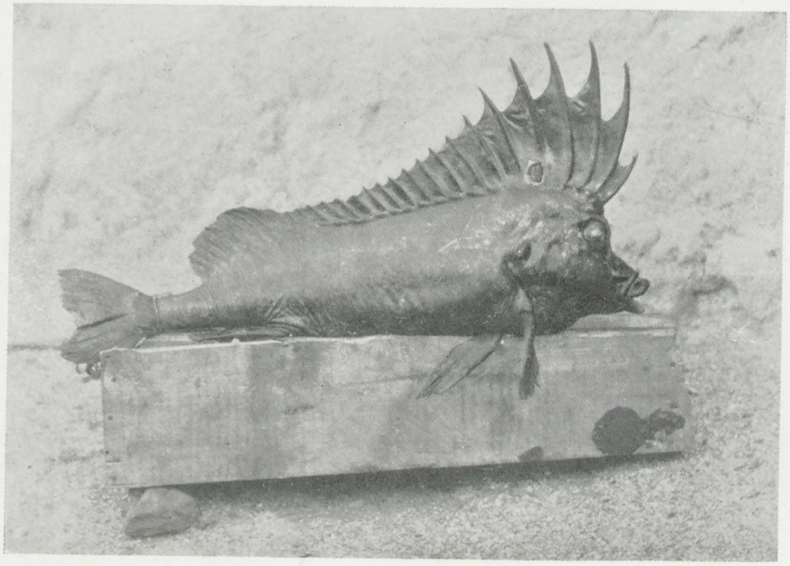
Sharks, as a rule, do not interfere with the diver, but the famous Lambert had an adventure with one in the Indian Ocean which deserves mention. The diver, whilst engaged in fixing copper sheets to a coal hulk off Diego Garcia, was annoyed by the attentions which the same shark paid him several days in succession. Each day it ventured a little nearer, but Lambert, by opening the air escape valve of his helmet, was able to scare the monster away. After this sort of thing had been going on for nearly a week, however, he determined one morning to end the annoyance. Signalling to his attendant for a large knife and a rope with a noose, which were promptly lowered to him, Lambert held out his bare hand as bait to the shark, and as it began to turn on its back for the attack, he stabbed it repeatedly, passed the noose round its body, and had it hauled to the surface.

A DIVER'S HAUL.

That individual divers have been known to make good hauls is proved by the following adventure:—

A Diver's El-Dorado

An old English diver, employed some years ago at a salvage job on the Galway coast, used to pass his evenings at an inn frequented by fishermen, one of whom, repeating a tradition which had long existed in the district, told the diver that one of the vessels of the Spanish Armada had been wrecked not far from the coast, and intimated his willingness to point out the spot. The diver, having finished the job upon which he was engaged, made terms with the fisherman and they were both out for many weeks dragging the spot indicated for traces of the wreck. They were at last rewarded by coming upon obstructions with their grapnels. The diver brought out his diving apparatus, descended to what proved to be the remains of an old Spanish vessel, and on making search came across a large number of dollars which had originally been packed in small barrels; the wood, however, had rotted away and left the coins stacked in barrel shape. With the proceeds the diver built himself a row of houses, which he called "Dollar Row."



Caught by a Diver when working under water at Durban, Natal.

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Photo No. 106.

A Sicilian Diver's adventure.

It is remarkable what a fascination anything connected with the exploration of the unknown depths has for most people. And this spirit, it would seem, was just as marked in bygone times as it is in our own. Father Kircher records the case of a Sicilian diver, Nicol Pesce, whose strength and power of endurance were astonishing. The king offered him a golden cup to explore the terrible gulf of Charybdis, where he remained for three-quarters of an hour amidst the foaming abyss. On his return he described all the horrors of the place, and the monarch was so astonished that he requested Pesce to dive once more in order further to ascertain its form and contents. The diver hesitated, but, upon the promise of a still larger reward, he was again tempted to plunge into the gulf. Unfortunately, however, upon this occasion he did not return.

We cannot help doubting the occurrence of this adventure, but if true, then our forefathers must have possessed means of supplying air and overcoming pressure, particulars of the construction of which have not been handed down to us. But the record at least serves to prove that our ancestors were just as much imbued with the desire to solve the mysteries of the deep as we are.

Fight between Divers under water.

During the operations on the wreck of the *Royal George* a desperate encounter took place between two divers named Girvan and Jones. There had been keen rivalry between the two, and each was jealous of the other's achievements. It appears that Girvan, whilst trying to release a certain cannon which had become deeply embedded in the sand, was reminded by Jones that that particular gun was his (Jones') property, he having been the first to find it. It may be added that there is a rule by which, in certain circumstances, the first diver to find an article is entitled to salve it.

Girvan was, however, disinclined to give way, with the result that the two men came to blows. Jones, feeling that he would soon get the worst of it, as Girvan was much the more powerful of the two, thought it wise to retreat, and had already ascended the shot-rope a few feet on his way to the surface when Girvan seized him by the legs and tried to draw him down. A desperate struggle ensued, in the course of which one of the windows of Girvan's helmet was smashed in. The attendants at the surface, noticing a violent tugging at the life lines and air tubes, and realising that something unusual was happening below, hauled both men up to the surface. Girvan was more dead than alive, but after a few days in hospital he recovered sufficiently to be able to resume work. The two combatants afterwards became the best of friends.

"Mary Rose," sunk 1545.
"Royal George," sunk 1782.

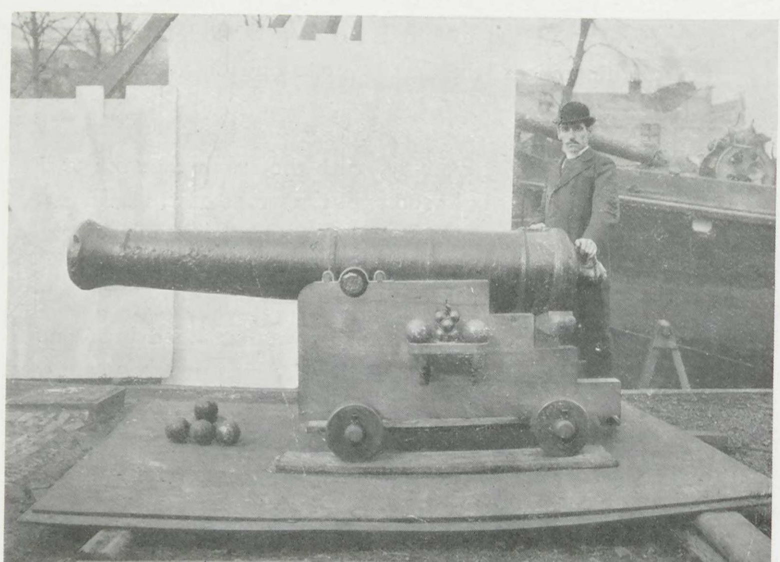
It was during the *Royal George* operations that the wreck of the *Mary Rose*, sunk in July, 1545, was accidentally discovered, by the fouling of some fishermen's nets, to be lying but a short distance from the former vessel. Turning their attention to the older wreck, the divers succeeded in recovering five brass cannon, bearing date 1535, and twenty of wrought iron. The latter were of peculiar construction, each gun being made of wrought-iron bars secured by thirty-three hoops. Many other relics were recovered, including granite shot, ancient bows, etc.

Diver attacked by a Conger.

A diver engaged on a harbour works had a curious experience a few years ago. He was repairing an old sea wall, when, to his horror, the head of a huge fish suddenly darted out of a hole in the wall quite close to where he was working, and tried to attack him, only missing him by a few inches. Subsequent investigation showed that the fish was a huge conger, which by some means had got trapped in the worn masonry, and was unable to get more than its head through the hole, for, although it was observed many times afterwards to seize passing fish, its body was never seen. A full-grown conger, weighing, perhaps, a hundredweight, and measuring eight or nine feet long, is an ugly customer to tackle, even in a boat. If it gets hold of a man's arm or leg, the only thing to do is to cut its head off, and even then its jaws will have to be prised open.

SUBMARINE SCENERY.

In some tropical waters the submarine scenery is very beautiful, the marine flora being unequalled by anything that grows on *terra firma*. Working amid such surroundings, the pearl or sponge diver's lot is indeed cast in pleasant places as compared with that of his less fortunate brother working in a London dock for instance.



Copyright. **Photo No. 107.**

Photo No. 107 shows a Cannon and some Shot recovered by Divers from the British Man o' War, "La Lutine," captured from the French, and which was lost with all hands near the island of Terschelling, off the Dutch coast, in 1799, with the equivalent of half a million pounds sterling aboard. Of this sum £100,000 has been recovered during the past century.

The vessel is deeply embedded in the sandy bottom, which fact renders the task of the salvors an exceptionally difficult one. Powerful sand suckers have been employed, but with little success, for as fast as the material is removed another lot takes its place. The latest scheme is to sink a huge tube, operated from the salvage steamer, right through the water and sand into the vessel, the sand sucker helping in the process of forcing the tube down.

The tube is provided with an air-lock chamber at its lower end, and the idea is that when a space has been cleared inside the vessel the diver, who has already entered the tube from the top, shall leave the air-lock and explore the cleared area, this operation being repeated till the whole vessel, or that part of it which is supposed to contain the treasure, has been searched.

DEPTH TO WHICH DAYLIGHT PENETRATES UNDER WATER.

This varies with the locality. For instance, in some of the Scottish lochs the water is so dark that daylight is lost to the diver when but a few feet below the surface. On the other hand, off the Rock of Gibraltar and in most tropical waters, he can see perfectly clearly when thirty fathoms and more down.

SUBMARINE PHOTOGRAPHY.

Many experiments have been carried out in this connection with varying degrees of success. We have in our possession photographs taken at Plymouth at a depth of sixty feet. For work of this description the camera is enclosed in a watertight metal case, and a very long exposure is necessary Further trials, which are now proceeding, will doubtless result in considerable developments in the art of photographing beneath the waves.

Copyright.

OXYGEN BREATHING APPARATUS.

(Fleuss, Davis and Hill's Patents.)

This apparatus enables a man to work with safety in the most poisonous atmospheres. The air in the breathing bag is automatically replenished with oxygen from steel cylinders carried on the wearer's back, the carbonic acid of the exhaled breath being absorbed by caustic soda.

Equipped with this apparatus, a man has accomplished over 350,000 foot lbs. of work in two hours.

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Printers,
Westminster, London, S.W.