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Dressing the Diver—Sending him down—Attendance and Signals—Bringing the Diver up—Decompression Tables

A diver may go down from a dockside, a staging, a boat or a ship. In any case, a suitable ladder (see page 78) must be firmly rigged up, and things arranged to save him as much climbing as possible when he comes out of water with his weights on. Any boat used should be strong and broad-beamed; if tempted to use a small or cranky boat, remember that a partly dressed diver, with his boots on, cannot swim.

Having got everything necessary (for list of items, see page 92) into the boat, arrange the positions of the ladder and pump. The pump must be out of the way of the diver and of 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 elbow room as possible. Secure lashings must be passed so as to ensure the pump being quite rigid in the boat. While the diver is dressing, the pump should be got ready. The iron caps protecting the crank-ends should be removed, and the nuts securing them replaced. The flywheels should then be fitted on to the crankshaft, the pump handles shipped at right angles, and the washers and nuts on the ends of the shaft screwed well 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 water jacket removed, and the jacket filled with water. The protecting caps of the air delivery nozzles should be removed, and the air-pipe screwed on. Whenever screwing on air-pipe, whether to the pump, or the helmet, or one length to another, make sure that leather washers are in place in the female connections, and use two spanners, one to screw up, and the other to prevent the connection from being wrenched.

After connecting the air-pipe to the pump, it should be tested by blanking off the open end, or closing it by pressure of the palm of the hand or thumb and then heaving round the pump till the gauge shows a considerably greater depth than that to which the diver is going to descend; the pump is then stopped and the gauge watched; if it falls, a leakage is indicated which must be traced and corrected. If two divers are going down on a double pump, the pipe of each must be tested in this way; if one diver is going down on a double pump, his pipe must be connected to the left-hand nozzle.

Joining Up Air-Pipe and Breast-Rope to Helmet. Before screwing the air-pipe on to the elbow-pipe at the back of the helmet, insert a finger into the inlet valve, and make sure that it is free on its seating, and that the spring is working properly; make sure that there is a leather washer in the female end of the air-pipe, and screw up with two spanners, so as to avoid wrenching the elbow-pipe.

Enter the plugs of the telephone cable into the correct sockets before screwing up the union nut of the breast-rope, and see that the washer is in good condition as a slight leakage at this point will short-circuit the telephone. Connect up the battery box and test the telephone.

The 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. A stout bench should be provided for the diver to sit on. 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 down close over the head, care being taken to leave no loose end which might possibly obstruct the air outlet. 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 the purpose). 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. Before putting on the corselet, the shoulder pad is slipped over his head and adjusted on his shoulders.

The boots are put on with the buckles outwards, and the lanyards well secured round the legs above the uppers of the boots. Carelessly tied boots may get pulled off when working on a muddy bottom, and the diver is responsible for the correct fitting and tightness of lacing of diving boots and fitting of wrist-rings (see below).

Putting on the Corselet. The diver sits down facing the pump, the inner collar of the dress is pulled up out of the way, and the corselet put into place by the attendants who then pull the outer rubber collar up over its rim, being careful not to tear the rubber when working the holes over the projecting studs. The diver now stands up and the attendants pull the inner collar up all round, to ensure that no fold of it is caught between the bearing surface of the corselet and the rubber collar, as this would spoil the joint. The clamping straps are shipped over the studs in their correct positions according to the markings stamped on them, and the wing nuts lightly run on to the studs. Before screwing them down, the collar is borne up so as not to be dragging away from the studs, and (in the six-bolt type) the beadings on the rubber collar are pressed into the corresponding recesses in the strips. In both the 6-bolt and 12-bolt types, the screws in the middle of each strap are screwed up first; those at the joints where two straps butt together being left to the last.

It is a mistake to use much force in screwing up these nuts with the spanner, as by so doing the straps (bedding on the compressible collar) may be bent out of shape, so that, instead of making a tight joint, too much force has the opposite effect. If the legs of the dress are fitted for lacing or strapping up, it can be done now.

Wrist-Rings are next put on and adjusted to suit the diver. The cuff should be worked back from the boniest part of the wrist.

The Jock-Strap, if one is worn, is now put on, and the diver stands while it is adjusted for length, so as to allow of the corselet lifting just clear of the shoulders, but no more.

The Helmet (without the front glass) is then gently lifted into place and screwed on, the hinged stop at the back being turned down into the recess at the back of the corselet. The lizard of the breast-rope is passed round the back of the diver, outside the air-pipe, across the front, and dipped under its own standing part, pulled moderately taut, and timber-hitched back round its own part. This secures the breast-rope and air-pipe to the right and left sides of the diver's waist respectively.

The Knife and belt go on next, with the knife hanging on the left side rather to the front, so that the diver's hand falls on it readily. Next the air-pipe and breast-rope are brought up under the arms and secured in front by the lanyards on the neck of the corselet or the special eyes in the front of the helmet.

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 to the Ladder, the attendant keeping the breast-rope and air-pipe in hand, lest the diver slip overboard. The diver being properly placed on the ladder, the attendants place the pipe and breast-rope outside it and take a complete turn with each round the sides while they put on the weights.

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 by a reef-knot. If using the clips, the front weight is put on first, the clips being placed over the studs on the corselet; then the back weight with its lanyards passing over the hooks on the helmet, the two being secured to the diver's body by the lanyard round the waist.

All Ready for Descent. 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 diver goes backward down the ladder till his head is just under water, when he stops and closes his outlet valve to allow of the attendant seeing whether bubbles are escaping from any leak that requires attention. If all is well, the attendant will give him a signal and he can open the outlet valve again, let go the ladder and allow himself to be drawn to the shot-rope down which he is to slide to the bottom.

The routine of putting on the weights while the diver is standing on the ladder and screwing in the face glass afterwards, as described above, is the usual one, but it is often more convenient to start the pump slowly, and screw in the face glass before he gets on the ladder; the weights may be put on at the same time.

Extra Air Supply During Descent. As soon as the diver is on his way to the bottom he should be given additional air by starting the second pump (if two are joined up) or by heaving round faster; this will help him to get down fast and comfortably. When he stops his descent, either on account of some hitch or because he has reached the bottom, the air supply is reduced to a volume suitable for the depth at which he is working.

Attendance. Each diver while under water requires an attendant to hold the breast-rope and air-pipe. The official in charge of the operations should see that the pipe and rope pay out clear.

The post of attendant is a very responsible one. From the time the diver gets on to 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 direction in which they are moving. Where there is much rise and fall of tide he must see that the shot rope is frequently hauled in or lowered, so as to keep the shot on the bottom and the rope taut.

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 if this should 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 be 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 either that 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 the 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 called up at once. 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.

Holding the Breast-Rope and Pipe. In attending the pipe and rope, give the diver 2 or 3 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 continually being 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.

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.

Undressing the Diver. When the diver comes up for good, remove the weights first of all; there is no hurry with the face glass. Assist the diver to step off the ladder, and guide him to the seat. The lanyards of the air-pipe and breast-rope are cast off, also the knife belt and lizard. The hinged stop at the back of the helmet is turned back and the helmet unscrewed and carefully lifted off the diver's head. The clamping straps (or brasses) of the corselet are next removed by unscrewing the wing nuts, starting with those at the junctions of the brasses. Next the rubber collar is lifted clear of the studs of the corselet. This is the time when roughness is likely to tear the collar. Take care to prevent the screw threads on the studs tearing the edges of the holes in the rubber collar. The corselet can now be removed. The boots should have been taken off by this time, also the wrist-rings. The diver should lubricate his hands with soft soap, or strong soap and water and stand up so that the attendant can, by pulling downwards on the end of the sleeve, turn the cuff back over the diver's hand, when a quick jerk on the part of the diver will disengage his hand. When both arms are out of the dress, it is pulled down on to the legs, the diver sits down again on something dry, and the attendant pulls the dress right off. If the day's work is now over, the dress and equipment should be treated as described under the heading of "care and maintenance" before being stowed away.

THE CODE OF SIGNALS

Signals from Diver to Attendant

On breast-rope:

One pull means	"I am all right."
Two pulls mean	"Send me a slate."
Three pulls mean	"Send me a rope."
Four pulls mean	"I am coming up."

On air-pipe:

One pull means	"Less air (ease pump)."
Two pulls mean	"More air (heave faster)."
Three pulls mean	"Take up slack pipe and breast-rope."
Four pulls mean	"Haul me up."

Working Signals or Bells

On breast-rope:

One bell means	. .. ..	'Hold on."
Two bells mean	.. .. ..	"Pull up."
Three bells mean	. .. ..	"Lower."
Four bells mean	. .. ..	"You are holding me too tightly."

When Working on a Slung Stage

On air-pipe:

One pull means	.. ..	"Foremost starboard rope."	*Followed by the ordinary "pull up" or "lower" signal*
Two pulls mean	.. .. ..	"After ditto."	
Three pulls mean	.. ..	"Foremost port rope."	
Four pulls mean	.. .. ..	"After ditto."	

Signals from Attendant to Diver

Direction Signals

On air-pipe:

One pull means	.. .. ..	"Search (or remain) where you are."
Two pulls mean	.. .. ..	"Go straight ahead."
Three pulls mean	.. .. ..	"Go to the right."
Four pulls mean	.. .. ..	"Go to the left."

The right and left signals are obeyed in the following way: On receiving three pulls the diver is to face his own shot rope or whatever corresponds to it and then move to his own right. On getting four pulls he is to face his shot rope and then go to the left.

On breast-rope:

One pull means	.. .. ..	"Are you all right?"
Two pulls mean	.. .. ..	"Am sending a slate."
Three pulls mean	.. .. ..	"You have come up too far; go down slowly till we stop you."
Four pulls mean	.. .. ..	"Come up."

A rapid succession of pulls on the breast-rope or air-pipe is the telephone call.

Foul Signals

can be made on either breast-rope or air-pipe (whichever is clear). "Two bells" repeated several times quickly mean that the diver is foul and requires the assistance of another diver. Three bells repeated several times quickly mean that the diver is foul, but can clear himself if left alone.

Signalling when Air-pipe and Breast-rope are seized together

Pipe and rope are sometimes made into one line by seizings, so as to lessen the risk of fouling when diving on a sunken wreck. It is then only possible to make a limited number of signals, and a special code must be devised according to the circumstances of the case and the nature of the work in hand, leaving out the signals which are least likely to be wanted. The following system of signals is inserted as a guide:

On breast-rope and air-pipe together:

From Diver

One pull means	.. . ..	"I am all right."
Two pulls mean	.	"Send me a slate."
Three pulls mean	.. .. .	"Send me a rope."
Four pulls mean	.. ..	"I am coming up."

From Attendant

One pull means	"Are you all right (when diver is ascending one pull means 'stop')."
Two pulls mean	"Look out for the rope or slate which we are now lowering."
Three pulls mean	"You have come up too far. Go down slowly till we stop you."
Four pulls mean	"Come up."

The signals for "pull up", "lower" and "hold on" would be the same as usual, except that they would have to be made on the pipe and rope together.

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 to the officer in charge. The person receiving a signal repeats it back 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 must ask the diver if he is all right from time to time, and if no reply can be obtained, the diver must be hauled up under the direction of the officer in charge.

If the breast-rope and pipe get turned round the shot rope it may become impossible to get 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 strike the helmet up against the diver's head and 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.

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 means 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.

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

Sending Down a Rope or a Slate. In very shallow water any article asked for by a diver may be bent on to his breast-rope and one pull given as a signal; the diver hauls down his breast-rope till the article reaches him. When he wants the attendant to haul back the slack, he gives one pull. This is a stupid way of doing things, except in the simplest conditions. If the water is dark, the diver is apt to get the coils of slack breast-rope, which he hauls down, into a tangle; or the tide may sweep the bight away and get it foul of some obstruction. When there is no question of stoppages, it is generally better for the diver to come up to the ladder for what he wants, or, in deeper water, to have it slid down to him on a shackle. (See pages 121-122.)

List of Equipment Required. Before setting out for diving the gear should be checked over to see that nothing is left behind. The following list will serve as a reminder:

- Air-pump with handles, wheels, etc.
- Helmet and corselet.
- Dress.
- Boots.
- Weights.
- Suit of woollens.
- Shoulder pad.
- Jock-strap.
- 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.
- Boat's compass.
- A large red flag on a staff, or
- Diving flag on staff.
- Long heaving line, large shackle and coil of rope for sending down to the diver.
- Decompression indicator and log.
- Tables of depths and corresponding pressures and decompression times.

Duties of the Officer in Charge. In shallow-water work and simple jobs the diver is often the person in charge of the operations, and everyone works under his orders, but in deep water, where the diver has to be gradually decompressed according to a fixed scale, or in complicated jobs, where much hoisting has to be done, or when more than one diver is at work, it is far better for an officer or supervisor on the surface to be responsible.

The following notes describe the duties of such an officer:

In the first place, he should be satisfied that he has enough men to manage the boat, work the pumps and attend the divers, also sufficient pumping capacity for the depth (see page 38). He should see that none of the gear is left behind, and supervise the preparation of the pumps, joining up and testing of air-pipe and telephone breast-rope as described on page 86. He then sees the diver properly dressed, and makes sure that he understands what he has to do and the procedure to be followed in coming up.

In hazardous work, where there is danger of the diver getting jammed or foul and unable to extricate himself, a second diver should be available to render assistance, and of course, an independent air supply must be available for this man. A large red flag should always be displayed where a diver is working, so as to warn passing craft to keep clear.

Working on a Ship's Bottom. When work is to be done about a ship's bottom, propellers, etc., the rigging of the 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 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 up on the opposite side of her to that alongside which the diving boat is lying.

When a man is sent down to examine damage to a ship, it is generally a good plan to 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. A proper diver's rule and spirit level will be found of great service in preparing reports of damage; as decisions involving many thousands of pounds often have to be made on the basis of such reports, they must be dead accurate.

Searching for Lost Articles. Take with you, at any rate, one good buoy with buoy-rope and sinker of your own. If the water is so thick that the diver is in darkness, the boat must be anchored in one spot while the diver works round in circles on his distance-line and explores the ground. When finished, that spot is marked and the boat anchored a little way off, so that the diver can search an adjoining circle, and so on. In clearer water the boat can be moored between two anchors and slowly warped from one to the other, the diver zigzagging across her course.

When the object sought is a cable or anything which can best be found by moving in a straight line, the 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 along the bottom while the boat covers the ground systematically.

When 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).

Where a particularly important or valuable article has to be located in a large area, or an area, such as a ship's berth, has to be searched carefully for obstructions, etc., a series of square searches is better than a number of circular searches. Square searches enable the area to be sectioned off economically without overlaps or "holidays".

Square searches are best carried out by using one of the "grid" methods developed during the war for locating mines and unexploded bombs. The "grid" must be prepared beforehand and is usually made of 1 inch or 1½-inch steel wire. It is laid out from a boat and anchored at the corners by shot-weights or boats' anchors.

One type of grid has wires spaced 6 feet apart in a 60-foot square. The diver works along one side of each wire sweeping to one side with his disengaged arm. He then crosses over the wire and comes back the other side still sweeping with the same arm. Thus, he covers a 3-foot zone either side of the wire.

Another type of "grid" has two jackstays with eyes spliced in every 6 feet and a portable "search-wire" with a spring hook each end stretched between them. Two divers are used and start at opposite ends of the "search wire", sweeping either side of it and passing each other in the middle. They then unhook the "search wire" and move it to the next eye and repeat the search until the whole area has been covered.

Such methods were used in the recaptured ports of Northern Europe in 1944 and 1945, when quite small objects were located among incredible debris and confusion on the beds of the harbours.

Work in a Tideway. In places where work has to be carried on in a tideway the officer must 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 half-hundredweight sinker refuses to remain on the bottom, but is swept off by the tide, it will generally be found impossible for a man to do any useful work there.

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 being exposed to too strong a tide while on the shot rope. On such occasions a heavy sinker must be used so as to render it impossible for the diver, while still on the shot rope, to be swept up to the surface by the tide.

While it is safe to send down a diver when the tide is still running before slack water because it will be easing all the time, caution must be used in sending him down after slack water when the tide has begun to make, lest he should get foul and be unable to clear himself in the increasing current.

Diver Blown Up to be Sent Down Immediately. A diver who blows up from deep water is in great danger of being attacked by compressed air illness. This can best be prevented by sending him down at once to the depth from which he came. The great thing is to get him down under pressure before bubbles have time to form, and the officer in charge must act promptly and without hesitation.

If the man has been got down in time, and has felt no ill effects, he can then be brought up by the ordinary scale in the tables, but it is advisable to keep an eye on him for an hour or two afterwards and to be ready to send him down again if illness should come on.

If a man blows up and becomes ill before he can be got down again, unless a recompression chamber is immediately available he should still be sent down, as the pressure acts as a cure as well as a preventive. If helpless, his valve should be opened and the man lowered down by his breast-rope and air-pipe, another diver being sent down to look after him as soon as possible. In this case he must be brought up much more slowly. (Full directions will be found in Chapter 6.)

Air Supply. Since a diver needs a volume of at least 1·5 cubic feet of air per minute, measured at the pressure corresponding to his depth (see page 37), it follows that the amount of *free* air (or air measured at atmospheric pressure) needed is greater in deep than in shallow water. Hence the pump must be hove round faster, or additional pumps joined up as the depth of diving increases. The data are summarized in the table on page 38, and the requirements at each depth are also given in the last three columns of the decompression tables on pages 100-108.

Joining Up Two Pumps to One Diver. To join up two or more pumps to one diver, the four-way junction described on page 78 is employed (Fig. 94).

The left-hand delivery nozzle of each pump is connected to one of the arms of the junction by a length of pipe. It is better to use 30-feet lengths with a double female connection and keep the 45-feet lengths for the diver.

The diver's pipe is joined up to the 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, and both pumps are hove round till the full pressure is reached; this is to test the connections. The four-way junction should be mounted on a board lashed to some 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 enough after the diver has reached his first stopping place. In joining up extra pumps or taking them off, the instructions on page 78 are to be carefully followed.

Explanation of the Haldane Decompression Tables. These tables (pages 100-108) embody the system of preventing compressed air illness ("diver's palsy") which was first adopted in the British Navy and has since spread to all the navies and deep-water divers of the world. In the first columns are set out the equivalents in feet, fathoms and pounds pressure for all depths up to 34 fathoms. The fourth column gives different durations of dives at each depth; the fifth to thirteenth columns give particulars for bringing up (or decompressing) the diver after each duration of dive;

and the fourteenth, fifteenth and sixteenth columns show the number of pumps and men and the speed of turning required to provide the necessary air supply at each depth. (See also page 38.)

At depths greater than ten fathoms a thick black line will be seen struck across from the fourth to the thirteenth column. The duration of a dive at a given depth should not be allowed to exceed the time immediately above this line in the fourth column. Thus, if we are going to send down a diver in 20 fathoms, the tables tell us that the pressure on him will be 53½ lbs. per square inch, and that we shall require four cylinders (two double pumps) turned at 20 revolutions by a shift of 12 men to keep up the proper air supply. The position of the thick black line indicates that 35 minutes is the longest time we can allow the diver for getting down to the bottom and doing his job, and that, after that, his ascent will take 33 minutes; if he comes up within 20 minutes after leaving the surface, his ascent will only take 19 minutes.

Up to ten fathoms there is no limit placed on the duration of the dive; beyond that the thick black line shows a limit which gets shorter as the depth increases. The object of this is to prevent a longer time than 33 minutes being required to decompress the diver. This limit should not be exceeded, but the times below the black lines are provided in case of the diver stopping too long, either through getting foul or through being allowed to stop down to finish an important piece of work.

Before the officer allows a diver to stay on the bottom longer than the limit shown by the thick black line, he should look up in the tables the time which is going to be required for bringing him safely up, and make sure that neither the state of the weather nor the tide, nor the temperature of the sea is likely to interfere with proper decompression. If the limit is greatly exceeded, serious compressed air illness may develop in spite of the long decompression, because long decompressions can be so exhausting as to defeat their own end; but if the limit is only slightly exceeded, there is not much danger, though "bends", which are painful though not dangerous to life, may occur.

Extra Precautions after a Second Descent. If a diver descends a second time into deep water with an interval of less than four 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. The safe rule is to add together the times on the bottom in the two dives and use the corresponding precautions shown in the tables. The extra time for coming up found in this way need only be used for the second half of the stoppages. For the first half of the stoppages use the times corresponding to the period for which the man really was on the bottom in his second dive.

If the number of stoppages shown in the tables is uneven, it should be divided so that the greater number is used for the stoppage times indicated for the sum of the two dives; e.g. if five stoppages are shown, the three at the lesser depths should be those for the combined dive figures and the two at the greater depths those for the second dive figures.

Example. A man goes down in 19 fathoms, remains on the bottom for 20 minutes, and then comes up according to the table. One hour later he again goes down and remains on the bottom for 30 minutes. What stops should he make in coming up the second time? Adding the two times together we get 50 minutes at 19 fathoms, for which, the table shows, there are three stops. We only require the last or shallower half of these, that is to say, the stops at 20 feet and 10 feet; so we note that the diver must stop 15 minutes at 20 feet and 20 minutes at 10 feet. For the first or deeper stops we look up the real time he actually was on the bottom in the second dive, viz. 30 minutes, for this there is no stop at 40 feet, but five minutes at 30 feet. The checks for this man after his second dive, therefore, are five minutes at 30 feet, 15 minutes at 20 feet, and 20 minutes at 10 feet.

Air Supply. The columns showing the number of cylinders of Siebe, Gorman & Co.'s double-acting hand 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 should not persist in trying to work without the proper quantity of air.

The column showing the number of men required on the pumps in a shift is only intended as a guide: for prolonged work at considerable depths the men will have to be relieved at fairly short intervals, in any case enough men must be kept on the pumps to maintain the number of revolutions shown to be necessary.

The desirability of using power-driven air compressors under certain conditions has been dealt with in Chapter 3.

Recording Dives. All times are to be taken by watch and recorded; any change of depth must also be noted and the gauges read and logged every few minutes when the diver is working in deep water and a slight change of depth is likely to make a difference in the time required for coming up.

The following example page from a diving officer's notebook shows the proper way of logging a diver, everything being, of course, written in at the time it happens, and not from memory:

Date: 7th August, 1934. *Diver's Name:* John Tar.

Nature of Work: Recovering cargo from SS. *Neptune.*

Maximum depth: 96 ft.

Left surface	6.23 a.m.		*Called up, 7.0 a.m. = 37 minutes under water.*	
Arrived bottom	6.26 a.m.		*Time to be allowed for decompression in accordance with the table, 27 minutes.*	
Depth by gauge	6.29 a.m.	95 ft.	*Left bottom*	7.2 a.m.
" "	6.35 a.m.	94 ft.	*Reached 30 ft. stage* ..	7.4 a.m.
" "	6.40 a.m.	90 ft.	*Left 30 ft.* " ..	7.6 a.m.
" "	6.45 a.m.	96 ft.	" *20 ft.* " ..	7.14 a.m.
" "	6.50 a.m.	94 ft.	" *10 ft.* " ..	7.29 a.m.
" "	6.55 a.m.	94 ft.	*Arrived surface* ..	7.30 a.m.

Management of the Diver's Ascent. When the diver is ready to come up the officer himself, or a reliable person detailed by him, attends at the gauge with watch and notebook for the purpose of controlling the pumps and stopping the diver. He is to look inside the pump lid for the error of the gauge (see page 50), and inform the attendant where the diver is to stop by ordering "Bring the diver up to 30 feet" or 10 feet, as the case may be. The gauge is watched carefully while the diver comes up; as soon as he is nicely on the move, the extra pumps may be stopped, but if there is a strong tide or other hindrance, give the diver plenty of air up to the last moment. If he is coming up too quickly, stop the pumps and check him at once; after giving this hint he may be allowed to come on again slowly. A diver should not be allowed to come up from the bottom to the first stopping place at a faster rate than 1 foot per second, and his ascent should be checked at once if he seems to be coming up too quickly and likely to overshoot the first stopping place. When he is 30 feet below the first stopping place, stop the last pump and tap the gauge continuously with the fingers. This is to prevent it showing too high or being sluggish; when the needle is just coming on to the proper depth (allowing for gauge error), order "Check the diver". This is done by the attendant giving one pull on the air-pipe. Start the pump again, log the time, see that the marks on the breast-rope correspond (roughly) with the gauge, and then stop the pump again to get a second reading of the gauge.

The attendant assists the officer at the gauge in this way: Suppose the diver is to be stopped at 20 feet, the attendant looks out for the 20 feet mark on the breast-rope as he is taking it in, and if he sees it appear at the surface before the officer at the gauge calls out, he is to stop the diver immediately without waiting for orders and report that he has done so. This is not to take the place of the gauge method, but only to check it. In a tideway the gauge alone must be relied on.

When it is time for the diver to come up to the next stopping place, call him up, stop the pump as soon as he answers, and proceed as before. If the diver overshoots the mark and comes too high, send him down at once by three pulls on the breast-rope; the pump must be restarted before he begins to descend, or he may get squeezed.

Surface Decompression. "Surface decompression" (or "crash surfacing" as it is sometimes known) is a method used by the Royal Navy of getting the diver inboard without carrying out long stops on the shot rope.

During the treasure recovery operations on the wreck of the *Laurentic* sunk at 132 feet (see Part II, Chapter 1), Captain Damant, R.N., was frequently compelled by some accident or sudden change of weather, or for military reasons, to bring his divers straight to the surface. They were put into the recompression chamber as quickly as possible, the pressure was run up to the diver's working depth and, after a minute or so they were decompressed by the ordinary tables as for a normal dive.

The method was used as routine during the salvage of 250,000 dollars worth of silver from the *Empress of Ireland* in 1914, when several hundred dives were made at a depth of 170-190 feet. The divers came straight to surface, were run up to 77 lbs. in the chamber, and then decompressed by the standard tables. There were no cases of compressed air illness. It should be remembered, however, that the greater the working depth the greater the risk of compressed air illness; it was for this reason that the author designed his three-compartment decompression chamber (see Chapter 7) with means for transferring the diver from the Davis submersible decompression chamber without interfering with the normal decompression process.

This method makes use of the delay in bubble formation due to the viscosity of human blood as opposed to that of water (see Chapter 1). It has been shown both in practice and in a large number of experiments carried out in our experimental department, that a diver can be brought to the surface without stops, provided he is instantly recompressed within certain prescribed time limits.

Surface decompression is described below. It must only be used, however, by an experienced and practised team. *The various limitations laid down must be strictly adhered to, otherwise a fatal accident may result.*

In surface decompression, the diver, at the end of his time on the bottom, is brought into the shot in the usual way. The diving officer checks over the telephone that the diver is all ready to leave the bottom and then gives the order "Come up; surface decompression—first stop surface".

On receipt of this order, the diver starts to ascend as fast as possible without losing control, but being always prepared to check his ascent within 10 feet or so if ordered to do so from the surface. As soon as he sights the ladder, the diver transfers himself to it and breaks surface on the ladder and not on the shot rope.

The attendants, seeing him break surface, take the weight on his gear and the diver continues to climb the ladder, up and inboard. The attendants, of whom there should be not less than three, quickly remove his front glass, knife and belt, and front and back weights. (The weights should be on lanyards, not lugs, and should be secured with a bow hitch before diving so that they can be released by one pull.)

The diver now sits on some convenient seat and the attendants remove his helmet, with air-pipe and breast-rope still attached, and help him as quickly as possible into the recompression chamber.

Here a fourth attendant must be waiting ready to receive him. As soon as the chamber doors are shut the pressure in the chamber is raised quickly until it reaches a pressure equivalent to that on the sea-bed at the depth at which the dive was carried out. It is usual to run up the chamber pressure fairly slowly for the first atmosphere, to give both diver and attendant a chance to "clear their ears". Thereafter the pressure is increased as rapidly as possible.

The whole operation from the time the diver "leaves bottom" of the sea to his arrival at corresponding pressure in chamber must not take more than five minutes. Normally this time is adequate and a good average time for 200 feet dives is three-and-a-half minutes. However, as there may be unexpected delays, it is essential that divers be drilled in making a rapid ascent and the attendants be thoroughly practised. The sooner the diver is safely in the chamber the better, as a time margin must be available to check for ears in the chamber, or to allow for slowing the "descent" should the diver feel unwell.

When the diver "arrives bottom" in the chamber, the maximum pressure is maintained for five minutes. This allows the diver to become re-stabilized at the maximum diving depth, and ensures that any small bubbles which may have started to form during the ascent from the bottom of the sea, are recompressed into the blood.

At the end of the five-minute period on the bottom in the chamber, the diver is decompressed, using the deep diving tables (Chapter 7) for all depths over 120 feet. Oxygen breathing, as laid down in these tables, is *absolutely essential.*

The "time on the bottom" to be used in looking up the stops from the table must always be taken for the total time of dive, i.e. from the time of "Leaving Surface (sea)" to that of "Leaving Bottom (*chamber*)", so that the time for the ascent and transfer to the chamber, and the five minutes' rest in the chamber, all count as time on the bottom at the maximum depth.

The following rules, therefore, are to be strictly adhered to for this method:

1. It is only to be carried out by a well-drilled team of divers and attendants and under experienced supervision.
2. A compression chamber with an adequate air supply and with a supply pressure well in excess of the maximum diving depth, must be *immediately* adjacent to the diving ladder.
3. The following times on the bottom of the sea are not to be exceeded*:

Depth	*Time on bottom*
Up to 130 feet	50 minutes
130-150 feet	40 minutes
150-170 feet	30 minutes
170-190 feet	20 minutes
190-200 feet	10 minutes

   (The times in this table do not include the time for ascent and transfer to the chamber, nor the time on the bottom in the chamber which must be added to the above times when looking up the Decompression Stops.)
4. Should these times on the bottom be inadvertently exceeded, stops are to be carried out on the shot rope in the normal manner.
5. Should there be a delay on the shot rope during the ascent, due, say, to the diver finding himself foul, the method is to be abandoned forthwith and normal decompression resorted to.
6. The method is not to be used in excess of 200 feet, beyond which depth it is dangerous.
7. The interval between leaving the bottom of the sea and "arriving bottom" in the chamber is not to exceed five minutes.
8. The diver is to be left at the maximum pressure in the chamber for five minutes before decompression is started.
9. Decompression is to be by the Deep Diving Tables when the depth exceeds 120 feet, and oxygen decompression is invariably to be used when prescribed by the tables.

* This table was compiled by Surgeon Lieutenant-Commander K. W. Donald, D.S.C., R.N., and Surgeon Lieutenant-Commander W. M. Davidson, R.N., of the Admiralty Experimental Diving Unit.

Provided that the above rules are adhered to, much valuable work can be and has been done in circumstances where normal decompression methods are impracticable, and there will be no ill effects upon the divers.

The greatest advantage of "Surface decompression" is that all the time that conditions permit of a diver being outboard can be spent on the bottom and on the job. This is, of course, invaluable in tidal conditions when slack water periods are limited. Surface decompression is also useful in emergency such as when a diver "blows up" out of control and cannot be got down again, or in the event of a diver meeting with an accident and damaging his gear when under water.

At present this method can only be carried out in the standard Siebe, Gorman dress and cannot be done in deep-diving equipment.

J. S. HALDANE'S DECOMPRESSION TABLES

TO LIMIT OF 204 FEET (AIR ONLY)

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80ft.	70ft.	60ft.	50ft.	40ft.	30ft.	20ft.	10ft.	Total Time for Ascent in Minutes.	Number of Cylinders needed.†	Revolutions of Pump per Minute.‡	Number of Men per Shift on Pumps.
0–33	0–5½	0–15	No limit	—	—	—	—	—	—	—	—	0–1	1	15–30*	2
33–42	5½–7	15–18½	Up to 3 hrs.	—	—	—	—	—	—	—	—	1–1½	2	15–20	2
			Over 3 hrs.	—	—	—	—	—	—	—	5	6			
42–48	7–8	18½–21	Up to 1 hr.	—	—	—	—	—	—	—	—	1½	2	20	2
			1 to 3 hrs.	—	—	—	—	—	—	—	5	6½			
			Over 3 hrs.	—	—	—	—	—	—	—	10	11½			
48–54	8–9	21–24	Up to ½ hr.	—	—	—	—	—	—	—	—	2	2	20	2
			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	4
			20 to 45 mins.	—	—	—	—	—	—	—	5	7			
			¾ to 1½ hrs.	—	—	—	—	—	—	—	10	12			
			1½ to 2 hrs...	—	—	—	—	—	—	4	10	16			
			2 to 3 hrs.	—	—	—	—	—	—	5	15	22			
			Over 3 hrs.	—	—	—	—	—	—	10	20	32			
60–66	10–11	26½–29½	Up to 15 mins.	—	—	—	—	—	—	—	—	2	2	25	4
			15 to 30 mins.	—	—	—	—	—	—	—	5	7			
			30 to 48 mins.	—	—	—	—	—	—	2	8	12			
			48 to 60 mins.	—	—	—	—	—	—	3	10	15			
			1 to 1½ hrs...	—	—	—	—	—	—	4	13	19			
			1½ to 2 hrs...	—	—	—	—	—	—	5	15	22			
			2 to 2½ hrs...	—	—	—	—	—	—	5	20	27			
			2½ to 3 hrs...	—	—	—	—	—	—	10	20	32			
			Over 3 hrs.	—	—	—	—	—	—	10	30	42			

* 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. For actual quantities of air required at different depths, see page 38.

‡ *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80 ft.	70 ft.	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.‡	Number of Men per Shift on Pumps
66–72	11–12	29½–32	Up to 15 mins.	—	—	—	—	—	—	—	2	4	2	25	4
			15 to 25 mins.	—	—	—	—	—	—	2	4	8			
			25 to 30 mins.	—	—	—	—	—	—	3	5	10			
			30 to 45 mins.	—	—	—	—	—	—	4	9	15			
			¾ to 1 hr.	—	—	—	—	—	—	5	12	19			
			1 to 1½ hrs...	—	—	—	—	—	—	8	16	26			
			1½ to 2 hrs...	—	—	—	—	—	—	10	20	32			
			2 to 3 hrs.	—	—	—	—	—	—	10	30	42			
			Over 3 hrs.	—	—	—	—	—	—	20	30	52			
72-78	12–13	32–34½	Up to 10 mins.	—	—	—	—	—	—	—	3	5	2	25	4
			10 to 20 mins.	—	—	—	—	—	—	—	5	7			
			20 to 30 mins.	—	—	—	—	—	—	3	8	13			
			30 to 38 mins.	—	—	—	—	—	—	4	12	18			
			38 to 45 mins.	—	—	—	—	—	—	5	15	22			
			¾ to 1 hr.	—	—	—	—	—	—	8	16	26			
			1 to 1¼ hrs...	—	—	—	—	—	—	9	18	29			
			1¼ to 1½ hrs.	—	—	—	—	—	—	10	20	32			
			1½ to 2½ hrs.	—	—	—	—	—	—	20	30	52			
			Over 2½ hrs.	—	—	—	—	—	—	30	30	62			
78-84	13-14	34½–37	Up to 10 mins.	—	—	—	—	—	—	—	3	5	2	30*	6
			10 to 20 mins.	—	—	—	—	—	—	—	5	7			
			20 to 30 mins.	—	—	—	—	—	—	3	8	13			
			30 to 40 mins.	—	—	—	—	—	—	4	13	19			
			40 to 45 mins.	—	—	—	—	—	—	5	15	22			
			45 to 55 mins.	—	—	—	—	—	—	8	16	26			
			55 to 65 mins.	—	—	—	—	—	—	9	18	29			

* 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. For actual quantities of air required at different depths, see page 38.

‡ *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes 80ft.	70ft.	60ft.	50ft.	40ft.	30ft.	20ft.	10ft.	Total Time for Ascent in Minutes.	Number of Cylinders needed.†	Revolutions of Pump per Minute.‡	Number of Men per Shift on Pumps.
78–84 *Contd.*	13–14	34½–37	65 to 75 mins.	—	—	—	—	—	—	10	20	32	2	30*	6
			1¼ to 1½ hrs.	—	—	—	—	—	—	10	25	37			
			1½ to 1¾ hrs.	—	—	—	—	—	—	10	30	42			
			1¾ to 2 hrs...	—	—	—	—	—	—	15	30	47			
			2 to 2¼ hrs...	—	—	—	—	—	—	20	30	52			
			2¼ to 2½ hrs.	—	—	—	—	—	2	23	30	57			
			2½ to 2¾ hrs.	—	—	—	—	—	3	27	30	62			
			2¾ to 3 hrs...	—	—	—	—	—	5	30	30	67			
			Over 3 hrs.	—	—	—	—	—	10	30	35	77			
84–90	14–15	37–40	Up to 10 mins.	—	—	—	—	—	—	1	3	6	2	30*	6
			10 to 20 mins.	—	—	—	—	—	—	3	5	10			
			20 to 30 mins.	—	—	—	—	—	—	4	10	16			
			30 to 40 mins.	—	—	—	—	—	—	5	15	22			
			40 to 50 mins.	—	—	—	—	—	2	7	15	26			
			50 to 60 mins.	—	—	—	—	—	3	10	15	30			
			1 hr. to 1 hr. 12 mins.	—	—	—	—	—	5	10	20	37			
			1 hr. 12 mins. to 1 hr. 20 mins. ..	—	—	—	—	—	5	15	20	42			
			1 hr. 20 mins. to 1 hr. 30 mins. ..	—	—	—	—	—	5	15	25	47			
			1 hr. 30 mins. to 1 hr. 44 mins. ..	—	—	—	—	—	5	20	25	52			
			1 hr. 44 mins. to 2 hrs.	—	—	—	—	—	5	25	25	57			
			2 hrs. to 2 hrs. 14 mins. ..	—	—	—	—	—	5	25	30	62			
			2 hrs. 14 mins. to 2½ hrs. ..	—	—	—	—	—	5	30	30	67			
			2½ hrs. to 2 hrs. 44 mins. ..	—	—	—	—	—	10	30	30	72			
			2 hrs. 44 mins. to 3 hrs. 14 mins.	—	—	—	—	—	20	30	30	82			
			Over 3 hrs. 14 mins.	—	—	—	—	—	20	35	35	92			
90–96	15–16	40–42½	Up to 10 mins.	—	—	—	—	—	—	1	3	7	2	30*	6
			10 to 20 mins.	—	—	—	—	—	—	3	5	11			

* 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. For actual quantities of air required at different depths, see page 38.

‡ *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80 ft.	70 ft.	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.‡	Number of Men per Shift on Pumps.
			20 to 30 mins.	—	—	—	—	—	—	5	11	18			
			30 to 35 mins.	—	—	—	—	—	—	5	15	22			
			35 to 45 mins.	—	—	—	—	—	2	8	15	27			
			45 to 55 mins.	—	—	—	—	—	5	10	15	32			
90–96 *Contd.*	15–16	40–42½	55 mins. to 1 hr. 12 mins.	—	—	—	—	—	5	10	25	42	2	30*	6
			1 hr. 12 mins. to 1½ hrs.	—	—	—	—	—	5	15	30	52			
			1½ hrs. to 1 hr. 54 mins.	—	—	—	—	—	5	25	30	62			
			1 hr. 54 mins to 2 hrs. 18 mins.	—	—	—	—	—	10	30	30	72			
			2 hrs. 18 mins. to 2½ hrs.	—	—	—	—	—	10	30	35	77			
			2½ hrs. to 2 hrs. 54 mins.	—	—	—	—	—	20	30	35	87			
			Over 2 hrs. 54 mins.	—	—	—	—	—	30	35	35	102			
			Up to 5 mins.	—	—	—	—	—	—	—	3	6			
			5 to 10 mins.	—	—	—	—	—	—	—	5	8			
			10 to 15 mins.	—	—	—	—	—	—	3	5	11			
			15 to 20 mins.	—	—	—	—	—	—	4	8	15			
			20 to 25 mins.	—	—	—	—	—	1	5	10	19			
			25 to 30 mins.	—	—	—	—	—	3	7	10	23			
			30 to 35 mins.	—	—	—	—	—	4	8	13	28			
			35 to 40 mins.	—	—	—	—	—	5	10	15	33			
96-108	16–18	42½–48	40 to 50 mins.	—	—	—	—	—	8	10	20	41	4	20	12
			50 mins. to 1 hr.	—	—	—	—	—	10	15	20	48			
			1 hr. to 1 hr. 18 mins.	—	—	—	—	—	10	20	25	58			
			1 hr. 18 mins. to 1 hr. 44 mins.	—	—	—	—	—	15	20	35	73			(*see page* 50)
			1 hr. 44 mins. to 2 hrs.	—	—	—	—	5	15	25	35	83			
			2 hrs. to 2 hrs. 18 mins.	—	—	—	—	5	20	30	35	92			
			2 hrs. 18 mins. to 2 hrs. 34 mins.	—	—	—	—	10	25	30	35	102			
			2 hrs. 34 mins. to 2 hrs. 50 mins.	—	—	—	—	15	25	30	40	112			
			Over 2 hrs. 50 mins.	—	—	—	—	15	30	35	40	122			

* 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. For actual quantities of air required at different depths, see page 38.
‡ *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80 ft.	70 ft.	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.†	Number of Men per Shift on Pumps.
108–120	18–20	48–53½	Up to 5 mins.	—	—	—	—	—	—	—	4	7	4	20	12
			5 to 10 mins.	—	—	—	—	—	—	2	6	11			
			10 to 15 mins.	—	—	—	—	—	2	3	7	15			
			15 to 20 mins.	—	—	—	—	—	3	5	8	19			
			20 to 25 mins.	—	—	—	—	—	5	5	10	23			
			25 to 30 mins.	—	—	—	—	—	5	8	12	28			
			30 to 35 mins.	—	—	—	—	—	5	10	15	33			
			35 to 50 mins.	—	—	—	—	—	10	15	20	47			
			50 mins. to 1 hr.	—	—	—	—	5	10	15	25	57			
			1 hr. to 1 hr. 22 mins.	—	—	—	—	5	15	25	25	72			
			1 hr. 22 mins. to 1 hr. 44 mins. ..	—	—	—	—	5	20	30	30	87			
			1 hr. 44 mins. to 2 hrs.	—	—	—	—	10	20	30	35	97			
			2 hrs. to 2 hrs. 22 mins.	—	—	—	—	15	25	35	35	112			
			2 hrs. 22 mins. to 2 hrs. 44 mins.	—	—	—	—	20	30	35	40	127			
			Over 2 hrs. 44 mins.	—	—	—	—	30	35	35	40	142			
120–132	20–22	53½–59	Up to 5 mins.	—	—	—	—	—	—	—	5	8	4	25	12
			5 to 10 mins.	—	—	—	—	—	—	3	7	13			
			10 to 15 mins.	—	—	—	—	—	2	5	7	17			
			15 to 20 mins.	—	—	—	—	—	3	7	10	23			
			20 to 25 mins.	—	—	—	—	—	4	8	13	28			
			25 to 30 mins.	—	—	—	—	—	5	10	15	33			
			30 to 38 mins.	—	—	—	—	—	5	15	20	43			
			38 mins. to ¾ hr.	—	—	—	—	5	10	15	20	53			
			¾ to 1 hr.	—	—	—	—	5	15	20	25	68			
			1 to 1¼ hrs...	—	—	—	—	10	20	25	25	83			
			1¼ to 1½ hrs.	—	—	—	5	10	20	30	30	98			
			1½ to 1¾ hrs.	—	—	—	5	15	20	35	35	113			
			1¾ to 2 hrs...	—	—	—	10	20	25	35	35	128			

* These figures are calculated on the supposition that the pump does not leak more than 20 per cent. at pressures up to 60 lbs. For actual quantities of air required at different depths, see page 38.

† *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80 ft.	70 ft.	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.†	Number of Men per Shift on Pumps.
120–132 *Contd.*	20-22	53½–59	2 to 2¼ hrs...	—	—	—	15	25	30	35	35	143	4	25	12
			Over 2¼ hrs.	—	—	—	15	30	35	40	40	163			
132-144	22-24	59–64½	Up to 6 mins.	—	—	—	—	—	—	2	5	10	4	25	12
			6 to 12 mins.	—	—	—	—	—	3	5	5	16			
			12 to 16 mins.	—	—	—	—	—	4	7	7	21			
			16 to 20 mins.	—	—	—	—	1	4	8	10	26			
			20 to 25 mins.	—	—	—	—	2	5	10	12	32			
			25 to 32 mins.	—	—	—	—	3	7	12	18	43			
			32 to 39 mins.	—	—	—	—	5	9	14	22	53			
			39 mins. to ¾ hr.	—	—	—	3	5	10	15	25	61			
			¾ to 1 hr.	—	—	—	5	5	15	20	30	78			
			1 to 1¼ hrs...	—	—	—	5	10	20	25	30	93			
			1¼ to 1½ hrs.	—	—	—	10	10	20	30	35	108			
			1½ to 1¾ hrs.	—	—	—	15	15	20	35	35	123			
			1¾ to 2 hrs...	—	—	—	20	20	25	35	35	138			
			2 to 2¼ hrs...	—	—	—	20	25	30	35	40	153			
			2¼ to 2½ hrs.	—	—	—	25	25	35	40	40	168			
			Over 2½ hrs.	—	—	—	30	30	35	40	40	178			
144–156	24–26	64½–70	Up to 5 mins.	—	—	—	—	—	—	2	5	10	4	25	12
			5 to 10 mins.	—	—	—	—	—	3	5	5	16			
			10 to 15 mins.	—	—	—	—	1	4	7	8	23			
			15 to 20 mins.	—	—	—	2	3	5	8	10	31			
			20 to 24 mins.	—	—	—	2	4	8	9	12	38			
			24 to 30 mins.	—	—	—	2	4	10	12	17	48			
			30 to 35 mins.	—	—	—	3	5	10	15	20	56			
			35 to 45 mins.	—	—	—	5	6	12	20	25	71			
			45 to 55 mins.	—	—	—	5	8	15	25	30	86			

* These figures are calculated on the supposition that the pump does not leak more than 20 per cent at pressures up to 60 lbs. For actual quantities of air required at different depths, see page 38.

† *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth. Feet.	Depth. Fathoms.	Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes. 80 ft.	70 ft.	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.‡	Number of Men per Shift on Pumps.
144–156 *Contd.*	24–26	64½–70	55 to 60 mins.	—	—	—	7	10	15	30	30	95	4	25	12
			1 hr. to 1 hr. 9 mins.	—	—	—	10	10	20	30	35	108			
			1 hr. 9 mins. to 1 hr. 18 mins. ..	—	—	—	10	15	25	35	35	123			
			1 hr. 18 mins. to 1 hr. 27 mins. ..	—	—	—	15	15	30	35	40	138			
			1 hr. 27 mins. to 1 hr. 37 mins. ..	—	—	5	15	20	30	40	40	153			
			1 hr. 37 mins. to 1 hr. 47 mins. ..	—	—	10	20	20	35	40	40	168			
			1 hr. 47 mins. to 1 hr. 56 mins. ..	—	—	15	20	30	35	40	40	183			
			Over 1 hr. 56 mins.	—	—	20	25	30	35	40	40	193			
156–168	26–28	70–75	Up to 5 mins.	—	—	—	—	—	—	2	5	10	4	30*	12
			5 to 10 mins.	—	—	—	—	2	3	5	5	18			
			10 to 13 mins.	—	—	—	1	2	4	6	8	24			
			13 to 16 mins.	—	—	—	2	3	5	7	10	30			
			16 to 23 mins.	—	—	—	2	4	8	11	15	43			
			23 to 30 mins.	—	—	—	3	5	10	15	20	56			
			30 to 40 mins.	—	—	—	4	7	12	20	25	71			
			40 to 50 mins.	—	—	—	6	10	12	25	30	86			
			50 to 60 mins.	—	—	3	10	10	15	30	30	101			
			1 hr. to 1¼ hrs.	—	—	5	10	15	20	35	35	123			
			1¼ to 1½ hrs.	—	—	10	15	20	25	35	35	143			
			1½ hrs. to 1 hr. 40 mins.	—	2	13	15	25	30	35	40	163			
			1 hr. 40 mins. to 1 hr. 55 mins. ..	—	3	17	20	25	35	40	40	183			
			Over 1 hr. 55 mins.	—	5	25	25	30	35	40	40	203			
168–180	28–30	75–80½	Up to 5 mins.	—	—	—	—	—	—	3	5	11	4	30*	12
			5 to 9 mins.	—	—	—	—	2	3	5	5	18			
			9 to 12 mins.	—	—	—	—	3	4	6	8	24			
			12 to 14 mins.	—	—	—	2	3	5	7	10	30			

* 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. For actual quantities of air required at different depths, see page 38.

‡ *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth.		Pressure Pounds per Square Inch.	Time under Water, *i.e.*, from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes.								Total Time for Ascent in Minutes.	Number of Cylinders needed.†	Revolutions of Pump per Minute.‡	Number of Men per Shift on Pumps.
Feet.	Fathoms.			80 ft.	70 ft.	60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.				
			14 to 20 mins.	—	—	—	3	3	7	10	15	41			
			20 to 30 mins.	—	—	2	2	3	10	15	25	60			
			30 to 40 mins.	—	—	2	2	6	14	20	30	77			
			40 to 50 mins.	—	—	2	6	8	15	25	35	94			
168–180 *Contd.*	28–30	75–80½	50 to 60 mins.	—	3	3	7	10	20	30	35	111	4	30*	12
			1 hr. to 1 hr. 11 mins.	—	3	5	10	15	25	35	35	131			
			1 hr. 11 mins. to 1 hr. 23 mins. ..	—	3	5	15	20	30	35	40	151			
			1 hr. 23 mins. to 1 hr. 34 mins. ..	—	8	10	20	25	30	35	40	171			
			1 hr. 34 mins. to 1 hr. 46 mins. ..	—	8	20	25	30	30	35	40	191			
			Over 1 hr. 46 mins.	—	15	25	30	30	35	40	40	218			
			Up to 5 mins.	—	—	—	—	—	1	3	5	12			
			5 to 10 mins.	—	—	—	1	2	3	6	8	23			
			10 to 13 mins.	—	—	—	2	3	5	7	10	30			
			13 to 20 mins.	—	—	—	3	3	7	15	15	46			
			20 to 30 mins.	—	—	3	3	5	10	15	25	64			
			30 to 40 mins.	—	—	5	6	8	10	20	30	82			
180–192	30–32	80½–86	40 to 50 mins.	—	—	5	8	9	15	25	35	100	6	25	18
			50 to 60 mins.	—	3	5	10	12	20	30	35	118			
			1 to 1¼ hrs...	—	5	10	15	15	25	35	35	143			
			1¼ hrs. to 1 hr. 26 mins.	—	10	15	15	20	25	35	40	163			
			1 hr. 26 mins. to 1 hr. 37 mins. ..	—	15	15	20	25	30	35	40	183			
			1 hr. 37 mins. to 1 hr. 48 mins. ..	—	20	20	25	25	30	40	40	203			
			Over 1 hr. 48 mins.	5	20	25	30	30	35	40	40	228			
			Up to 7 mins.	—	—	—	2	2	3	5	5	20			
192–204	32–34	86–91½	7 to 12 mins.	—	—	2	2	3	5	7	10	32	6	25	18
			12 to 20 mins.	—	—	3	3	5	7	10	20	51			
			20 to 30 mins.	—	3	3	3	5	10	20	20	67			

* 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. For actual quantities of air required at different depths, see page 38.

‡ *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

HALDANE'S DECOMPRESSION TABLES (AIR ONLY)—*continued*

(See explanation on page 94)

Duration of dive: In ordinary circumstances, the diver should not be allowed to remain on the bottom longer than the time shown immediately above the thick black line drawn from the fourth column to the thirteenth column at each depth.

Depth.		Pressure Pounds per Square Inch.	Time under Water, *i.e.* from Surface to beginning of Ascent.	Stoppages at different Depths in Minutes.								Total Time for Ascent in Minutes.	Number of Cylinders needed.*	Revolutions of Pump per Minute.†	Number of Men per Shift on Pumps.
Feet.	Fathoms.			80 ft.	70 ft.	60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.				
			30 to 40 mins.	—	3	3	4	8	15	25	25	86			
			40 to 50 mins.	—	3	4	5	15	20	25	30	105			
			50 to 60 mins.	3	3	5	10	15	20	30	35	124			
			1 hr. to 1 hr. 10 mins.	3	3	7	12	20	25	35	35	143			
192–204 *Contd.*	32–34	86–91½	1 hr. 10 mins. to 1 hr. 20 mins. ..	3	4	8	15	25	30	35	40	163	6	25	18
			1 hr. 20 mins. to 1½ hrs.	3	7	10	20	25	35	40	40	183			
			1½ hrs. to 1 hr. 40 mins.	5	10	15	25	30	35	40	40	203			
			1 hr. 40 mins. to 1 hr. 50 mins. ..	10	15	20	30	30	35	40	40	223			
			Over 1 hr. 50 mins.	15	20	25	30	30	35	40	40	238			

* These figures are calculated on the supposition that the pump does not leak more than 20 per cent. at pressures up to 60 lbs. For actual quantities of air required at different depths, see page 38.

† *i.e.*, using a Siebe, Gorman two-cylinder double-acting pump.

For Siebe, Gorman & Co.'s Decompression Tables to 300 feet (Air: breathing oxygen during later stages of decompression) see Chapter 7

5

Hints for the Diver and Methods of Doing Work

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 valve is open and the front tap 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 down the ladder till the water is up to his face; he then lets go the ladder and allows the attendants to draw him to the shot rope by means of the breast-rope and the air-pipe. The diver grips the shot rope between his legs, holding on to it with his left hand while he adjusts his 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 heaving satisfactorily, and makes sure that no water is coming in at the cuffs or other parts of the dress; he should also close his valve for a few seconds, so that the slight increase of pressure within the dress will disclose any leaky joints to the attendant who will be watching for them at this stage. When satisfied that all is correct, the diver 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 instant.

Pains in the Ears. By the time the diver is a fathom or two down he will probably notice pain in his ears which may get severe as he gets a little 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 the ear-drums as outside, 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 easily, and the pressure does not readily become balanced.

To get rid of the pain these passages must be opened, which is best done by blocking up the nose as much as possible, closing the mouth and making a strong expiratory effort, so as to produce an excess pressure in the throat and force the tubes open. Most men can block up their noses well enough by forcing them against the front glass of the helmet, or against a part of the inner collar, which is pulled well up in front for the purpose while dressing. A more certain method is to wear a nose clip (see Chapter 10) it can be knocked off against the helmet on reaching the bottom. Other aids to clearing the tubes are to go through the motions of swallowing, yawning or chewing; as an aid to the last, chewing gum or something of the sort can be taken down in the mouth. A cold in the head makes it hard to open the tubes, and delays the diver's descent. Sometimes it is impossible to get them open, and in this case the dive should be abandoned, lest permanent damage be done. But as far as the ears are concerned, a diver who is fit should have no difficulty in going down as fast as 20 fathoms in 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 being that the diver will get a 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 pumps heaving for the one diver. Provided there is enough air in the dress, as explained above, and the ears are not painful, a diver may confidently slide down the rope at a good speed.

Diver to Go Down Fast. To hang about unnecessarily on the shot rope wastes time, and by increasing the time under water, adds to the danger after coming up. Nevertheless, no diver should ever try to go down faster than his own best speed, and no attempt to beat some else's "record" should ever be made. To clip 30 seconds off the descent only to spend the first minute-and-a-half on the bottom recovering one's breath and senses is of no gain to anyone. If severe pain is felt on the ears and they cannot be "cleared" by the normal methods, then the diver must stop and rest for a minute or so when the pain will probably ease and he will be able to proceed. Again there is no point in forcing it, since it has been clearly shown in recent experiments that subjection of the ear-drums to pressure differences causes temporary congestion of the middle-ear cavity which in turn hinders the final "clearing" process.

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 be difficult to find the shot-rope again. The diver should now get to his work without further delay.

Management of the Valve. Comfort under water depends largely upon the correct adjustment of the valve. The valve is correctly adjusted when there is enough air under the corselet to support the weights so that the diver does not feel any great weight on 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 and no further adjustment is required. One-half or three-quarters of a turn open will generally be found to be about right. But divers on the bottom are often in a crawling or lying position, and the state of affairs is then different because the air tends to inflate any parts of the dress which are at a higher level than the valve before it will escape from the valve, however widely it is opened.

For instance, a diver who is lying on his right side, with the valve downwards, or is on all-fours with his head close to the ground, may accumulate so much air in the baggy dress that he becomes buoyant and is blown up to the surface. This must be prevented by emptying out the excess air at frequent intervals. When working in such a position, the diver must keep his valve wide open (no air will escape from it while the head is down) and, as soon as he 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 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. If the job in hand is searching for some lost article, the diver must explore the whole of the ground within the sweep of his distance-line as thoroughly and as 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 round 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), he fleets in a short distance along the distance-line and makes a fresh circle in the opposite direction, thus avoiding the twisting up of his pipe and breast-rope round the shot rope. It is nearly always best to crawl on the bottom when searching, though in exceptionally clear water a better field of view may be obtained by walking. He should not fleet in too much, but let each new circle just overlap the last.

It is often a good plan to keep the distance-line low by reeving it through the shackle on the shot so that, scraping over the ground, it will catch on any obstruction.

When the 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 in reach of the distance-line and should come up and ask the officer to shift the shot, or the boat, so that a new area can be searched. This method should always be followed, for crawling about the bottom at random, in any direction, on the chance of knocking up against the object is not systematic searching and, however long the process is continued, there can be no certainty that the object of the search is not lying within the area that has been so carelessly examined.

On finding the thing sought for, the diver should immediately bend 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 is most likely to be the impurity of the air in the helmet which he is breathing. The usual symptoms are a sensation of distress, with deep breathing or panting, and a dazed feeling as if consciousness were going. Often flashes of light appear before the eyes. Under these circumstances the worst thing a man can do is to attempt to struggle up to the surface, since any exertion when breathing impure air greatly increases its bad effects.

The diver should signal for more air and stop moving about, resting quietly while the bad air in his helmet is swept out by the 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. With the supply indicated in Haldane's tables (pages 100-108) it is impossible for too much air to be pumped, i.e. more than the diver can easily control with his valve.

Coming Up. 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 valve should be closed by pressing in the spindle 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 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.

Getting into the Boat. On reaching the surface, and before letting go the shot rope, he should look up to see whether he has taken any turns round it with his air-pipe or breast-rope. 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 is much sea, the diver should keep under water as much as possible and so avoid being knocked about. If there is a strong tide he must keep his dress empty and his feet down, or 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 try to 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.

Distance-Line Lost. If the distance-line is 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.

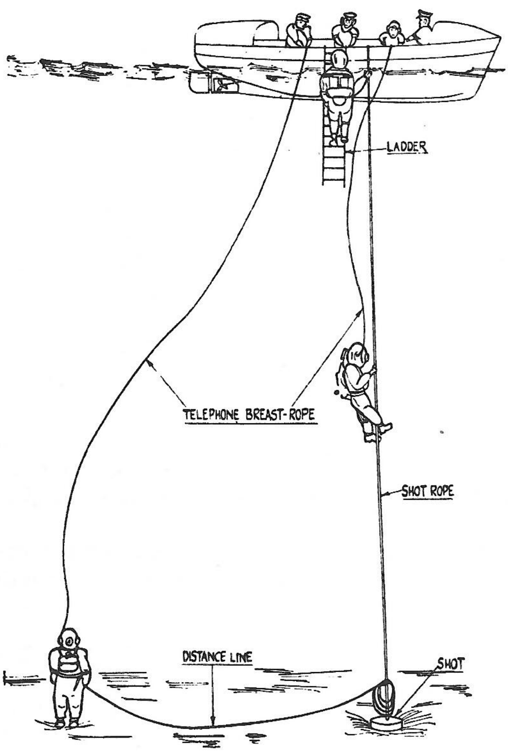


Fig. 112A

Foul. If you find that you are foul, think the matter over, and try to remember how you got foul 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 attendants 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 it up; a cloud of mud will prevent your 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, gloves will protect the 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 often wise to wear some sort of gloves to protect the hands. If wearing the 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 comfortable.

Tide. Remember that there may be much less tide on the bottom than at the surface, so it is generally worth while to make an attempt at diving, although the tide seems 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; it is not difficult to maintain this position 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. In strong tides it may be impossible to cling on to the shot rope, much less climb up it, if you keep on the wrong side. The best plan is to ask the attendants to pull you up if you find it a struggle 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 an object may be the less effect will the tide have on it, therefore the valve should be kept as wide open as reasonable comfort in breathing will allow. If, when searching, 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. When working at a ship's bottom never run a risk of falling off; always have something substantial to hold on to, and make your attendants 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 corselet weights for this sort of work.

Going to the Assistance of a Fouled Diver. In going to the assistance of a fouled diver, descend, keeping his breast-rope or air-pipe, whichever is believed to be foul, 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 ropes.

Cold Weather. If a long job has to be done in really cold water it pays to obtain and use proper cold-water dresses (see page 57). They enable more work to be done as well as saving divers from unnecessary suffering. Extra woollen clothes should be worn underneath. When working in shallow water, with bare hands, men can endure longer spells by going down at first for a short spell and coming up as soon as the hands are thoroughly chilled. The attendants then rub the hands briskly till a full circulation returns and they begin to glow, after which a longer spell than before can be worked.

Use of the Front Tap on the Helmet. Moisture often condenses on the front glass of the helmet and makes it difficult for the diver to see. It can be washed off by sucking a mouthful of water in through the tap and then spurting it out over the glass which then will remain clear till nearly dry.

The tap is also of some use as an auxiliary to the outlet valve, especially when the diver is lying on his back, but, having no non-return action, it is apt to let water into the helmet every now and then.

Slipping the Weights. In a grave emergency, the diver can release his back and front weights. The lanyard round the waist is let go first and then the bow hitches. If free, the diver will then float up to the surface. Such a drastic step might be called for by a sudden total failure of the air supply or by a wreck or some other object of enormous weight settling down on his air pipe, so that there was no hope of clearing it or of getting it disconnected from the helmet and a fresh air-pipe joined up by a rescue diver. In this case, a man might save himself by cutting his air-pipe and breast-rope, then slipping his weights and floating up to the surface where the attendants, if warned beforehand, would be ready to haul him inboard quickly.

Slipping the weights should only be done as a last resource, for once a diver has abandoned them, he becomes almost helpless and unable to control his movements.

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 blown up to the surface from deep water 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 decomposition the symptoms will pass off when he gets down, while permanent disablement or death may result if he remains at the surface or gets into the boat. Going down again is the diver's only chance of avoiding compressed air illness if he blows up from deep water after a long dive.*

* Unless, of course, a recompression chamber is immediately available.

CLEANING SHIPS' BOTTOMS

This can only be carried out slowly by divers; a good deal depends on the proper rigging and working of the rope ladders or stages. Generally the divers from other ships* will be assisting in the work and extra ladders can be borrowed. In using the rope ladders (Chapter 12) 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 then clean a breadth of 12 feet, and fleeting down from rung to rung can work down from waterline 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 diver can then lie back in it and clean the bottom above him with comparative ease.

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 (Figs. 113 and 114).

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 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, 6 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 along each spar in turn 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 six hours daily below the bottom of a vessel, and can clean from 7 to 12 square yards per hour, according to the condition of the bottom.

Good scrubbing brushes can be made from the bottom 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 PROPELLERS

Propellers usually get fouled by rope or wire hawsers, and at times are most difficult to clear; a stage should be rigged near the fouled part to enable the diver to work in comfort. An iron diver's ladder, or any grating with bars at wide intervals through which the diver can pass his legs, will make a good stage.

The engineer officer must, of course, be informed before anyone goes near the propeller, lest the engines should be turned.

* This applies to the Royal Navy

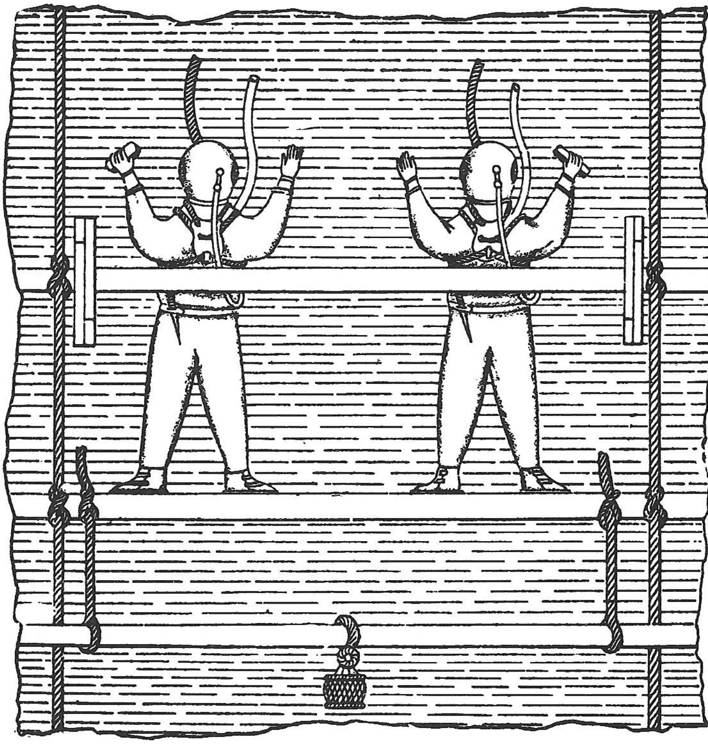


Fig. 113

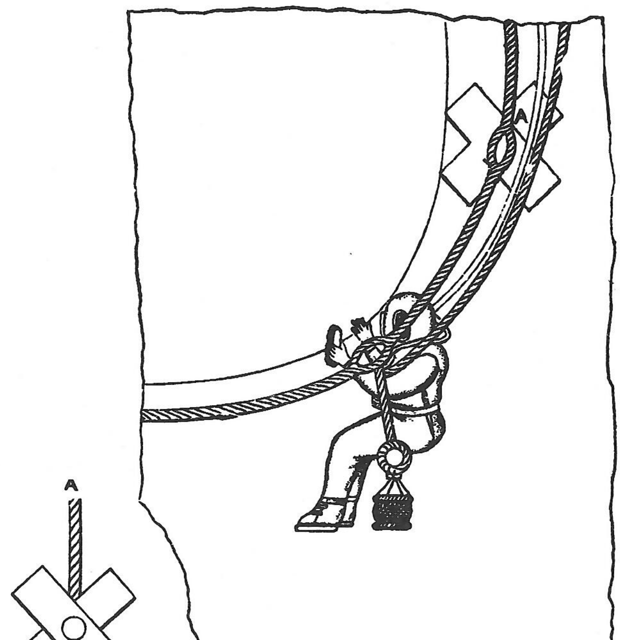


Fig. 114

First thoroughly examine the fouling, and see if it is possible to clear an end; if so, and if the turns are jammed, rope ends or tackles from the surface must be got down and put on to break them out. Back turns can be taken, or the propeller turned by hand 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 chisel and hammer or hacksaw. This is a long, tedious job, especially when the wire is partly unlaid and springy, so that it will not stand up to the tool; in such cases the writer has seen quick results follow the use of a tool made out of a screwdriver, slightly bent, which is used to lever out the individual wires composing the strand, one by one, so that they can be cut individually with suitable wire-cutters.

When available, oxy-hydrogen cutting gear (see Chapter 12) is invaluable for cutting through steel-wire hawsers badly jammed on a propeller or shaft. By using a torch, not only is the job done quickly and with minimum physical effort, but the severed ends of the strands get welded together and are prevented from forming an awkward dangerously spiked mass. To prevent cutting into the metal of the shaft by mistake, the cutting oxygen is not used and the heating flame will be found sufficient to melt away the strands.

All tools must be secured to the diver by lanyards, so that he cannot drop them into the void. Plenty of fresh, sharp chisels must be in readiness as well as hacksaw blades. Get lights fixed in good time if the job seems likely to last into darkness.

CLEARING OR EXAMINING VALVES

A simple bottom line, a rope ladder or a stage (according to the amount of work to be done) is put over the ship's side in line with the valve. It is often difficult for the diver to be sure that he has got to the right valve, especially when there are several close together. To make sure, arrangements should be made for someone inside the ship to tap with a hammer on the pipe or valve casing as close to the ship's side as possible; the sound will guide the diver.

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. It should first be marked so that it can be replaced exactly.

If a small valve aperture has to be plugged from outside, so that some work can be done inside, it is usual to drive in a taper plug of soft wood, sometimes padded with fearnought, which has previously been prepared on deck from the drawings of the valve. The end is sawn off flush, and if possible some preventer rigged up to make it impossible for the plug to come out. For larger apertures a patch held on by hook bolts, as shown in Fig. 118, page 124, and seating on a rubber washer may be used.

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, taking care 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 halfway 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 head of any nail break off, the hole should be re-punched and fresh ones put in.

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

RECOVERING A SHIP'S ANCHOR

Always a nasty job and apt to turn out more difficult than expected, partly because it involves sending down a lifting wire from a boat, and has often to be attempted at very short notice under conditions of stress and hurry. The officer in charge of divers would do well, on joining a ship, to consult with the gunnery and cable officers, and, with their approval, draw up a scheme of the boats, wires, shackles and strops that are to be used, if he is ever called upon to recover a bower anchor with or without cable. With this scheme posted up in the diving room, things are more likely to go smoothly if the emergency arises.

If the anchor buoy is watching, the diver would naturally go down that. If a search has to be made, it is done in the usual way, and the diver, on finding the anchor, bends on his distance-line, and then his shot rope itself as a temporary mark while a whaler or cutter lays out a small anchor and warp to hold the diving boat in good position. It is a good plan to have the lifting wire in another boat, and not in the diving launch. If working with a fleet, the officer should now make sure that there is no chance of any ship swinging foul of him on the turn of the tide. For sending down the lifting wire, the directions on page 122, sub-heading "Sending Down a Wire", are applicable, except that in this particular job there is generally no sense or object in keeping the diver on the bottom while lowering the wire; he can come up to his first stop and be swung off to a hanging shot rope out of the way. Do not use a larger wire than necessary, having regard to the weight of the anchor and any cable attached. Divers, of course, cannot be expected to handle big anchor shackles like a blacksmith with two mates. If the ring of the anchor is accessible, the simplest thing is to reeve the lifting wire through it and shackle back to its own part; lifting wires should be fitted with an eye about 2 feet long; no thimble is needed. If the ring is not available, a wire strop round the shank or arm must be used. For anchors or other weights of a ton or so, it is more easy to work with 1-inch to 1½-inch flexible wire (new) than a stiff strop. A few turns are passed round the object and the ends reef-knotted and seized.

CUTTING OFF PILES

Old piles projecting from the bottom in the neighbourhood of piers or landing-stages often prove a nuisance to boats, and divers are called on to cut them off. If large, sawing them will be found very difficult, and the proper method of doing the job is to run through a series of auger holes close together, and cut away the remaining wood with a chisel. The difficulty is to make the auger holes parallel, and for this purpose a jig can be made of hard wood, with a number of parallel holes ready drilled in it at the right distance apart, through which the auger is passed so as to steady it and start the hole in the right place and direction. The jig should be about 3 inches thick, the same width as the face of the piles, and fitted with metal clips by means of which it can be secured to the pile by a couple of nails (Fig. 116A).

Piles have also been cut successfully with small explosive charges. The charge is made up of plastic explosive (P.E.2 or 3) and is wrapped in a rough canvas belt which can be lashed round the pile below water. It has been found that ¾ lb. of P.E.2 laid against one side of a 14-inch square oak or green-heart pile will cut it through as cleanly as a saw.

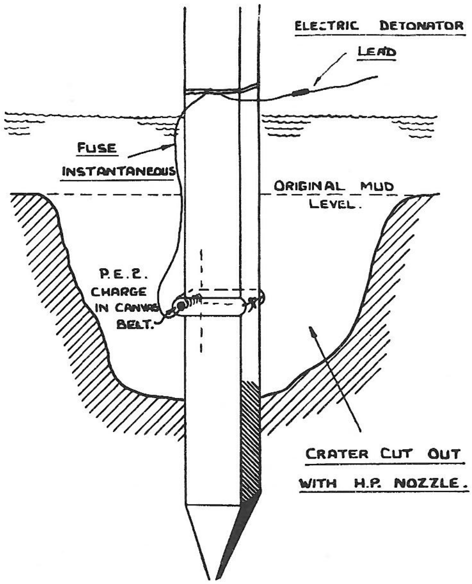


Fig. 115

A length of instantaneous fuse is connected to the charge and led above water where it is stopped to the pile and connected to the electric firing leads. The firing mechanism is operated from shore or from a boat.

In the particular instance where this method was used extensively with success, the requirement called for the piles to be cut off 2 feet below the level of the mud in which they were sunk so that dredging operations could then be carried out.

The mud was forced away rapidly by means of a high-pressure air-jet, and in 15 or 20 minutes it was possible to surround each pile with a crater big enough and deep enough to allow the diver to stand in it to secure the charge at the proper level. (See Fig. 115.)

WORKING ON WRECKS

The hints given here refer to wrecks which are totally submerged and are going to be examined, entered or searched by divers. After the wreck has been located by sweeping or otherwise, she has to be located in the diving sense by having a shot rope made fast to her; this work is best done from a boat if possible. There are emergencies, such as the sinking of submarines, in which speed is vital, and time will be lost by trying to work from a trawler or tender which can only be moored and moved slowly. Much of the following represents experience gained in diving on a large number of submarines and other vessels sunk during the war, when it was essential to work as rapidly as possible.

If the wreck is being searched for by sweeping craft, try to retain them on the spot and prevent them from dropping a mark-buoy and clearing off as soon as they have located something. When they have caught some obstruction likely to be the wanted wreck, they should close and anchor, keeping a good strain on the sweep-wire; both ends of it can then be passed into one vessel, leaving the other available to help the diving boat. The sweeper which is fast can veer cable and shorten up the sweep as much as she dare, in view of the risk of causing it to slip clear of the wreck. The diving boat comes alongside and arranges a large shackle and sinker for sliding down the sweep wire, bends a light shot rope to it, and passes a light warp (3-inch coir is good for this sort of work) on board the sweeper, then veers astern till the shackle is believed to have reached the obstruction, when the diver can go down on its line.

If the tide is running from the obstruction towards the sweeper, the disengaged sweeper should anchor on the up-tide side, and pass a light hawser to the diving boat, by which she and the sliding shackle can be hove back against the tide. Before the turn of the tide, it is well for the disengaged trawler to anchor this light hawser, get under

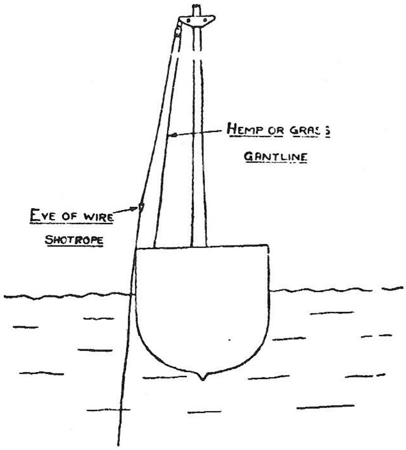


Fig. D
Tricing up shotrope when ship is rolling

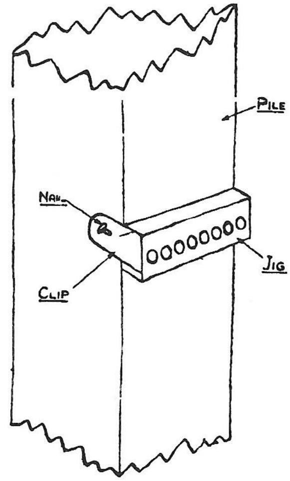


Fig. A. Jig for boring piles.

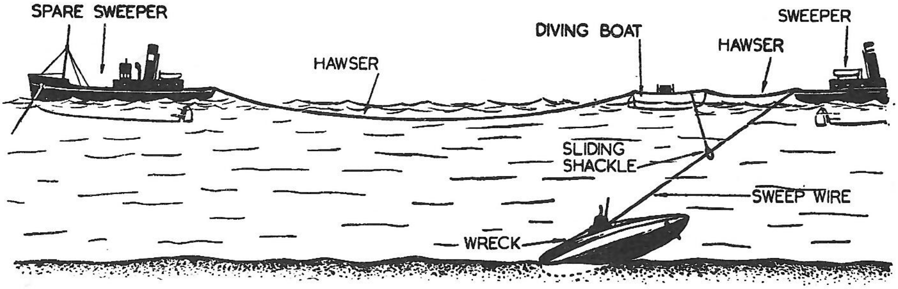


Fig. B. Manoeuvring the diving boat to a swept-up wreck.

Fig. 116

way, and stand by to help the diving boat by breasting her over with a beam-line on whichever side it may be required. Otherwise, just at slack water, when perhaps the diver is able to go down for the first time, you will be pulled out of position by the swinging of the sweeper (Fig. 116B).

When the wreck has not been swept up, and divers have to search the bottom, the same principle of working from a diving boat and using auxiliary craft (anything from a trawler to a motor boat) as mooring points, can be advantageously employed. By intelligent use of anchors and tide, large areas can be covered without any exertion on the diver's part (Fig. 117, page 120). This can be done in worse weather than would seem likely, for the behaviour of a diving launch on a long scope of grass hawser is quite different to that seen when she is snubbing at her own chain cable in harbour work. If the tide is too strong for diving, the time of waiting for slack water can be usefully employed by fishing with a grapnel from the diving boat while she is systematically warped over the area. Sometimes the oil fuel of a submarine can be smelt on the surface, when there is not enough of it to make a "smooth" or visible patch.

With no outside help at all, a diving boat can cover a lot of ground if she has one good anchor and a couple of warping anchors. Do not try to make sinkers do the work of anchors.

Modern electronic methods of searching with Asdics and Echo-sounders and locating the ship by "navigational aids", such as radar and "Decca" are invaluable in diving work when ships fitted with them are available.

A wreck can be found, identified, and its direction of lie on the bottom determined by Asdics, and then located with considerable accuracy by crossing and recrossing it on Asdic bearings and watching for its "signature" on the Echo-sounding trace. As soon as the abrupt shallowing of soundings over the wreck is seen, a buoy is slipped, on which the ship can later moor with reasonable chance of the divers dropping straight on to the wreck. Once the wreck has been really found the diving vessel can usefully employ the "Decca" navigational aid to return and position herself accurately over the job every time she comes out.

As an example, it is interesting to note that the *Egypt* took nearly two years to find in the Bay of Biscay, and the *Niagara* two months' continuous sweeping off New

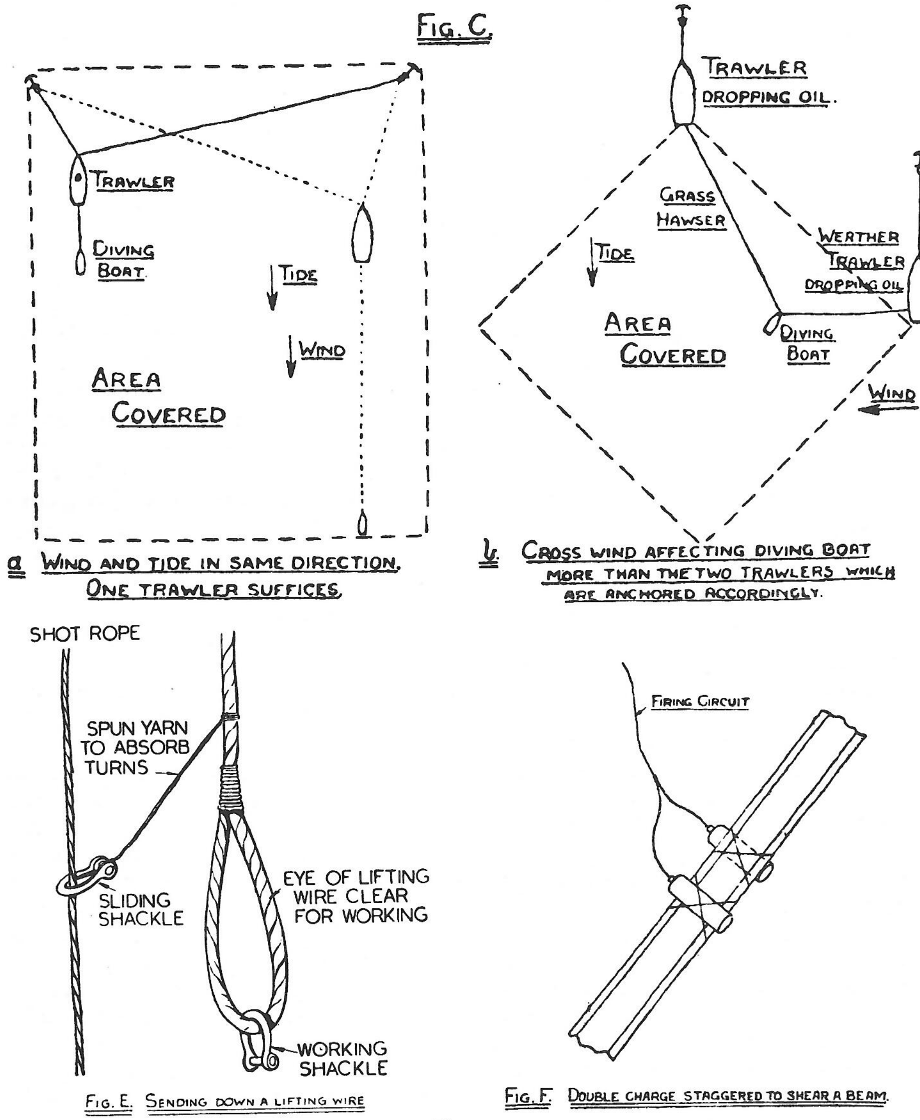


Fig. 117

Zealand. A seven-year-old wreck in mid-Channel whose position was only known approximately, was found in one forenoon by an Asdic and Echo-sounding fitted ship in 1946.

Once a diver has landed on the wreck, the first consideration is to buoy it so well that it will not be lost again, and there is nothing so difficult to buoy as a wreck; mark-buoys tend to disappear on account of the slack buoy-rope fouling the wreck at the low-water slack tide, with the result that the buoy, being submerged at high water, is run under by the tide and crushed or waterlogged. The ideal to aim at is to place a large buoy (with its buoy-rope on the short side) at each extremity of the wreck to serve as moorings for diving boat work. In an exposed position, a wise precaution is to lay down an extra mark-buoy on a bearing about one cable clear of the wreck, till working moorings have been laid. These working moorings for securing a salvage ship or diving tender over the wreck will generally consist of from two to six buoys with their ground tackle. Only in shallow water and calm weather will two buoys be enough; the greater the depth the more slack will there be in mooring the ship and, therefore, the more need to have a warp in direct lead against wind or tide.

Shot Ropes. The large hemp shot rope of the diving schools, with its sinker and distance-line, is comfortable for stoppages and handy for searching, but unsuitable for wreck work or for acting as a jackstay down which tools, lifting wires, explosive charges, and so on, can be passed to the diver. The first diver going down to a wreck should use a light hemp or wire shot rope, having a large eye at the bottom end to which the sinker is loosely seized. On reaching the bottom, the diver cuts off the sinker with one stroke of his knife, reeves his arm through the eye, and clambers off towards the point (stem, conning tower, etc.) where the mark-buoy is to be attached or the work done. On getting there, he secures his shot rope and uses it for a jackstay to slide down the permanent buoy rope or otherwise. If called up before reaching his point, he makes the shot rope fast wherever he happens to be, and comes up without the delay of returning to the point where he landed.

When work on a wreck is in full swing, the shot rope is, like the shaft of a coalmine, the one and only channel of communication between top and bottom, and the speed of the whole job depends on its smooth and efficient working. Constant thought and attention to minute detail are called for, so that whatever the diver asks for, from a fore-lock pin to a fire hose, will reach his hands without a moment's avoidable delay How often does one hear those bawlings on the telephone, which are the hall-mark of bad management, e.g.:

Diver: "How much longer are you going to be sending that wire down?"

Attendant: "The wire is down there. Can't you see it?"

Diver: "There is no wire down here."

Attendant: "We have lowered 50 fathoms of it. It must be down there. Have a look round."

And so on, endlessly.

The best shot rope for jackstay purposes is a $1\frac{1}{2}$-inch or $1\frac{1}{4}$-inch wire rope, and the lead should be from the surface down-tide towards the bottom; if the shot rope leads against the tide, the moorings need attention. When diving from a large vessel in bad weather, the shot rope can be kept moderately taut, without risk of parting, by tricing the end up aloft with a masthead gantline (which may be of coir), so interposing a long, springy drift (Fig. 116D). The hauling part of the gantline is stopped to a cleat or ringbolt on deck, so that if an extra heavy roll carries anything away, it will be the stop, and, if it is required to get the shot rope bar taut for a few minutes while something is travelling down, the attendants can put their weights on effectively without casting off anything. The divers go down and ascend on this wire shot rope, but, so as to keep it clear of obstructions, they do their stoppages on short auxiliary shot ropes which are lowered down to them at their first or second stop. The diver swings off on to this special shot rope, which is then fleeted along to some quiet place out of the traffic, where one attendant can look after him. Directly a jag appears in the shot rope it should be replaced; a spare one properly fitted is kept in readiness. In continuous work, the wear on the crutch of the dress is heavy, so that when wire shot ropes are in use, it pays to use overalls or, at any rate, the crutch part of the overall trousers which can be patched and strengthened with canvas.

Buoying Off the Shot Rope. When leaving a wreck with the idea of resuming work later on, one would naturally like to leave the shot rope in place, so that the diver can get straight down to his job on the restart. For reasons already given, there is great probability of the rope fouling the wreck and being lost if it is buoyed in the usual way. In a certain North Sea wreck, which was worked for some years, the shot rope was so fitted that an extra buoy could be shackled into the bight of it. This buoy was always submerged, even at dead low water, and its object was to keep a constant strain on the lower part of the shot rope and prevent any slack dropping foul of the wreck. In this case there was no sliding traffic on the shot rope. In another wreck, which was worked almost daily for several seasons, the presence of a shot rope and buoy right in the middle of the mooring area was a constant threat to the salvage ship's propeller while mooring up, and caused so much delay that it was eventually abolished and time saved by leaving a clear field for mooring smartly. The last diver down would unshackle the shot rope from the wreck and shackle it back to its own part so as to collect and save the scores of shackles which had accumulated on it during the day's work; then he would stop the end to some part of the wreck with spunyarn, so as to secure it during his ascent. As soon as he had swung off to the hemp hanger for his stoppages, the wire shot rope would be brought to the winch, torn adrift and weighed. On resuming next day or later, the salvage ship being moored as plumb as could be judged by the marks on the hawsers, a new wire shot rope, with the sinker seized on in the manner previously described, was put over and the first diver's job was to make his way to the working place and shackle it on. As he had to go down through 130 feet of tide, it was unusual for the diver to land on the wreck within sight of the working place, and this particular ship was such a jungle of twisted and unrecognizable plating that even men who had worked on her for years were hopelessly lost when out of sight of the usual working place. For this reason the first dive was always done by the same warrant officer, who thus acquired a special knowledge of the outlying parts and developed a homing sense which generally enabled him to get the shot rope shackled on in a quarter-of-an-hour or so.

Sending Down a Wire. A stock of large shackles to act as travellers is kept handy on deck. When putting them on, remember that there is a right way; it is surprising how readily the pins of sliding shackles become unscrewed by the friction of the shot rope if they are put on upside-down. A most important point is that if the wire is being paid out from a coil on deck there will be turns coming out of it as it slides down, so that, if the end of the wire be seized direct to the sliding shackle, the twist comes straight on to the shackle, which consequently binds or girds against the shot rope so that after a certain distance it will slide no farther. To prevent this, there should always be interposed between the end of the wire and the sliding shackle a drift of about 1 foot of spunyarn, which will absorb the turns as they come out of the wire and guard the sliding shackle against any twisting strain (Fig. 117E). Of course, the wire should be paid over the rail at a point some distance from the shot rope, so that it gets no chance to twine around.

It is wiser not to lower a large wire, such as a $4\frac{1}{2}$-inch, to a diver; it should either be lowered before he goes down or else he may come up to his first stop and meet the wire there, getting his foot on top of the sliding shackle and treading it down in front of him to the bottom. A lanyard should be attached to the eye of such large wires for the diver to use as a drag-rope in hauling them from the bottom of the shot rope to the place where they are wanted. It is a good plan to keep a stock of rope tails or lizards (signal halyard stuff is good) handy for such purposes. As an example, when sending up plating and debris after blasting in a wreck the lifting wire goes down with a shackle for the main hoist, and also half-a-dozen rope tails which can be hitched on to bits of planking or fragments of iron work, so that a bunch of smaller stuff comes up with each heavy hoist. A large and a small marline spike for dealing with stiff shackle pins and perhaps a few simple tools ought to be kept stopped to some well-known plate or object near the bottom of the shot rope.

Using Explosives (see also Chapter 13). Riveted joints are easily destroyed when there is a strain on them; thus a wreck soon gives way under the impact of charges placed along the waterways at the junction of frames and deck beams, but after she has collapsed it is difficult to cut pieces away. A useful method is to shackle on the lifting wire to the plate one wants to tear adrift, put a good strain on it, stopper off the wire, then place your charges on what seems to be the weakest point, and fire. Besides increasing the effect of the charge this procedure saves time. The darkness produced by the explosion would generally prevent the diver from shackling on the plate for lifting till a considerable interval had elapsed. As it is bad policy to leave charges soaking at the bottom in deep water, while the diver is doing a long decompression, it pays to use two divers. The first shackles on, sees the strain applied, runs a guiding distance-line to the point where the charge should be applied, and comes up. When he is near the end of his last stage, with about five minutes more to do, a second diver goes down with the charge, secures it and comes up so soon that he will only need very short stops or none at all. The two divers being now due on deck together, the charge can be exploded with a minimum of delay.

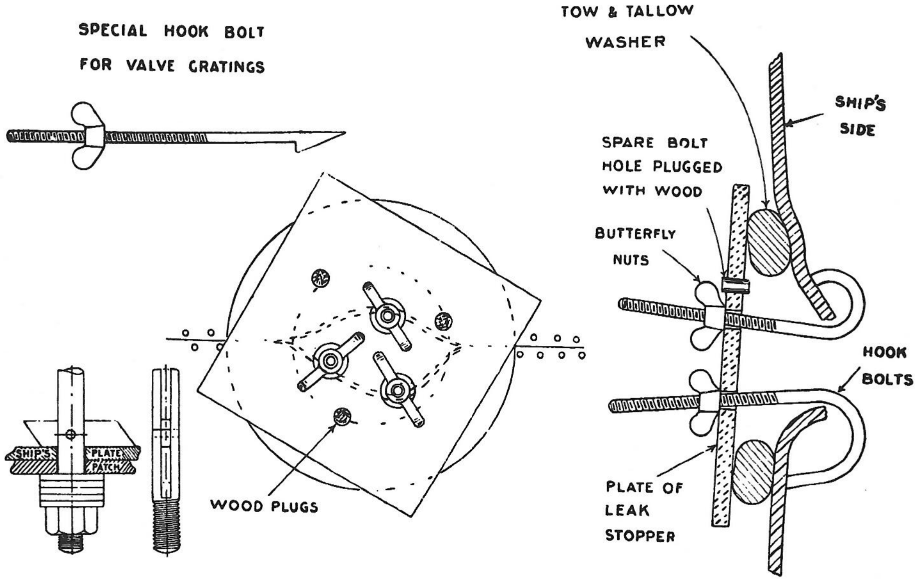
If the charge misses fire it should be countermined at once (by placing a fresh charge beside it and firing); this may produce the intended explosion, and it is safer than leaving the charge about, or trying to send it up.

Double charges are often very effective. For instance, one charge in the bight of a long beam will usually do no more than bend it; two charges directly opposite each other will do nothing at all, but two on opposite sides of the beam, staggered so as to produce a shearing effect, will cut it neatly. (Fig. 117F, page 120.) Heavy charges are best reserved till the end of the day's work, so that the mud will have a chance to settle down during the night and the salvage ship can conveniently slip some of her buoys and swing or drift clear of the worst of the shock.

The possibility of a blasting charge detonating explosives belonging to the wreck must be borne in mind. A foreign salvage ship was blown up by the detonation of a cargo of explosive which had been submerged for many years. At the same time, much important work has been done in the Royal Navy with explosives, on wrecks carrying gun ammunition and even torpedoes, which would have been impossible if the fear of a secondary explosion had been allowed to paralyse all effort.

Seizing Air-pipe and Breast-rope. Many things are quite properly done by experienced men in wreck work which would be out of place in the routine tasks of training classes. Seizing the pipe and breast-rope together enables one attendant to do the work of two while the diver is on the bottom, lessens the risk of getting foul, and quickens up things all round. If done at all, a good, smooth job should be made of it. Start at the diver's end as (depending on the exact method of dressing) the free end of pipe may need to be a few inches longer than the free end of breast-rope or vice-versa. Heave the pipe and breast-rope taut along the deck with a handy billy, and put on codline seizings, 2 feet 6 inches apart, heaving them taut with a mallet. If, in the course of work, stretching or shrinking should produce awkward bights between the seizings, all should be cut adrift and the work done over again.

It is often a great help for a diver to stop down his air-pipe and breast-rope to some object on the bottom or in a wreck, so that the attendant can keep it taut in a tideway without any of the strain coming on the diver. Of course, the diver should allow himself 30 feet, or as much slack as he thinks necessary before putting on the stop. Again, when one diver is going down a hatch or through a hole and another is stationed



Tumbler Bolts for securing patches

LEAK STOPPING AND PATCHING DEVICES

Fig. 118

outside to assist him, the outside man can usefully stop on the bight of one or both pipes and lines, so leaving his hands more or less free to deal with the inside diver's slack pipe and signals.

Working a Hose. In using a hose to wash away mud or sand, tide is apt to buckle the canvas pipe into sharp kinks and throttle the flow, so that one needs to use a long drift which will come down to the diver in an easy curve. Hosing generally produces pitch darkness, and if the diver allows the branch pipe to jump out of his hand, he will find it pretty difficult to recapture. For this reason a rope tail should be attached, about 6 feet back of the branch pipe, for securing the hose to some object on the bottom, and a becket (through which the diver can pass his arm) fixed to the branch pipe.

American naval divers using such a powerful jet that the branch pipe was almost uncontrollable got over their difficulties by devising a reaction branch pipe with some backwardly directed jets which counterbalanced the recoil set up by the main working jet. A case is on record of a diver being immobilized by some hundredweights of sand which drifted in between his dress and overalls while working the hose for a long spell, so one should be careful about using overall suits for such work.

LEAK STOPPING, ETC.

Collision mats, swabs, cotton waste caulking, wooden wedges and cofferdams, have all been used successfully in making emergency repairs. For stopping small holes, such as shot holes, valve inlets, scuttles or openings in the deck of a wreck being salved, the patch described below is valuable; two or three of them should be made on board and kept ready for emergencies. The idea can be easily understood by referring to Fig. 118, it consists of an iron plate large enough to cover the damage, a soft grommet or thick rubber washer to act as caulking and three or four hook bolts with nuts to hold the contrivance in place.

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

A good way to make the grommet is to use tow and tallow well kneaded and worked together and then parcelled round. Grommets can easily be made up to the size of a lifebuoy. Where the ship's side round the hole is quite flat a rubber washer may be used instead of a grommet. The number of hook-bolts to be used depends on the area of the hole to be stopped. and it is well to have five or six holes ready drilled in the plate; those not required are easily plugged with a wooden bung. The hook-bolts must be of the best material, so that the hook shall not give way when the heavy strain of screwing down watertight comes on it. The hook itself must be fairly large as a hold-fast for it may not be obtainable close to the edge of the hole.

A special form of hook-bolt capable of passing through the bars of the grating and then being turned so as to catch is used for stopping inlet valves, etc. Butterfly nuts are the handiest and quickest to use. In salvage work, etc., where large quantities of these leak stoppers may be wanted, they can be extemporized out of pieces of stout planking; large iron washers must be used under the bolts to prevent splitting the wood.

In the case of a large hole in a flat part of a ship's side, a repair may be made by bolting two Z bars parallel to each other on opposite sides of the hole, and then sliding thick planks down between them like shutters; careful caulking is required and provision made to prevent the planks shifting much when they swell.

Leakage from an imperfect repair, or from strained bulkheads or riveted joints, may sometimes be controlled by "feeding" with straw, flock from mattresses or similar stuff. Pumps are kept at work in the damaged compartment, and the diver goes down to the outside, or wherever the water is thought to be coming from, with armfuls of the material which he spreads about so that the suction may draw it into chinks and crannies.

Where the ship's plates are still reasonably intact and not unduly distorted round the hole, a patch can be rapidly bolted over the hole by means of the Cox Submerged Bolt Driving and Punching Gun (see Chapter 12). This gun drives a threaded bolt into steel plate by means of an explosive charge in such a way that the bolt is gripped firmly in the plate and the threaded portion left protruding ready to take the patch and nut.

Different grades of ammunition are supplied according to the thickness of the plates. The detachable barrels are loaded on the surface and passed down to the diver who remains in position and can drive many bolts in the time taken to drill and tap a single hole with ordinary tools.

Punch ammunition is supplied for punching holes in the patch plate with equal rapidity.

A further variation allows hollow bolts to be driven in exactly the same way. An adaptor is provided to screw on to the air-bolt to take a standard Siebe, Gorman air-hose connection so that air pressure may be blown into a compartment or tank to expel water and add to the wreck's buoyancy.

These air-bolts have also been used to blow air through the bottom of a wreck and break the mud suction which was preventing her from lifting after pumping and blowing.

6

First Aid to the Diver in Case of Illness or Accident

COMPRESSED AIR ILLNESS, ASPHYXIA, DAMAGE TO THE EARS, DROWNING, ETC.

The above are dealt with in the following pages, as being accidents to which divers may be liable. For other injuries or illnesses, books on "First Aid" should be consulted.

COMPRESSED AIR ILLNESS

This may arise from a long dive at a moderate depth, or from a short dive at a great depth. Although the decompression and other precautions laid down in Chapter 4 can be relied on to prevent the illness in practically all cases, emergencies or stress of weather may interfere with these precautions; thus a diver may be detained on the bottom far beyond the proper limit of time, his ascent may have to be hurried on account of stress of weather or some accident to the gear or, again, he may prove to be one of those men in whose body bubbles form with exceptional ease. In these and in other ways, cases of compressed air illness may arise, so that if a large amount of diving in deep water is going to be done, a recompression chamber for curing cases of compressed air illness is a necessary part of the equipment. In addition to saving life, it saves time and money on the job, because it enables diving to go on in conditions which no experienced officer would risk unless he had at hand the means of curing his divers in case of accident.

Symptoms of Compressed Air Illness. As the illness is caused by the liberation of bubbles of gas which may form in any part of the body, or block any of the blood-vessels, it can take many different forms, but its cause is always the same, namely, transition from a higher to a lower atmospheric pressure; thus it could not occur during a diver's descent, or while he was on the bottom, but it might appear during his ascent, or as long as four hours after he had reached the surface. One or more of the following symptoms may be observed:

Local pain in the arms or legs (called "bends").
Giddiness or affections of the sight or hearing.
Severe pain in the chest or abdomen, often accompanied by gasping for breath.
Paralysis, generally in the legs.

All these can be cured by recompression which may be applied by sending the diver down under water again, but, far better, by subjecting him to increased air pressure in a recompression chamber.

Recompression Chambers. The simplest possible form is a cylindrical steel chamber just large enough to contain a man lying down, and fitted with a door through which he can pass (Fig. 124), page 131. A glass window, through which the occupant can be watched, is necessary, and there must be some means of raising the pressure, inlet and outlet valves and a gauge. The chambers generally used have additional conveniences such as:

Room for a second man inside to look after the patient.
A large air-lock by which a doctor or an attendant can pass in or out, without disturbing the pressure on the patient (Figs. 119, 120 and 123), pages 128 and 129.

Small air-lock for passing in food or medicine. Electric light and telephone.

Means for working the valves from inside as well as outside, and an internal pressure gauge.

On pages 128-131 will be found illustrations of three types of recompression chambers. It will be noticed that the door of Fig. 124 opens outwards, and when closed is secured by a series of swivel bolts. For chambers of such small diameter this is the most convenient form, since doors opening inwards, as in the bigger chambers, would take up too much room in the entrance. The system more frequently adopted is that shown in Figs. 119, 120 and 123—i.e. both outer and inner doors opening inwards, so that the air pressure forces the doors on to their seatings—which are fitted with rubber washers—thus making a thoroughly tight joint. The chamber shown in Figs. 121 and 122 enables the diver to lie down full length and to sit up, but does not allow him to stand upright. The chamber illustrated in Fig. 124 allows him only to lie down full length. The best chamber, where space is available, is undoubtedly that shown in Figs. 119, 120 and 123. Very many cases can be cured by pressures below 45 lbs. per square inch, but most modern chambers are strong enough to withstand 100 lbs. per square inch if necessary.

The pressure in a small chamber can be raised by one or more diving pumps, but this is a slow method and it is better, if no compressor is available, to carry a few cylinders of highly compressed air for the purpose and to use the diving pump for ventilation when required. The larger chambers are usually carried in ships fitted with steam air compressors, and reservoirs which can be connected to the chamber.*

Treatment of Compressed Air Illness. Recompression is the only cure. The illness is caused by bubbles of gas in the body, and the effect of recompression is firstly to squeeze them into such a small size that they no longer cause trouble, and secondly, to drive the gas back into solution and so cause the total disappearance of bubbles. The cure takes place quickly, and the next thing that has to be done is to reduce the pressure in the chamber to atmospheric, so that the door can be opened and the man allowed to get out. This reduction of pressure must be done slowly and cautiously, lest the bubbles should reappear during the process and cause the man to become ill again. The practical rules for treatment are:

If a man shows symptoms of compressed air illness he should be got into the chamber with as little delay as possible, and the pressure raised while the patient is watched or told to report as soon as he feels better. In some slight cases, such as "bends", the pain may disappear by the time 5 or 10 lbs. is reached; a man who has lost consciousness may regain it and sit up at 20 lbs., while other cases show no improvement till a much higher pressure is reached. In any case, the pressure should be raised 10 lbs. above that at which he obtains relief and maintained there for 30 minutes before starting decompression which should be carried out as in the table below. In refractory cases where recompression fails to relieve the symptoms, it is recommended that local heat should be applied to the site of the pain by means of either hot-water bottles or kaolin poultices.

While the pressure in the chamber is between	*Pressure may be allowed to fall at a rate not faster than*
100 lbs. and 90 lbs.	4 lbs. in 1 minute
90 lbs. and 75 lbs.	2 lbs. in 1 minute
75 lbs. and 60 lbs.	1 lb. in 1 minute
60 lbs. and 45 lbs.	1 lb. in 1½ minutes
45 lbs. and 30 lbs.	1 lb. in 3 minutes
30 lbs. and 15 lbs.	1 lb. in 5 minutes
15 lbs. and zero	1 lb. in 8 minutes

* For large three-compartment chambers see Chapter 7.

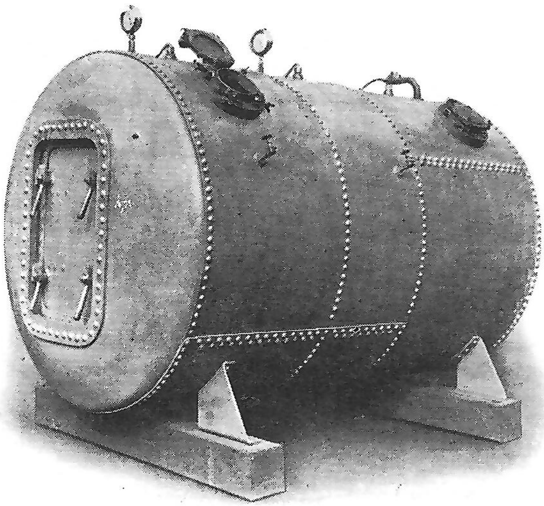


Fig. 119. Chamber with man-lock at entrance (for sectional view see next page)

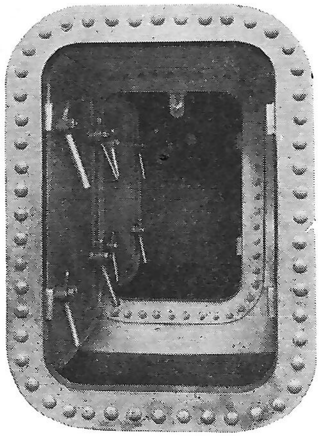


Fig. 120. Entrance doors of chamber in Fig. 119

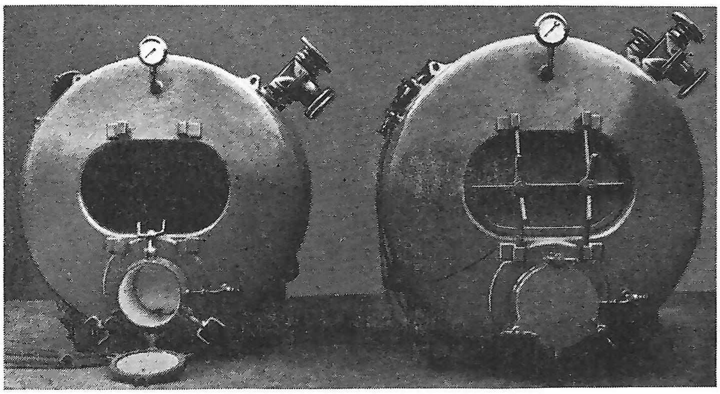


Fig. 121. Single compartment chamber with hand lock. Front view. Door open and closed

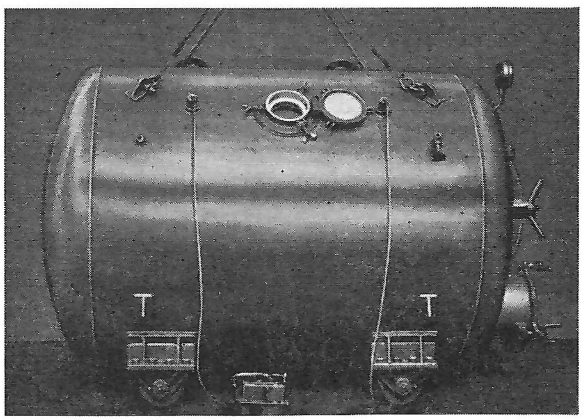


Fig. 122
Portable single compartment chamber. Side view showing telephone connection and wheels

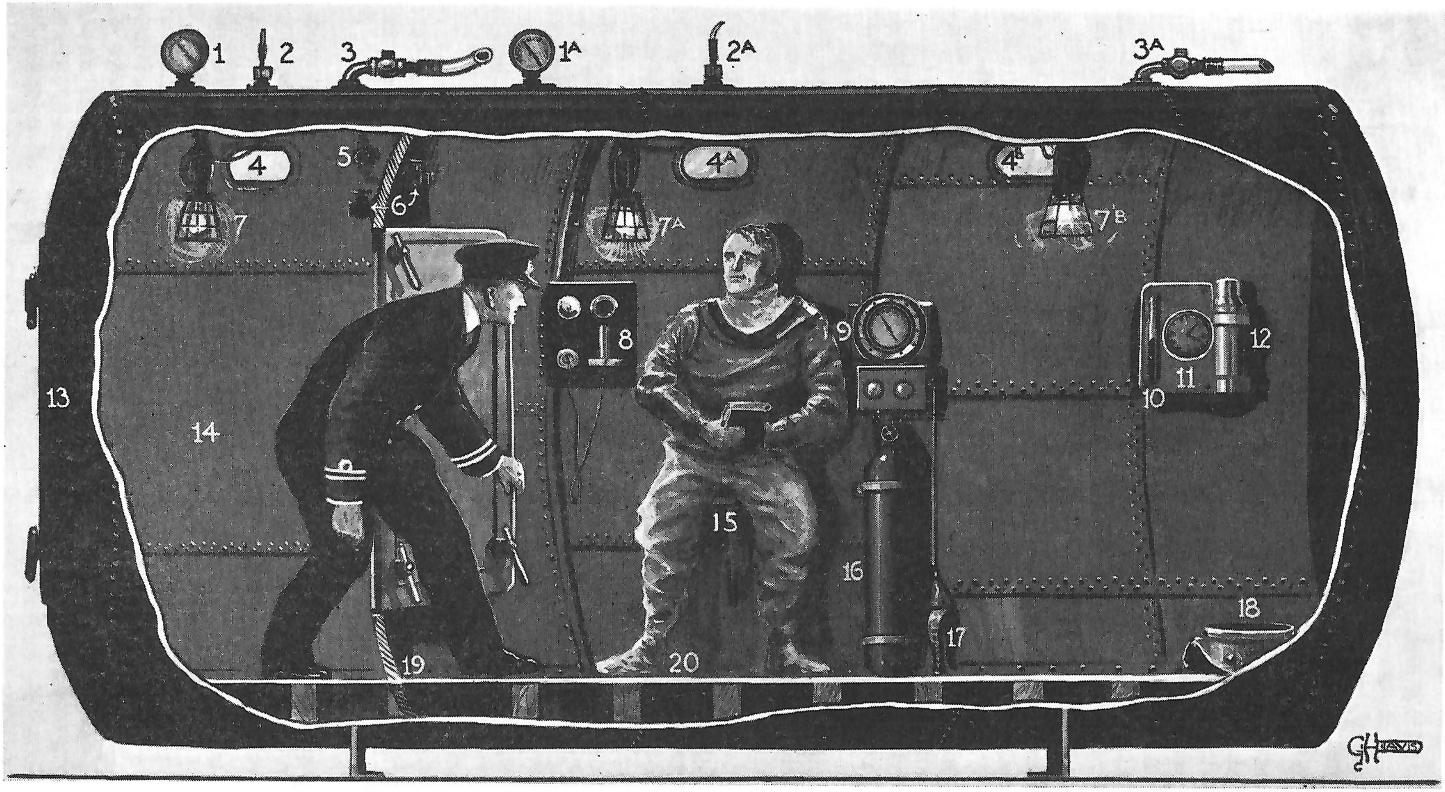


Fig. 123. Interior of recompression chamber as in Figs. 119 and 120. Officer passing from air-lock to treatment chamber

In the case of a diver who has suffered persistent "bends" of the same limb the decompression time may be extended as follows:

While pressure in the chamber is between	*Pressure may be allowed to fall at a rate not faster than*
45 lbs. and 30 lbs.	1 lb. in 4 minutes
30 lbs. and 15 lbs.	1 lb. in 6 minutes
15 lbs. and zero	1 lb. in 10 minutes

On no account must the last few pounds of pressure in the chamber be blown off quickly; such a procedure is likely to cause the symptoms to reappear, when the whole process will have to be undergone a second time.

If the patient becomes ill again while the pressure is falling, the escape of air must be checked, and, if necessary, the pressure raised till he recovers, after which pressure may again be allowed to fall, but at a slower rate than before. An addition of 50 per cent to the time-table should be tried first, and if illness comes on again, showing that this rate is too fast, the time should be doubled, and so on.

Remarks on Recompression. No one who has seen a victim of compressed air illness, gravely ill or unconscious, put into a chamber and brought back to life in a few minutes by the application of air pressure will forget the extraordinary efficiency of recompression, or be backward in applying it to a subsequent case of illness, but deep diving is sometimes undertaken by men without such experience, and cases have been known of divers dying of compressed air illness when a chamber was available, but remained unused. It is important to be well prepared. In the first place the chamber must be on the spot, i.e. on board or close alongside the vessel from which the diving is taking place; and secondly, men should keep within reach of the chamber for four hours after their last dive. Generally, compressed air illness develops soon after reaching the surface, but in some cases there is a long delay.

Thirdly, the chamber must be perfectly ready—hinges and door-clamp oiled and working freely; door seatings in good condition and airtight; no leakage in the air-lock; gauge accurate, or error known and posted up beside it; inlet and outlet valves working freely, and in the ready position; men available who know how to use the chamber and work the valves; plenty of compressed air ready for raising the pressure; nothing stowed in the chamber except gear required for treating patients. The following list will serve as a guide to what should be kept inside:

Mattress and blankets.
Towels.
Electric torch.
Pad and pencil for writing notes.
Table of decompression times.
Watch or clock.
Thermos flask of hot coffee, with plenty of sugar.
An oxygen breathing apparatus.

Trials should be made at intervals to ensure that everything is in good order and that a man can be got into the chamber, and as high a pressure as necessary applied, within a very few minutes of his being taken ill.

Need for a Doctor. The presence of a medical man is, of course, an advantage but recompression can be carried out perfectly well by any sensible man who can work the valves and will carry out the foregoing rules. On one big diving job where attendants were scarce, men suffering from "bends" used to go into the chamber and cure themselves, without any assistance except in closing the outer door. A doctor should not go into the chamber with the patient unless he is sure that his own ears can stand a rapid rise of pressure. The person in charge should generally remain outside the chamber where he can control the air pressure and watch the decompression, and decide what is to be done if a fresh case should turn up and require recompression.

If the patient is very ill or unconscious, of course someone should go into the chamber with him to report changes in his condition to those outside.

Raising the Pressure. The first few pounds should be run in quite quickly, and then the rate of admission of air slowed down so that the point at which the patient is cured may not be overshot. The great majority of cases are cured with less than 50 lbs. pressure, and reference to page 28 will show why it is that a low pressure such as 15 lbs. has a great effect on the size of the bubbles causing the trouble. Some people

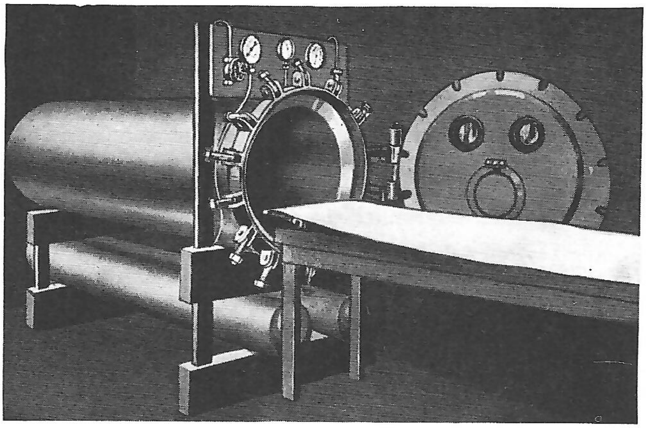


Fig. 124

without much experience of recompression have supposed that it is desirable to raise the pressure in the chamber to that at which the diver has been working, but such reasoning is unsound and would lead to an enormous waste of time in decompressing. The pressure should be raised as high as necessary to cure the man, and no higher.

Bends and Paralysis. The most common form of compressed air illness among divers is "bends" in the elbow, shoulder, or knee, the severity of an attack varying from extreme pain to a dull ache which does not even prevent sleep. Most divers in the course of a big job will put up with a mild pain in preference to inconveniencing themselves and others by seeking treatment in the chamber; but "bends" are far more easily cured if treated at once, and it has happened that, after bearing pain for several hours, a diver has had to be recompressed in the middle of the night, and required a high pressure and an extra slow decompression lasting well into the next day, whereas, judging from similar cases, if he had reported for treatment immediately the pain came on he could have been cured within an hour. Hot applications afford considerable relief to the pain. Bends alone are not dangerous, and need not be taken so seriously as paralysis, which is a matter of the utmost gravity, and if allowed to continue will probably be permanent.

Paralysis shows itself by loss of feeling or the power of movement, most frequently in the legs or feet. Prompt recompression can cure it, but the greatest care and patience must be used in decompressing afterwards, in order to make sure that it does not recur. The patient should not be allowed to go to sleep or even to rest quietly, and enquiry as to his state should be made every few minutes. Paralysis must be treated with the highest pressure available up to 100 lbs. per square inch which must not be exceeded. If it does not pass off within half an hour, it is probably useless to wait any longer at the high pressure, and decompression should be started, but as the exposure to high pressure has been so long great caution should be used, and it is advisable to use a rate twice as slow as the standard rate given on page 127 in lowering the pressure.

Use of Chamber for Preventing Illness. A diver who has done something likely to cause compressed air illness, but who has not yet shown any symptoms, must be got into the chamber as soon as possible and the pressure raised to that corresponding to the depth at which he has been working, or as near to it as the working pressure of the chamber will allow. He must be kept at this pressure for five minutes, after which, if no symptoms have developed, he can be decompressed according to Haldane's Tables (pages 100 to 108). The five minutes spent at high pressure in the chamber must be allowed for in looking up the stoppages in the tables.

N.B.:	10 ft. depth	= $4\frac{1}{2}$ lbs. pressure		40 ft. depth	= 18 lbs. pressure
	20 „ „	= 9 „		50 „ „	= 22 „ „
	30 „ „	= $13\frac{1}{2}$ „ „		60 „ „	= $26\frac{1}{2}$ „ „

Should symptoms of illness appear during this decompression proceed as already described under "Treatment of Compressed Air Illness".

Ventilation. During long stays in the chamber some ventilation will be needed.* If it is necessary to economize the compressed air supply, a diving pump can be joined up to supply it. A slight leakage in the chamber is of small moment provided it does not reduce the pressure too quickly.

Glass Scuttles. These can never be absolutely depended on, and the sudden release of pressure which would be caused by one of them bursting might lead to serious results. It is best to keep the deadlights screwed down while pressure is rising; they may be opened while pressure is steady or falling.

Delay in Onset of Illness. Symptoms may not appear for four hours after a diver has come up, and the chamber should be kept ready for that time if dangerous work is being done.

Use of Oxygen. If the patient breathes pure oxygen from a suitable apparatus while in the chamber, his cure will be hastened, but there are certain dangers in breathing oxygen at high pressures. On no account should oxygen breathing take place at pressures exceeding 25 lbs. per square inch; disregard of this will lead to oxygen poisoning or convulsions. The following are the safe periods in which oxygen can be breathed at various pressures.

While pressure is between:	*Minutes*
25 lbs. and 15 lbs. for	15
15 lbs. and 0 lbs. for	90

If the breathing apparatus is properly used, there should be no escape of oxygen into the decompression chamber, but precautions should be taken against any sparking from electric fittings, and no matches should be taken inside as in the presence of excess oxygen fire would have most serious results.

Sending the Diver Down Again. If no chamber is available, the only way to apply the recompression is to get the diver into the dress as quickly as possible and send him down again.

If very ill and helpless, another diver may go down to look after him, but do not wait for a second diver; get the ill man under pressure as soon as you can by opening his valve and gently lowering him to a depth at which he is relieved or cured; leave him there for a minute or two to make sure that he is all right, and then bring him up very slowly.

Bringing Him Up. If the diver is brought up too quickly, the symptoms will probably return; he will be as ill as before, or worse, and the whole business of sending him down will have been useless. On the other hand, the very slow rate necessary for absolute safety, which is practicable enough in a comfortable chamber, will nearly always be too exhausting for a man under water. Some risk must, therefore, be taken; the officer should try to keep the man in spirits and use any means of diverting his

* Especially as increased carbon dioxide is thought by many authorities to increase the liability to "bends".

attention while (using the following table as a guide) he brings him up as slowly as he dare, having regard to the temperature of the water, weather, light, etc., and especially the condition of the patient as far as it can be made out by telephone or other means.

The following table is inserted as a guide, and gives a rate which might reasonably be tried in ordinary circumstances:

While the pressure on the gauge is:	*Pressure shall be allowed to fall at a rate not faster than:*
Over 30 lbs.	1 lb. in 1 minute
Between 30 lbs. and 15 lbs.	1 lb. in 2 minutes
„ 15 lbs. and 10 lbs.	1 lb. in 3 minutes
„ 10 lbs. and zero	1 lb. in 5 minutes

If symptoms return, a slower rate should be tried. Pains in the joints are by themselves not a dangerous symptom but cannot be disregarded.

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, perhaps after signalling for more air.

Transient loss of consciousness from excess of CO_2 is not a very serious condition in a diver, because the poisonous effect of the gas is increased by pressure, as explained on page 36, and reducing the pressure (by bringing the diver up) generally revives him. 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 compressed air illness; and a death clearly proved to be brought about in this way has been recorded.

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, as the concentration of carbon dioxide will be reduced proportionately to his depth by expansion of gas and venting.

If he does not now answer signals, he should be hauled up, and put into the recompression chamber if one is available. If he is not breathing, artificial respiration should be applied at once. If no recompression chamber is available, on his recovery he ought to be sent down again, as already described.

Asphyxiation might also be caused by the presence of fumes or noxious gases in the air supply; for instance, if the oil in a power-driven compressor fired or if, when working in the hold of a wreck, the pump was drawing air vitiated by decaying cargo. In self-contained diving apparatus and in rescue apparatus asphyxiation may also occur from failure of the oxygen supply without any excess of CO_2 being present, and this is a more serious matter than the foregoing, as without oxygen life will not last many minutes. In all cases artificial respiration is the proper treatment, and, of course, use should be made of proper reviving apparatus such as "Novox" or "Novita" if it is available.

Oxygen Poisoning. The advantage of using pure oxygen in self-contained diving apparatus and the limitation of its use to a maximum depth of 33 feet (two atmospheres absolute) have been explained in Chapter 1. It has also been shown that although it is safe to breathe it in a dry compression chamber at an equivalent pressure to that found at 60 feet depth, the above limitation of 33 feet must be adhered to when the diver is totally submerged in water. At greater depths of water than this the oxygen must be diluted with nitrogen or helium, in a percentage according to depth, in order to make it safe.

The symptoms of oxygen poisoning are many and varied, and are fully dealt with in Chapter 1, but unfortunately they are not easy to distinguish from the surface. If, inadvertently, a diver should submerge to a depth at which oxygen poisoning is possible he should be called or hauled up without delay. Failure to answer signals, erratic tugs on the life-line or a sudden uprush of bubbles to the surface, indicating that the diver can no longer control his mouthpiece, are all danger signs and should not be ignored.

A diver suffering from the ill-effects of oxygen under pressure may very quickly relapse in unconsciousness, and severe convulsions and death may follow if oxygen breathing is not terminated as soon as possible.

All divers using oxygen apparatus should be instructed in the possible warning symptoms that they themselves may feel, and should be taught to come up at once should they occur.

The only cure for oxygen poisoning is to breathe fresh air. Get the diver's head out of the suit, if he is wearing one, and make him as comfortable as possible on deck. Convulsions, if present, will gradually subside and the diver will go off into a deep sleep for an hour or two. On waking, although he may suffer a headache and some temporary loss of memory for 24 hours or so, there will be no serious after-effects.

"Shallow Water Blackout". This is another malady which may attack oxygen divers. It can occur in even a few feet of water, hence the name, and takes the form of mild unconsciousness or mental disassociation which quickly clears when the diver is out of the water and rested. He may not even "black out", but may appear suddenly on the surface and have no idea why or how he came up.

This "blackout" has now been shown to be nothing but a mild form of CO_2 intoxication. Normally, if CO_2 begins to build up in small quantities in the lungs, the respiratory nerve centre automatically increases the depth and speed of respiration so as to "hyper-ventilate" and clear the accumulation. It appears, however, that when a high percentage of oxygen is breathed, this natural reaction does not take place, so that, neither is there the normal warning of panting, nor is the accumulation of CO_2 cleared away.*

Modern apparatus and absorbent canisters should prevent any form of CO_2 build-up, so that if "shallow water blackout" occurs, a defect in the apparatus or the canister should at once be suspected.

Schafer's Method of Artificial Respiration.† Every instant of delay is serious. Remove the helmet and corselet, leave the diving dress on the man and place him face downwards with a folded coat or other garment under the lower part of his chest and begin artificial respiration without losing a moment.

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 the back (on the lowest ribs), one on each side, and gradually throw the weight of your body forward on to 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 forwards and backwards upon your arms 12 to 15 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 are many cases on record of drowning in the diving dress, including one in which the diver cut his dress in trying to sever his breast-rope to clear himself when foul, and others in which the diver's helmet came off under water. Such an accident would have been impossible had the safety catch been down and the weight lanyards rove through the hooks provided for them on the helmet. A diver has also been drowned through the pipe connection at the back of the helmet being torn away

* It is also very difficult to appreciate any increase of ventilation while exercising.

† For Holger Nielsen method see Appendix G.

through the ship swinging away from him while he was foul on the bottom. Cuts in the dress are not dangerous if the diver at once gets into the erect position and comes 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.

Injury to the Ears may be caused, as explained on page 35, by going down with a cold, or by other cause of blocked Eustachian tubes. If the ear-drum has been torn, a small amount of blood may ooze out, which will be noticed when the diver is undressed, and he will be deaf on that side. Nothing should be done except to cover the ear with a dressing or bandage to keep out the dust and dirt till medical help is available. The ear-drum generally heals in a few weeks and hearing returns.

Falls Under Water. The effect of falling is described on page 34. Severe shock and bleeding from the mouth and nose may result. The diver should be made as comfortable as possible, with his head and chest well propped up and kept warm with hot-water bottles, etc., till medical assistance is obtained.

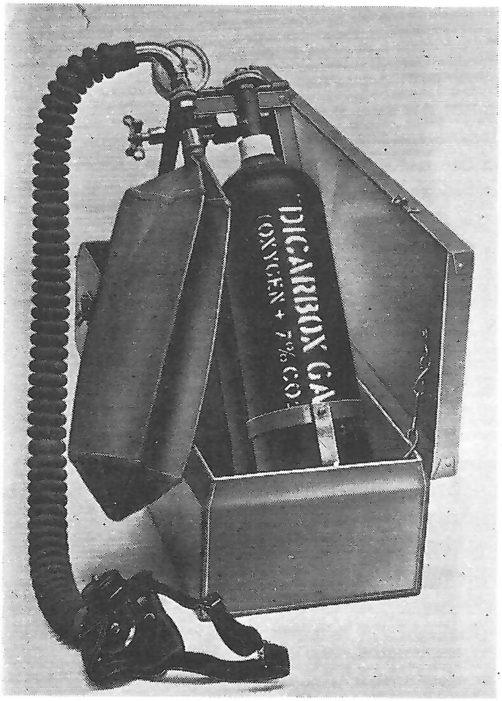


Fig. 124A. "Novita" resuscitation apparatus for administration of oxygen (hand-controlled). Also made with two cylinders

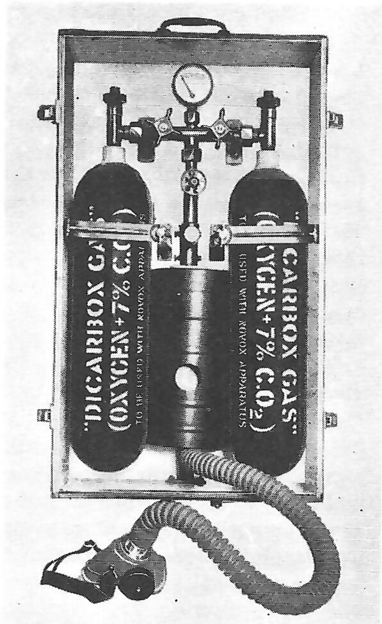


Fig. 124B. "Novox" resuscitation apparatus for administration of oxygen (Lung-governed). Also made with one cylinder