12

Underwater Tools, Instruments, etc.

UNDERWATER CUTTING OF METALS

To attain any degree of success in the use of an underwater cutter, it is essential that the diver should have had practical experience in the use of ordinary oxy-acetylene or oxy-hydrogen cutting. If he is not already qualified in this respect, he should endeavour to obtain such experience before using an underwater cutter.

Temperatures of the various flames at cutting points:

Oxy-acetylene ..	.. .. ..	3,110° Centigrade
Oxy-hydrogen ..	.. .. ..	2,645° ,,
Oxy-electric ..	.. .. ..	3,000° ,,

Oxy-hydrogen Underwater Cutting. The ever-increasing use of iron and steel for underwater constructional work in rivers, harbours, docks, dams, etc., has brought about the necessity of providing a quick and effective method of cutting metal under water. Until comparatively recent times only manual tools were used by the diver and, whilst they dealt effectively with timber, they were of little use for cutting away or piercing metal.

The cutting of iron and steel under water is one of the most important developments of the oxygen cutting process. Underwater cutting was primarily developed for marine salvage work, and an oxy-hydrogen cutting outfit has now become an essential part of the equipment employed by port and harbour authorities and other concerns in the salvage of vessels and their cargoes, where the process is used for cutting away parts of the superstructure, damaged shell plating and frames; for making bolt holes for securing patches, for bleeding compartments and clearing away debris. Furthermore, a vessel may sometimes foul a wire or chain with its propeller when mooring or getting under way in docks and harbours; almost invariably the wire or chain becomes wound tightly, with many turns, around the propeller shaft, and is firmly wedged between the propeller boss and stern tube. By using the underwater cutter, an experienced diver can clear this type of obstruction in a few hours.

Considerable use was made of underwater cutting during the Second World War, and on many occasions the process proved a vital factor to the progress of naval and military operations, as for example during the campaigns in North Africa, Normandy and the Far East.

The Germans, before retreating from Tripoli, made a determined effort to prevent advancing British Forces from making use of the port by sinking a number of vessels in the entrance to the harbour. British naval salvage parties, however, soon cleared the blocked entrance to the harbour; divers using oxy-hydrogen underwater cutters, together with explosive experts and other specialized personnel, worked night and day under the most hazardous conditions to clear a channel through the blocked entrance, and after the amazingly short period of seven days the first large supply ship entered the port.

During the Normandy operations the underwater cutting process proved most valuable in connection with the repair of damaged landing craft; the damaged parts being frequently removed by underwater cutting prior to the welding in of patches by underwater welding, thus avoiding the delay which would have been caused by docking the craft.

Perhaps the most outstanding underwater cutting operation ever undertaken was that on the battleship *H.M.S. Valiant*. This famous warship, during operations against the Japanese, sustained damage which considerably reduced her speed and seriously affected the steering. Inspection of the damage indicated that, before the ship could proceed to a naval dockyard for repair, it would be necessary to remove the port and starboard inner propeller shafts.

This decision presented a formidable problem, since not only did it involve the cutting of 18½ inches diameter shafting but also cutting through the arms of the cast steel brackets which supported each propeller shaft. The massive arms of these "A" brackets, as they are called, are oval in section, being 42 inches wide and 14½ inches maximum thickness.

A naval salvage party successfully accomplished this difficult task. Fig. 182 is based on a drawing by the officer-in-charge of this salvage party and shows the diver, using a B.O.C.-Siebe, Gorman oxy-hydrogen underwater cutter to complete the final cut on the horizontal arm of the starboard propeller bracket, whilst the artist sits on the bracket housing and watches for the cut on the vertical arm to start opening up.

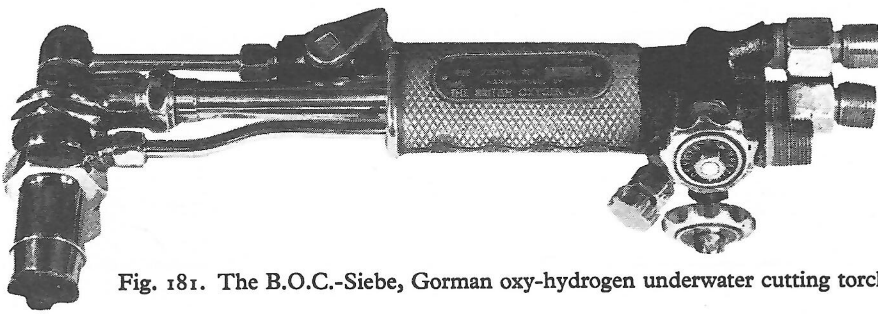

Fig. 181. The B.O.C.-Siebe, Gorman oxy-hydrogen underwater cutting torch

In order to complete this difficult operation as speedily as possible, the two divers worked under water continuously for seven hours, which is an amazing feat in itself when one considers that normally a diver rarely works under water for longer than one to two hours at a time without coming to the surface for a period of rest.

With the termination of hostilities against Germany and Japan, engineers of the Allied Forces of Occupation were faced with many problems, among which were the removal of blown-up river bridges, the restoration of damaged harbours and port installations and the clearing of coast defences, etc.; in carrying out such work the oxy-hydrogen underwater cutter played an important part in speeding up the job of restoring those countries which have felt the full force of destruction arising from total war.

In addition to marine salvage work, the oxy-hydrogen underwater cutting process has many applications, at the present time, in civil engineering constructional work, such as:

(i) **Bridge construction**—The removal of sheet steel piling which is extensively used in the construction of cofferdams surrounding excavations for bridges, piers, etc.

(ii) **Structural repair work**—Alterations to existing structures such as bridges, dock gates, etc.

(iii) **Demolition work**—The removal of jetties which have become damaged or obsolete.

(iv) Alteration or additions to water intakes, wells, sluices, weirs, etc.

The basic principle of underwater cutting is essentially the same as that for ordinary surface gas cutting, namely, the direction of a closely regulated jet or stream of pure oxygen on to an area of iron or steel which has been previously heated to its kindling or ignition temperature (1,600° F. or 870° C.), so that the metal within the direct path of

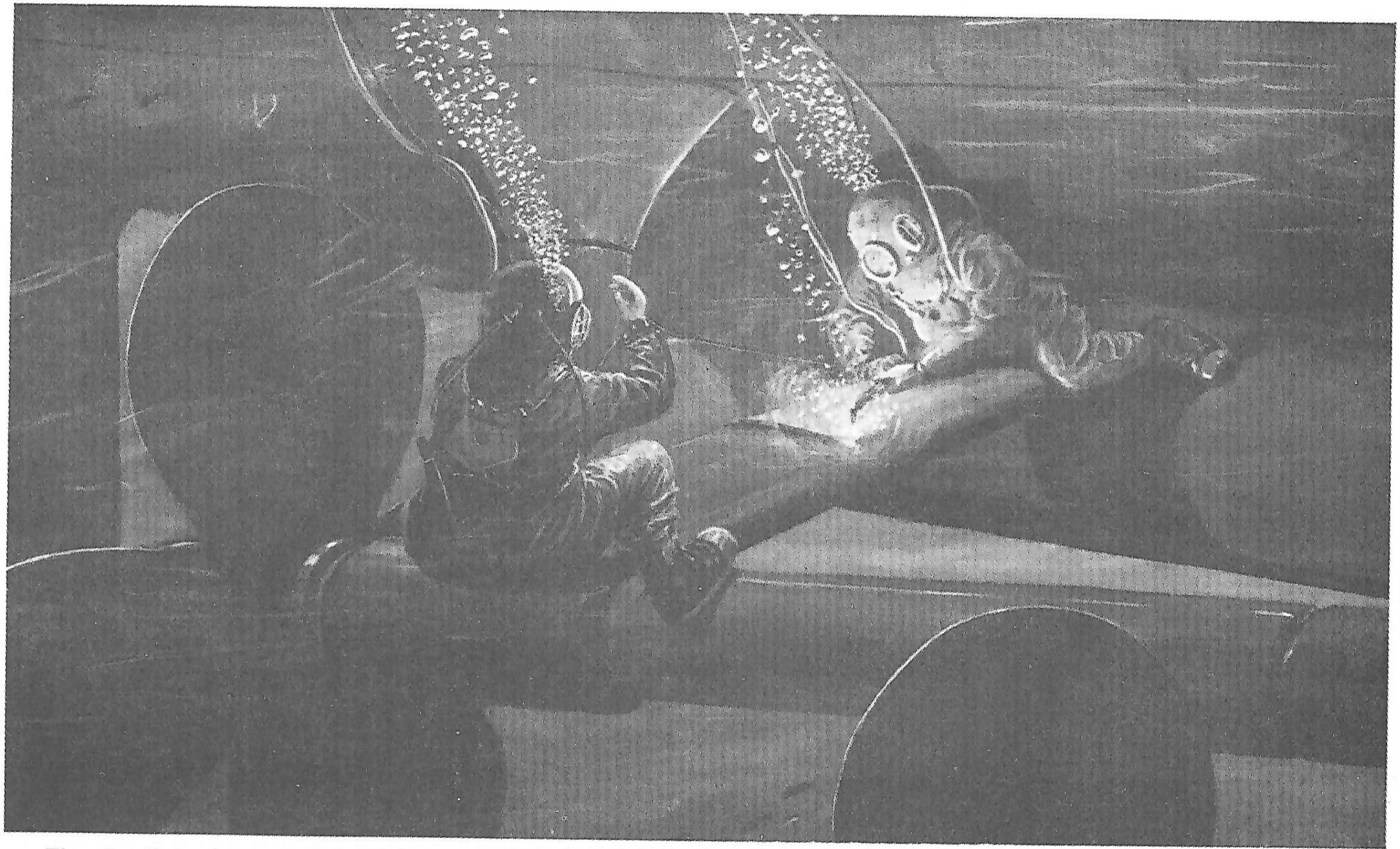

Fig. 182. Removing starboard inner propeller shaft of *H.M.S. Valiant* during the Second World War with B.O.C.-Siebe, Gorman oxy-hydrogen underwater cutter

the oxygen stream is rapidly oxidized and removed to form a "kerf" or cut. The equipment required for underwater cutting, however, has certain essential differences from that used for normal gas cutting.

Equipment. The modern type of B.O.C.-Siebe, Gorman underwater cutter (Fig. 181), is designed to operate with oxygen and hydrogen at nominally equal pressures. Hydrogen is selected as the fuel gas because it is suitable for cutting at greater depths than acetylene which can only be employed for cutting at depths not exceeding 30 feet.

The combustion of hydrogen or acetylene in oxygen causes a rapid expansion of the products of combustion in proportion to the temperature rise. Use is made of this phenomenon by trapping the rising pressure inside a hood (Fig. 183) which is incorporated in a nozzle specially designed for underwater cutting; due to the fact that air is supplied to this nozzle, a protective shroud is created around the flame which, together with the impetus of the products of combustion produced by the effect of the hood, enables the flame to be immersed and remain alight under water.

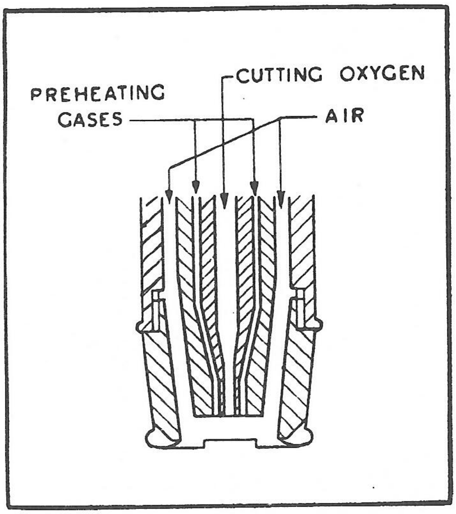

Fig. 183. Section through underwater cutting nozzle

The complete B.O.C.-Siebe, Gorman oxy-hydrogen underwater cutting outfit is contained in a box and, being very compact, can be easily mounted in the boat from which the diver is working, or alternatively it can be mounted on a staging or any convenient site close to the scene of operations.

Time is a vital factor in underwater cutting; if, therefore, the amount of cutting to be undertaken exceeds 3 or 4 lineal feet of $\frac{3}{4}$-inch plate, it is advisable to couple together two or more cylinders of the gases required, i.e. oxygen, hydrogen, as well as the necessary compressed air.

Each gas supply must be controlled by its own pressure regulator for reducing the high pressure of the gas in the cylinders to the required working pressure, details of which are given in the table on page 227. The gases are conveyed by flexible rubber tubing from the pressure regulators to the underwater cutter, the regulation of the gas pressures being carried out at the surface by an attendant who usually has direct telephonic communication with the diver, thus relieving the latter from the necessity of making any pressure adjustment to the flame whilst under water. To facilitate the work of pressure adjustment, a master pressure gauge board, fitted with three 4 inch diameter 0-200 lbs./sq. in. pressure gauges, is supplied, which enables the attendant to see easily the pressures being used and to make speedy alterations to either the oxygen, hydrogen or air pressures in accordance with the diver's requirements.

In the past, one of the most irksome difficulties encountered by the diver occurred when, for various reasons, the flame became extinguished, and to relight it necessitated hauling the cutter to the surface, leaving the diver waiting below, frequently in icy-cold water. This problem has now been overcome by the introduction of the spark lighting system, which permits the diver to light the flame under water. This is achieved simply by connecting one lead from a 12-volt battery to a terminal on the cutter and a second lead from the battery to a cast-iron striking plate. Upon receipt of instructions from the diver, the attendant at the surface switches on the electric current and the diver, after opening *all valves* on the cutter, then rubs the nozzle of the cutter against the striking plate, thus creating a spark which ignites the preheating gases.

A general arrangement of the B.O.C.-Siebe, Gorman oxy-hydrogen underwater cutting outfit is shown in Fig. 184.

Operational Details. Before cutting is commenced, all barnacles and other encrustations which may be present, should be cleared away from the line of the proposed cut and, if possible, the cut should be started from an edge, in which case, the cutter is positioned so that the nozzle is just within the edge and in contact with the surface of the metal. The metal is preheated until the colour of the flame changes from blue to orange, whereupon the cutting oxygen valve is opened and the cutter moved slowly and steadily along the line of cut. It is essential that the cutter be kept steady during preheating and also when cutting, for if the cutter is allowed to sway, due to the effect of currents, success will be impossible. For this reason many experienced divers adopt the practice of placing their free hand, either left or right as the case may be, over the head of the cutter, thereby ensuring that the nozzle is pressed firmly against the metal surface and thus counteracting any tendency towards sideways moevment.

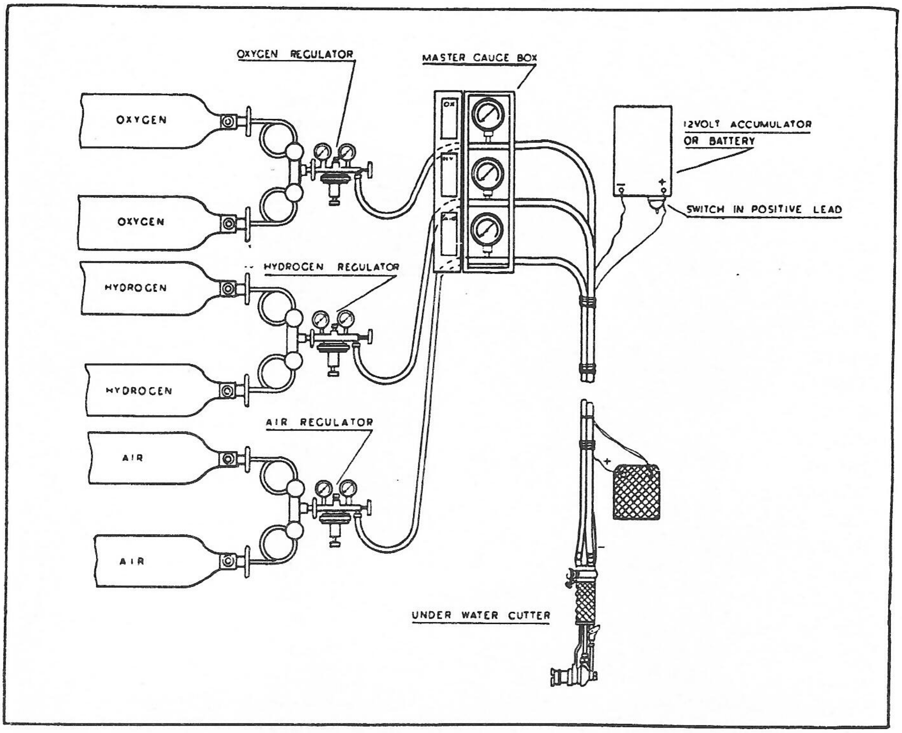

Fig. 184. General arrangement of B.O.C.-Siebe, Gorman oxy-hydrogen underwater cutting equipment

If it is not possible to start the cut from an edge, a hole must be pierced at a spot where the cut is to be started. To pierce a hole in a piece of steel plate, the cutter should be held steady over the desired spot and in contact with the surface metal; preheat until the colour of the flame changes from blue to orange, then open the cutting oxygen valve. In this manner, a hole of about $\frac{1}{8}$ inch diameter will be made, and to enlarge this hole keep the cutter vertical and move it in a circular path immediately after the initial piercing operation. Recommended operating conditions for underwater cutting are given in the table.

Fig. 185. Underwater cutting in operation

OXY-HYDROGEN UNDERWATER CUTTING RECOMMENDED OPERATING CONDITIONS

Depth in feet	Oxygen and Hydrogen Pressures lbs./sq. inch					Air pressure lbs./sq. in.
	Thicknesses: Up to ½ in.	½ in.-1 in.	1 in.-1½ in.	1½ in.-2 in.	2 in.-3 in.	
Surface	30—35	35—40	40—45	45—50	50—55	5—6
10	35—40	40—45	45—50	50—55	55—60	10—12
20	40—45	45—50	50—55	55—60	60—65	15—17
30	45—50	50—55	55—60	60—65	65—70	20—22
40	50—55	55—60	60—65	65—70	70—75	25—27
50	55—60	60—65	65—70	70—75	75—80	30—32
60	60—65	65—70	70—75	75—80	80—85	35—38
80	70—75	75—80	80—85	85—90	90—95	45—48
100	80—85	85—90	90—95	95—100	100—105	55—58
120	90—100	95—105	100—110	105—115	110—120	65—70

B.O.C.-SIEBE, GORMAN OXY-HYDROGEN UNDERWATER CUTTER SCHEDULE

1. 60 ft. length compressed air hose.
2. 60 ft. length hydrogen hose.
3. 60 ft. length oxygen hose.
4. 7 ft. length compressed air hose.
5. 7 ft. length hydrogen hose.
6. 7 ft. length oxygen hose.
7. Compressed air regulator.
8. Hydrogen regulator.
9. Oxygen regulator.
10. Two-way cylinder coupler for compressed air.
11. Two-way cylinder coupler for hydrogen.
12. Two-way cylinder coupler for oxygen.
13. Instruction booklet.
14. Set of tools.
15. Spares for cutter (including spare nozzles).
16. B.O.C.-Siebe, Gorman underwater cutter.
17. Master gauge box.
18. 60 ft. length positive and negative cables.
19. Sealed steel package of electrolyte (for export only).
20. Cast-iron striking plate.
21. Twelve-volt battery.

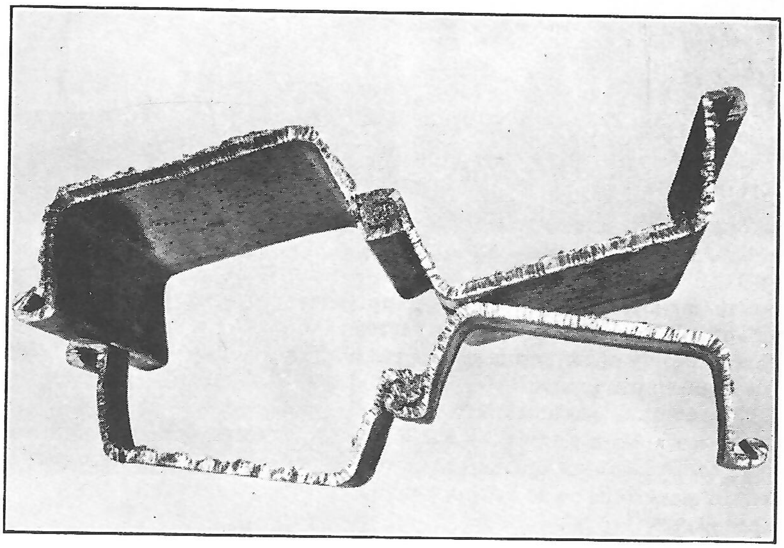

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Fig. 186. Examples of underwater cuts through steel, using the oxy-hydrogen cutter

Electric Underwater Cutting. Electric underwater cutting was in use in this country during the First World War, but considerable developments have taken place since then.

Two types of electrodes are used—steel and carbon. The latter gives much better results than the former. The actual cutting process is similar to the oxy-hydrogen process in that the material is heated locally to a point of incandescence but in the electric process this is done by means of the arc.

The electrode is tubular, the oxygen being conveyed through the bore. It is fully insulated, and immediately it makes contact with the work in hand an arc is formed giving intense heat. Almost at the moment that contact is made, pure oxygen is allowed to pass through the core of the electrode, with the result that the material, whether it be iron or steel, becomes readily oxidized.

The supply current for underwater cutting is D.C.; the generator should be capable of developing up to 70 volts and 550 amps. approximately.

The work to be cut must have the positive cable of the generator securely attached to it, the cutter itself being made the negative.

The carbon electrode has a special covering to prevent oxygen percolating through the carbon. The changing of electrodes under water is easily accomplished.

The oxy-arc process is suitable for cutting cast-iron and non-ferrous metals both under water and on surface.

The oxy-arc process is more suitable for cutting the thinner materials. For materials thicker than 1 inch, it is better to use the oxy-hydrogen process; cutting with the latter is also cleaner. However, cutting with the former process can take place at greater depths.

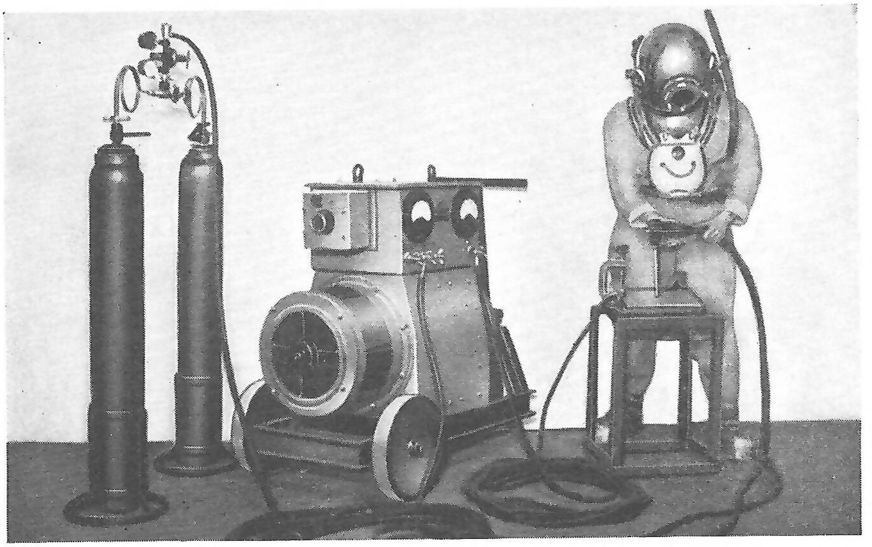


Fig. 187. Diver with complete outfit for oxy-arc cutting

Complete oxy-arc cutting plant will comprise the following:

1. A fully insulated underwater cutting torch.
2. Sufficient supply of oxygen in cylinders.
3. An oxygen reducing valve.
4. A D.C. generator, 500/600 amps. capacity.
5. Sufficient cable with proper connections for both the positive and negative line.
6. Oxygen hose for conveying oxygen from the reducing valve to the cutter.
7. Coloured glass to fit on to helmet window.
8. Rubber gloves.
9. A supply of coated electrodes

Safety Precautions:

1. Both the cable and torch should be carefully checked for possible leakages.
2. The diver should not allow any part of his body or gear to be part of the electric circuit.
3. The diver should always use suitable rubber gloves.
4. The diver should always use the coloured glass on his helmet before striking the arc.
5. The diver (fully qualified, of course) should have had the necessary tuition in the use of the cutting apparatus above water before attempting underwater cutting.
6. When cutting piling, which is, perhaps, one of the most difficult of all underwater cutting jobs, the diver-cutter should not allow the electrode to arc on the side of the cut, for, besides consuming a great deal of current, the temperature of the electrode becomes so low as to prevent efficient cutting.
7. The oxygen pressure must always be in excess of the sea-water pressure, and for economical cutting it is always advisable to follow the directions given by the manufacturer.

ARC UNDERWATER WELDING

Underwater welding has been carried out more or less experimentally for a considerable time, but real progress has only been achieved since World War II.

Fig. 188

Fig. 189

Diver welding under water

Underwater arc welding technique is similar to that of ordinary surface arc welding. The diver-welder should have had several weeks' training at surface work before attempting underwater welding. At present, submerged welding is applied to mild steel work only. Undercutting of the weld may be expected, due to the greater pressure applied by the operator. However, very satisfactory welds are possible. The welding rods should be coated with a synthetic paint, particularly for welds in salt water.

The diver's helmet is fitted with special coloured glasses to protect the eyes from the glare of the arc. The diver should use rubber gloves when welding. It is quite safe to change the electrode under water, and spare electrodes should be carried in the electrode quiver which is supplied with the equipment. For vertical welding it is sometimes advantageous to use electrodes a size smaller than the normal.

D.C. current must be used, and the voltage should be approximately 15 volts higher than is normally used for surface work. The amperage should also be between 15 to 20 above that ordinarily used.

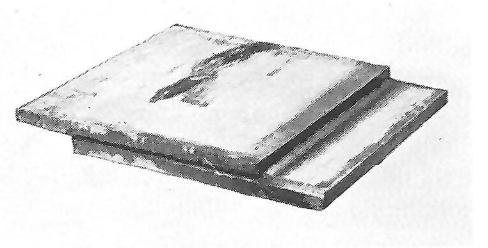


Fig. 190. Steel plates welded under water

The holder to carry the electrode should be well insulated to prevent current leakage and electrolysis. It is essential to make the work positive and the electrode negative; if the procedure were reversed, the holder would burn very rapidly. The generator should have a capacity of at least 300 amps. per operator.

The speed in clear water is slightly slower than the speed at the surface. When properly made, the weld should have a tensile strength of between 75 and 80 per cent, and between 45 and 55 per cent ductility, as compared with a similar weld at the surface.

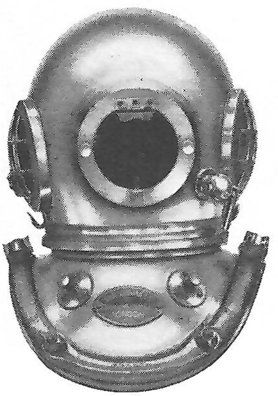


Fig. 191
Diver's welding protective screen—shut

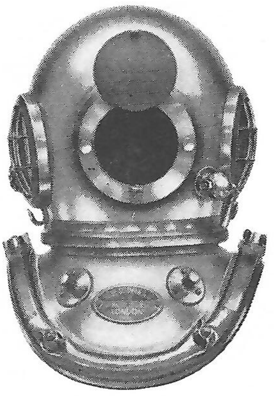


Fig. 192
Open

THE COX SUBMERGED BOLT-DRIVING AND PUNCHING GUN

This device, an effective aid in marine salvage operations, is an explosively-actuated gun which drives screwed bolts through, and punches holes in ships' steel plates with equal facility above or below water, and without recoil, flash or report. It is a compact instrument, easily carried and manipulated by a diver at any working depth. The saving of time and labour over some other methods entailing the lengthy processes of drilling, tapping and bolting is obvious, particularly in the securing of steel and wooden patches to holed plates in damaged ships, and in the construction of cofferdams, etc.

The gun is made in one size and weighs 36 lbs. It fires heat-treated alloy steel bolts into steel up to 1 inch in thickness. Solid securing bolts are $\frac{5}{8}$ inch diameter, $4\frac{1}{2}$ inches long, threaded B.S.F. Hollow air bolts are $\frac{3}{4}$ inch diameter, threaded Whitworth. Punch ammunition punches holes $\frac{11}{16}$ inch diameter in steel up to $\frac{3}{4}$ inch thick. The material for these bolts is a 90-ton tensile steel and the solid bolts will take a bend of 15° before yielding. Pressure required to remove a bolt from $\frac{3}{4}$ inch plate is 12 tons.

Fig. 193. Diver using Cox gun under water

Other work accomplished with the gun includes: (*a*) The sealing of inlet valves in a vessel, enabling the salvors to proceed with internal cementing, though, on examination in dry dock, it has been found in some cases that the diver's work was so rigid that the cementing might have been dispensed with in an emergency; (*b*) loose rivets have been tightened by shooting bolts through them; (*c*) seams have been made tight by shooting bolts between the riveting; (*d*) shoring and stiffening have been pinned to 'tween decks; (*e*) brackets have been shot on to tank tops to form steps for the heels of shores; (*f*) eye-plates for slinging and holding pumps in difficult situations have been secured; (*g*) loose, leaking and staggered rivets have been punched out (using the punch ammunition), and then replaced with wooden rivet plugs.

The method adopted in timber patching and cofferdam construction is to use 1 inch Whitworth mild steel extension bolts which are screwed on to the fired-in bolts and are finally secured with a washer plate and wing nut. Extension bolts are provided in 12-inch, 18-inch and 24-inch lengths. A plate-squaring attachment on the gun permits a square stand of the bolt for this extension work.

In cofferdam work, the bolts can be shot through a template as fast as the gun can be loaded and the staging moved, with the result that the securing bolts are at standard pitch and the timber work can be drilled in readiness for securing by the diver without delay.

In steel plate patching, the procedure is as follows: The patch-plate is bridged on timber, or laid on sand or earth, and the bolt-clearing holes are punched with the appropriate ammunition. One or more tack-bolts are fired into the holed plate, and the patch-plate, with its joint, is held in position with tack-nuts finger-tight only. The remainder of the patch-bolts are then fired through the patch-plate clearing-holes, and the bolts are finally nutted and the joint tightened up.

Additional loaded barrels are taken down by the diver, or can be lowered to him.

AIR BOLT EQUIPMENT FOR USE WITH STANDARD SUBMARINE BOLT-DRIVING AND PUNCHING GUN

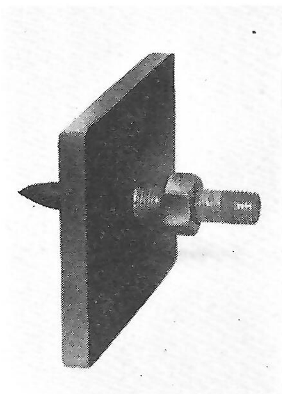


Fig. 194
Solid bolt fired through ½ inch steel plate

This apparatus uses a hollow bolt with a detachable solid nose, and is designed for the supply of air or oxygen for breathing, or for the supply of compressed air for lifting operations, or for the introduction of small wires for electrical circuits to otherwise enclosed spaces. Suitable adaptors are provided to enable a Standard ¾ inch gas compressor line, or ⅝ inch diving line to be coupled to the hollow bolt after insertion in the plating. The process is independent of any access to the inner side of the plate, the whole operation of inserting the bolt, the unsealing of it, and the coupling up of the air supply line, being performed from the accessible side of the plate. A series of bolts may be inserted and the adaptors fitted. A watertight joint is maintained and the unsealing may be performed when convenient. This is done by inserting a special screwdriver through the adaptor and bolt, and engaging a slot in the detachable nose, allowing it to fall away and thus giving access within.

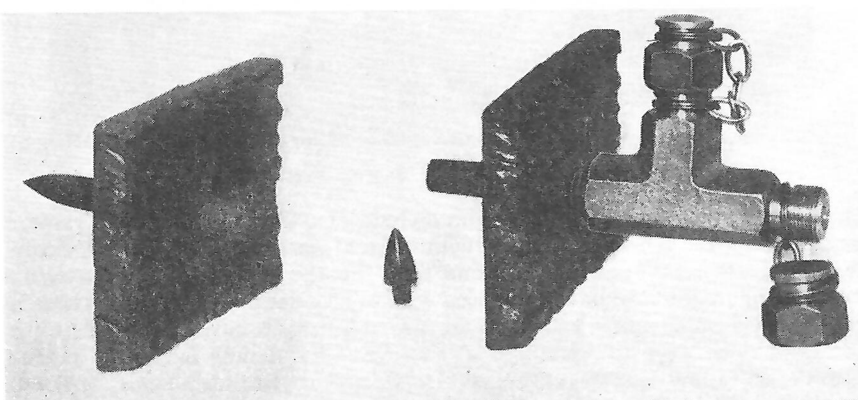


Fig. 195. Hollow bolt fired through ⅝ inch steel plate. (Left) Before removal of solid nose. (Right) After solid nose is unscrewed and with adaptor for compressed air supply attached

PNEUMATIC TOOLS (see also Chapter 13)

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

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

Nature of Work. Cutting off to 6 inches above ground level pitch-pine sheeting piles, 24 inches by 6 inches. In each of these piles 11 2-inch holes are bored, one diver doing 12 piles in eight hours = 132 holes 2 inches diameter by 6 inches deep.

Rock Drilling. See Chapter 13.

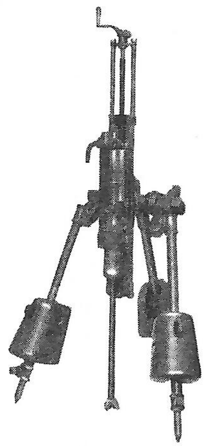


Fig. 196
Drifter on tripod

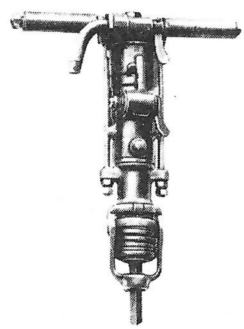


Fig. 197
Rock drill—dry

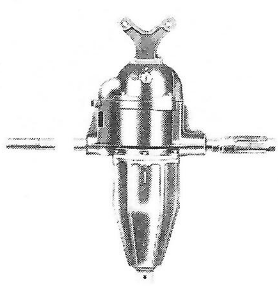


Fig. 198
Impact wrench

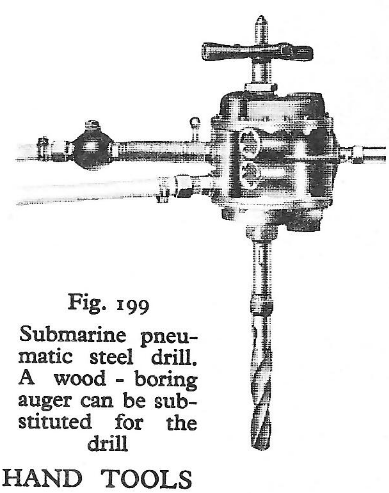


Fig. 199
Submarine pneumatic steel drill. A wood-boring auger can be substituted for the drill

WORK WITH HAND TOOLS

Cases sometimes occur where the diver has no alternative but to employ hand tools. The approximate amounts of work that a good diver, using such tools, can accomplish at depths down to, say, 40 feet are as follows:

Excavating. (*a*) In stiff clay and stones, ¾ to 1 cubic yard per shift.*

(*b*) In loose gravel, 1 to 1¼ cubic yards per shift.

Using a strong water jet, the above quantities would be considerably increased, perhaps doubled or even trebled.

(*c*) Hard chalk, ½ to ¾ cubic yard per shift.

But by hand drilling and blasting, and the use of a high-pressure water jet, this quantity might be trebled.

* = three hours' actual work.

Boring through Timber. A hole $1\frac{1}{2}$ inches diameter by 30 inches deep can be bored in greenheart timber in from 35 to 40 minutes.

Sawing Timber. Two divers, using a cross-cut saw, could saw through a 12 inch by 12 inch pitch-pine pile in 35 to 45 minutes, or through three 12 inch by 6 inch in about the same time.

Greenheart or oak would take 75 per cent to 100 per cent longer. At greater depths, longer times must be allowed.

SUBMARINE WIRE-ROPE AND CHAIN CUTTING MACHINE

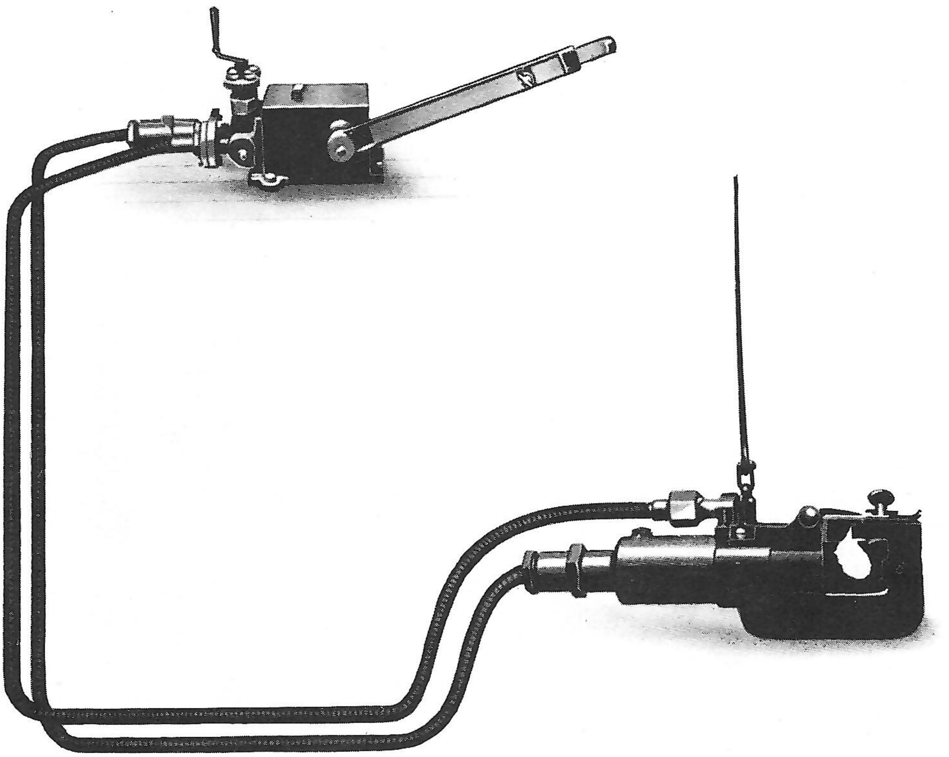


Fig. 200

For Cutting Wire-Rope and Chain under water or in any other difficult situation. This machine can be operated at any convenient position or distance from the actual cutter. It is specially adaptable to salvage work, and in cases of wire-ropes fouling ships' propellers, dock gates, etc.; also for naval purposes, such as clearing away obstructions used in harbour defence—buoy-lines, mine-cables, etc.

Wire-ropes up to 6 inch circumference can be cut in about one minute, only one man being required to work the machine. Larger sizes of machines for cutting up to 10 inch rope are also made.

WATER TELESCOPES

The water telescope (Fig. 201) is used where the water is clear when searching for objects below the surface. It is fitted at its lower end with a strong circular plate glass, and with lugs to which ropes are attached for keeping the tube perpendicular and steady in strong currents or tideways. It is also fitted with handles at the upper end for conveniently holding the tube under water. The tube can be supplied in one length, or in sections so arranged that they can be easily and quickly connected together; the usual lengths are from 4 to 8 feet. The tube can also be made with trunnions to fit into the rowlocks of a boat. An eye-piece is fitted at the upper end of the tube; sometimes powerful binoculars are supplied as shown in illustration.

Fig. 201

The telescope shown in Fig. 202 is fitted with a submarine electric lamp, which throws its light directly on to the object to be examined when darkness prevails. A special arrangement is provided for directing the tube at any desired angle.

In using the tube, the operator adopts the same method that a photographer does when focusing a camera; he places a dark cloth over his head and the binoculars.

The instrument illustrated in Fig. 203 is designed for making examination from a vessel, or from a mural construction projecting above the surface of the water, of the nature of the sea-bed, or the condition of the sea-wall, or other submerged material. For examining the sea-bed, etc., a plain lens is fitted to the lowermost flange of the tube, while for examination of sea-walls, etc., the lens is replaced by a special periscopic chamber, with lateral lens through which the object is reflected and is observable through binoculars at the surface-end of the tube.

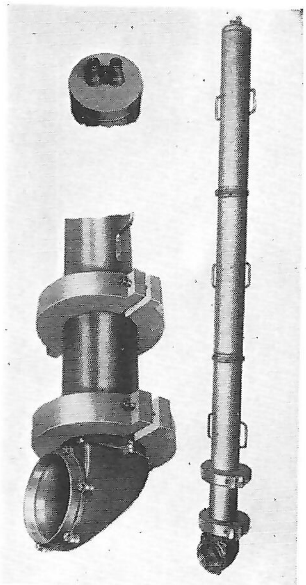


Fig. 203. Enlarged upper and lower ends of telescope shown on left

The telescope is used in conjunction with a 3,000 candle-power submarine electric lamp, which throws its light on to the object to be examined. If observation is being made of the sea-bed, the reflector is used to throw the light downwards; if lateral examination is desired, then the circular reflector is removed and the lamp used with the side reflector.

The telescope shown in Fig. 203 is 15 feet long by 8 inches diameter (where the length exceeds 20 feet, the diameter is usually increased to 10 inches or 12 inches), but longer or shorter lengths are made to suit requirements. Lead collars are fitted at the lower end of the instrument to give the necessary sinking weight.

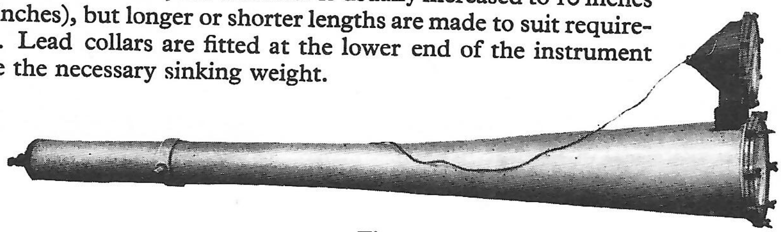


Fig. 202

DIVER'S STAGE FOR DESCENT AND ASCENT

British deep-water divers invariably descend and ascend on a shot rope, but some foreign divers prefer to go down and come up on a stage, as shown, while others favour a saddle device on which they are slung by a rope.

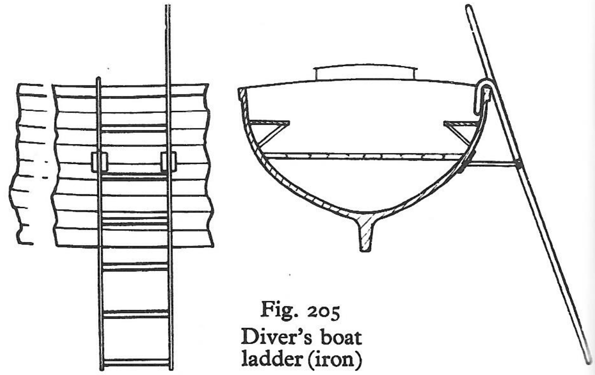


Fig. 205
Diver's boat ladder (iron)

Fig. 204

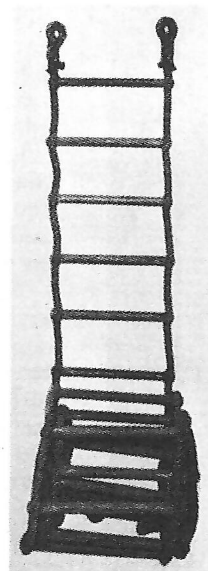


Fig. 206
Diver's rope ladder with ash rungs

DIVER'S DECOMPRESSION RECORDER AND LOG

The instrument here illustrated has been designed to facilitate the accurate regulation, in accordance with the decompression tables, of the diver's ascent from great depth. It comprises: (*a*) a dial with two sets of figures, one representing depths of sea-water up to 320 feet, the other the corresponding pressures in lb. per square inch*; (*b*) an alarm clock, which is set to ring on the completion of each stage of the diver's ascent; (*c*) a decompression table, giving the time limits in deep water, stoppages during ascent, and air supply required; and (*d*) log cards on which the diver's working depth, decompression stages, etc., are recorded. The apparatus is carried in a mahogany case, fitted with a drawer containing 24 log cards and a copy of the Decompression Tables.

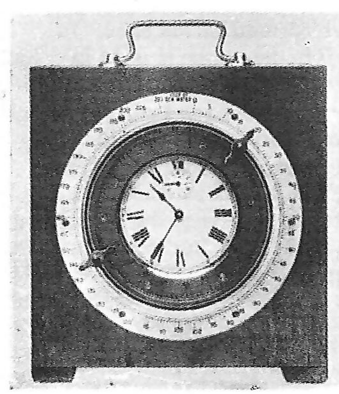


Fig. 207

* The dial can alternatively be calibrated in metres and kilogrammes per square centimetre.

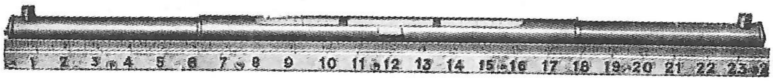


Fig. 208

Diver's Spirit Level mounted on heavy base, with 2-foot rule with raised figures, so that diver can take measurements visually when working in clear water, or by sense of touch when in darkness.

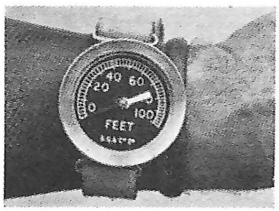


Fig. 209. Diver's wrist depth gauge

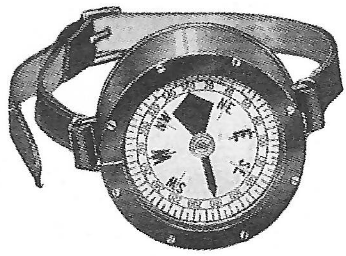


Fig. 210
Diver's wrist compass (luminous)

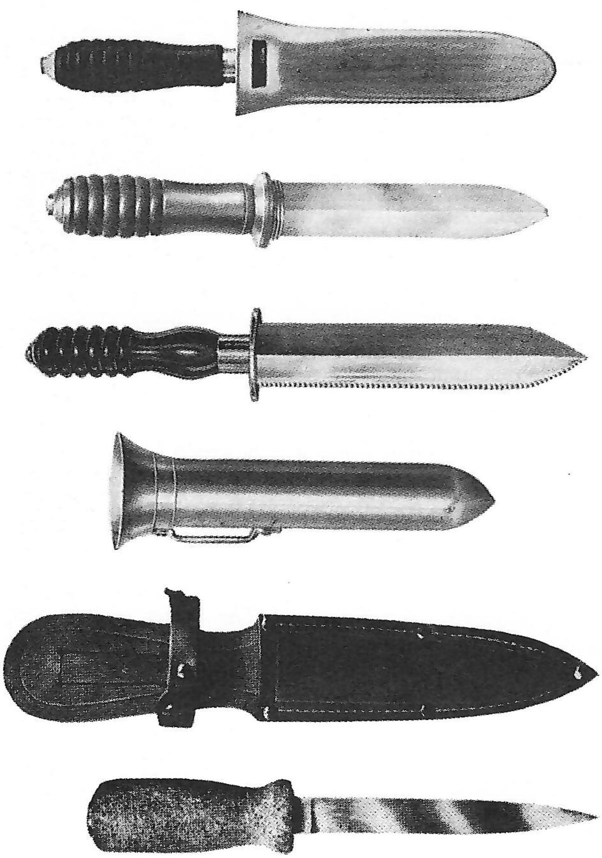


Fig. 211. Diver's knives
The bottom knife is of the floating type with cork handle. Its sheath is of leather

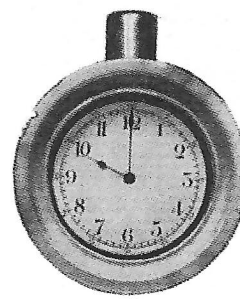


Fig. 212
Diver's wrist watch with luminous dial, in watertight case

SUBMARINE PHOTOGRAPHY

Efforts to obtain successful photographs under water go back for many years. An early type of camera with a cluster of three electric lamps (Fig. 213) was made by the author's firm during the First World War for the late Commodore Sir Frederick Young, K.C.B., R.N.R., head of the Admiralty Salvage Department. Another interesting apparatus, unique in the purpose for which it was to be used, was made just after that war, and because of its novelty we describe it in some detail.

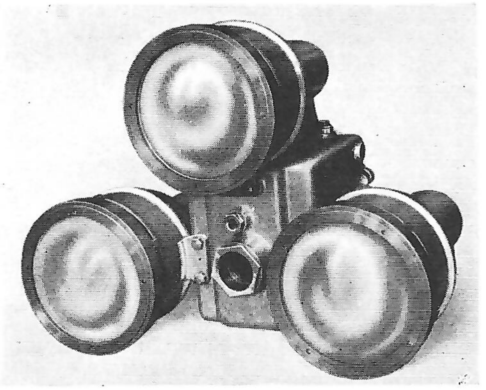


Fig. 213

Before their retreat from the Lens district in 1918, the Germans not only flooded the coalmines, but laid booby traps in them, with the result that when operations were begun for the recovery of the mines, a number of serious accidents occurred which greatly retarded reconstruction. The French Government, in order to avoid as far as possible a repetition of these accidents, decided to use a camera for taking photographs under water, to ascertain where the lining of the mine shafts had been punctured, and to ensure that everything was safe before sending divers down. Siebe, Gorman & Co. were commissioned to make the apparatus illustrated in Fig. 214. It measured overall 3 feet 4 inches by 3 feet 4 inches by 4 feet 9 inches high, weighed about 15 cwt. and consisted of three main gunmetal castings bolted together. The upper and lower castings were each formed with four watertight chambers, each of which contained a mercury vapour lamp giving 3,000 c.p., or 24,000 c.p. altogether. The middle casting comprised four chambers which contained the lamp resistances, and four smaller chambers which held the cameras. A cable junction-box and four lifting eyes were fitted on top of the upper chamber. The lamps were of the quartz or silica type, and were made by the Westinghouse-Cooper Hewitt Company. The mercury vapour was contained in a quartz vessel 9 inches long. The lamps operated in parallel on a direct current supply of 200 volts at a current consumption of $3\frac{1}{2}$ amps. As the candle-power of each lamp was 3,000, the efficiency was in the neighbourhood of $\frac{1}{4}$ watt per candle-power. The light from the lamps was extremely actinic and the photographic effect, it was claimed, was equal to that of other lamps using a very much higher current. The lamps were made as simple as possible, so as to avoid unnecessary complications, the tilting to start the action being effected by means of special levers actuated by rods on the outside of the box. These rods and the leads to the lamps passed through stuffing boxes. The cameras were of a special box type and were fitted with "behind lens" shutters which were electrically controlled. A very wide angle lens was employed.

In the early 1930's Mr. U. V. Bogaerde, Art Editor of *The Times*, also became interested in the subject. At intervals for some years, experiments were carried out by Mr. Bogaerde in collaboration with the author and the Williamson Manufacturing Co. Ltd. of London, and improved apparatus and lighting arrangements (Fig. 215), when tested off Falmouth harbour, achieved fairly satisfactory results considering the poor conditions of light experienced in British waters. These experiments were interrupted by the Second World War.

In the U.S.A. J. E. Williamson had obtained considerable success with still photography and cinematography in the crystal-clear waters of the Southern States (see Part II, Chapter 3). The American naturalist, William Beebe, and his colleague, Otis Barton, had also obtained excellent photographs of submarine life (see Part II, Chapter 3).

The idea of a lightly-equipped self-contained diver carrying a cine-camera in his hands was brought to fruition after the Second World War. W. D. Chesterman and J. B. Collins, of the Admiralty Research Laboratory, after considerable experiment produced a cine-camera operated by an electric motor, fitted into a watertight case, with external controls, made by Siebe, Gorman & Co. (Figs. 216, 217 and 218). In the clear and tideless waters of the Mediterranean, clad in bathing trunks and swim-fins, and using self-contained compressed-air breathing apparatus (Fig. 219), the late H. J. Hodges, R.N.V.R., took some remarkably successful underwater films with this camera as those readers who have seen "Wonders of the Deep" and "Morning Departure" will know. The difficulties of obtaining good results in the dull light conditions met with off our own shores have yet to be fully overcome, but research and experimentation continue.

EARLY TYPES OF UNDERWATER PHOTOGRAPHIC APPARATUS

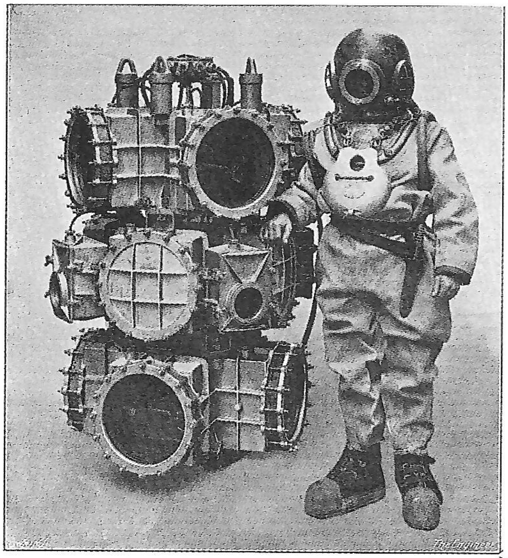


Fig. 214. Special Submarine Camera designed and manufactured by Siebe, Gorman & Co. Ltd., to detect booby traps left by the enemy in flooded French mines after World War I 1914-18

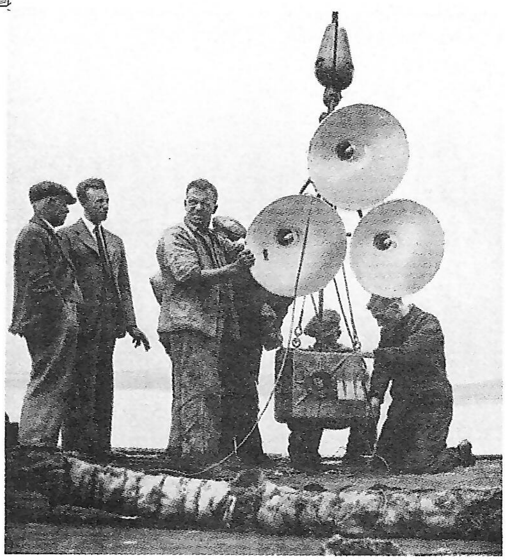


Fig. 215. Underwater Camera made by Siebe, Gorman & Co. Ltd., in collaboration with *The Times* newspaper in the early 1930's

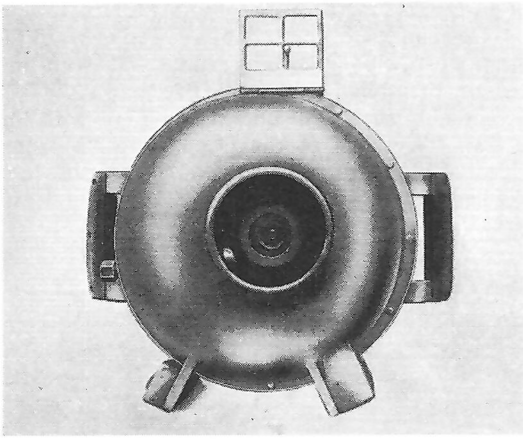


Fig. 216
Front view

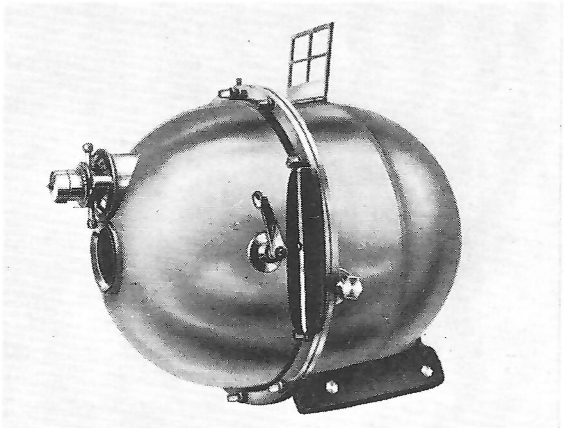


Fig. 217
Side view

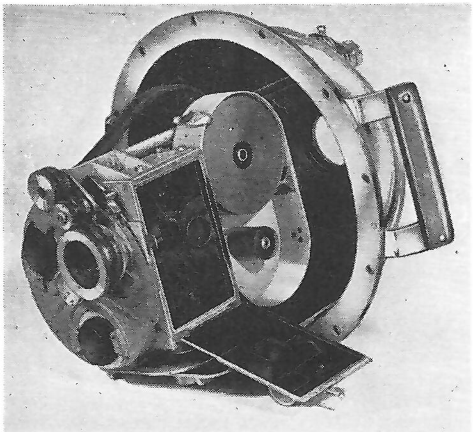
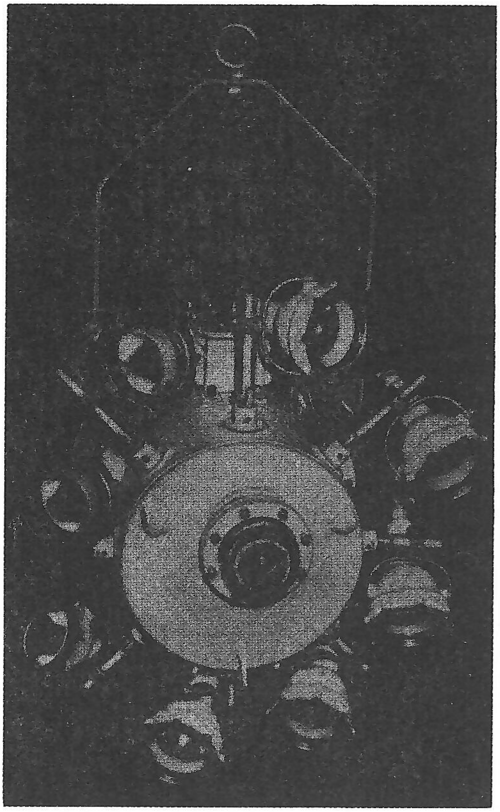


Fig. 218
Interior mechanism



MARCONI-SIEBE, GORMAN UNDERWATER TELEVISION EQUIPMENT

(See also Appendix E)

Fig. 218A.

As used by the British Admiralty in the search for the B.O.A.C. Comet airliner, wrecked off Elba, January, 1954. As soon as the salvage ship was securely positioned, the camera was lowered. Its periscopic eye, roving through 360 degrees in azimuth, soon found the first of several loose collections of wreckage. A $4\frac{1}{2}$-ton grab, with 10-foot jaws, was dropped and, guided by a diver seated in an observation chamber nearby, closed over the fragments.

(The camera is normally pointed vertically downwards and not as shown in the photograph.)

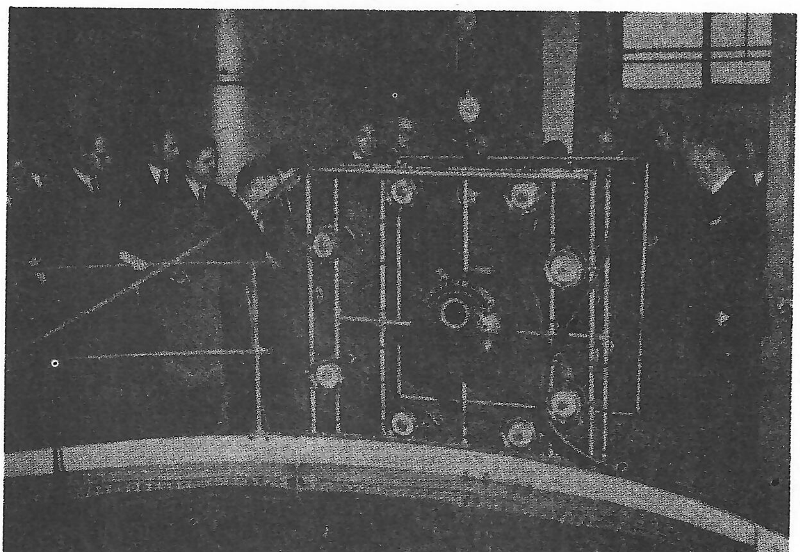


Fig. 218B. A group of foreign Naval officers witnessing a demonstration in Siebe, Gorman & Co.'s Experimental Department, of an early model.

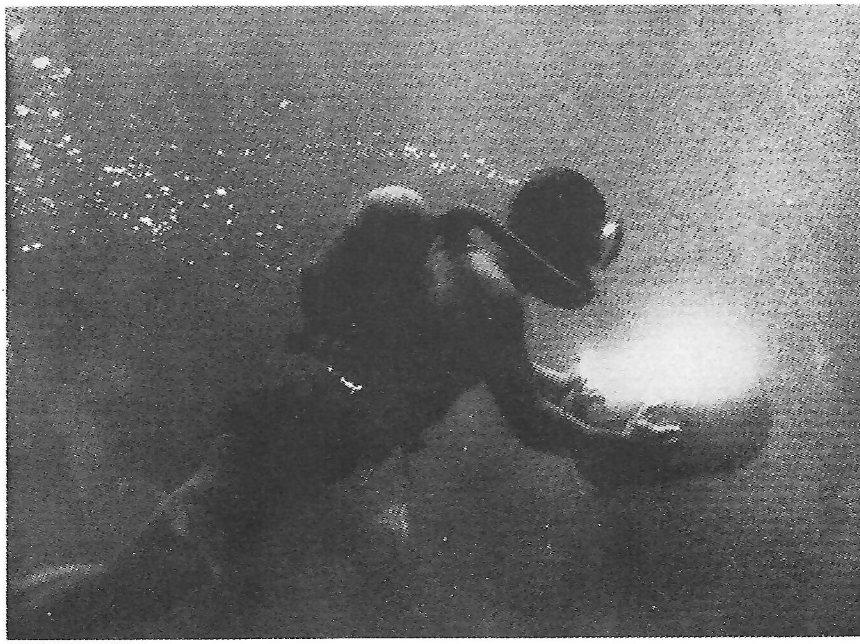


Fig. 219. Diver in self-contained compressed-air diving apparatus with underwater 35 mm. cine-camera at depth of 40 feet

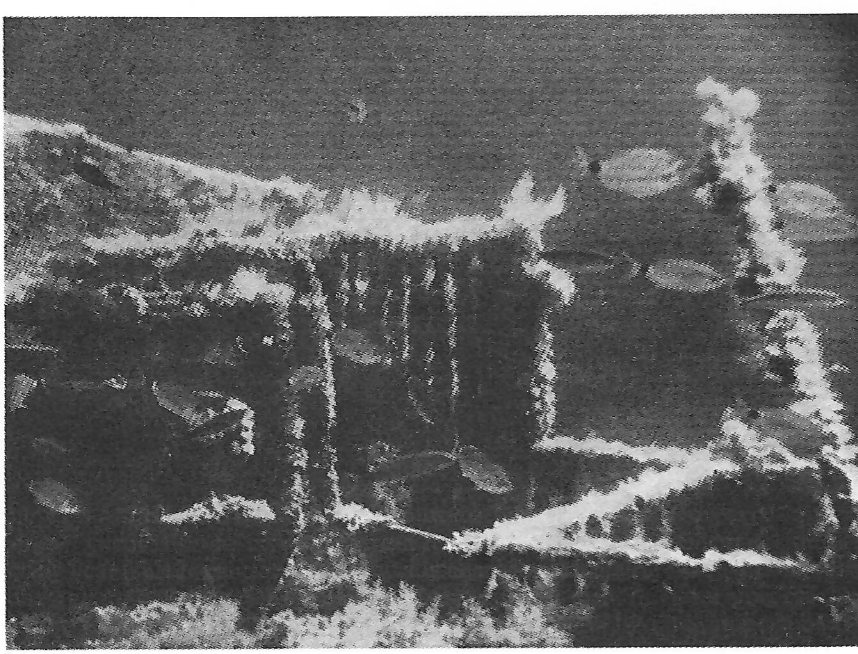
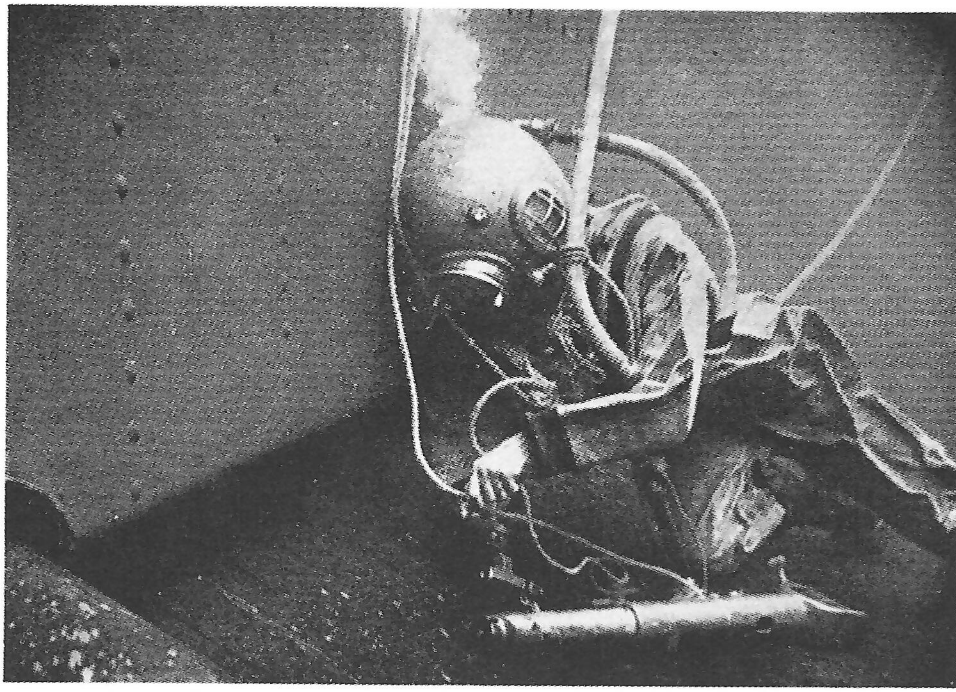
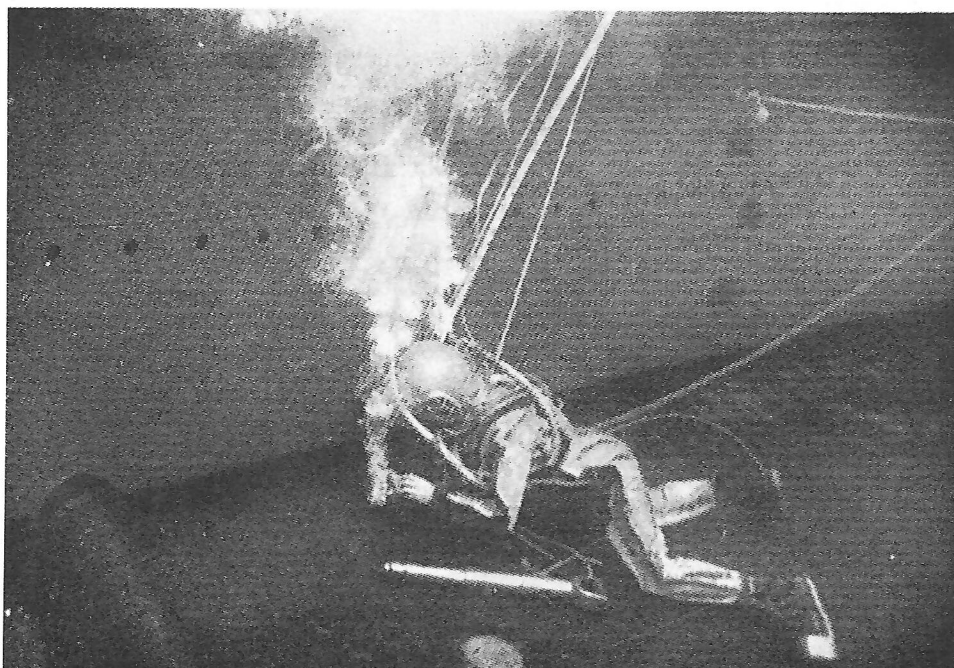


Fig. 220. Underwater photograph of wreckage of *s.s. Breconshire* in 60 feet of water off Malta. Note the fishes and the marine growth on the wreckage



(*Photograph from film "Morning Departure"*)

Fig. 221. The diver has fired a hollow bolt into the hull of a T-class submarine with a Cox gun and is unscrewing the nose of the bolt. Underwater photograph taken at depth of 90 feet



(*Photograph from film "Morning Departure"*)

Fig. 222. The diver, as in Fig. 221, securing the air-pipe connection to the hollow bolt

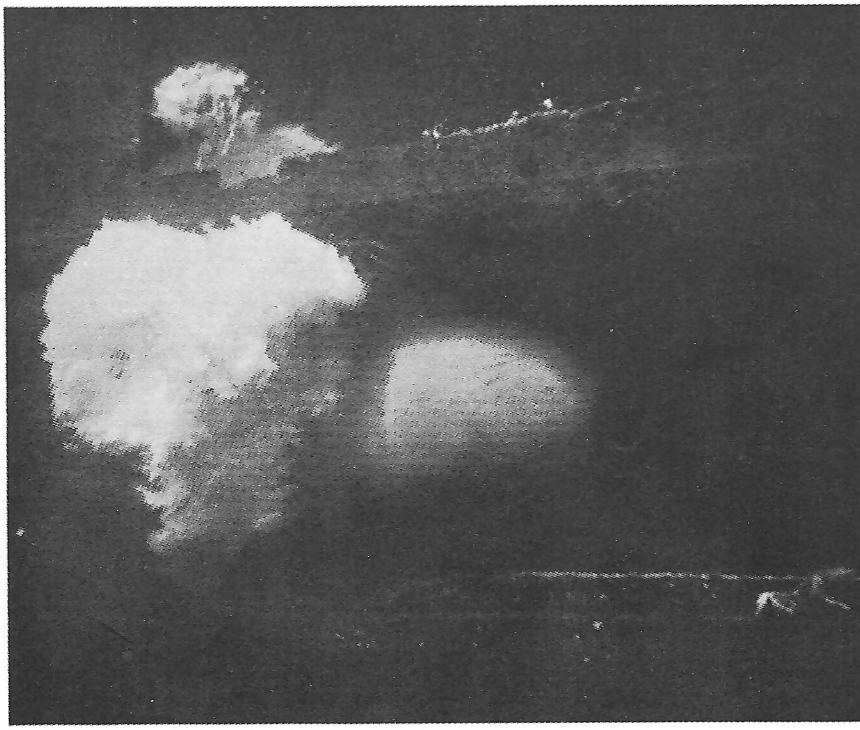


Fig. 223. Underwater photograph of a torpedo at the moment of leaving one of the tubes of an "A" class submarine. Exposure 1/700th second

Fig. 224. Underwater photograph of the bell of *s.s. Breconshire* at a depth of 60 feet. The ship, sunk by enemy action, was subsequently raised by a Royal Navy salvage unit in September, 1950 (see Part II, Chapter 2)