difficult to compress into a limited space, but if he had succeeded in giving members an idea of the general principles of the apparatus and operations, he considered that his efforts would have been rewarded.

Captain Wilkinson answered a number of inquiries by the President, Messrs. Clements, T. Hill, A. E. Smith, J. A. Smith, and others, relating to details of the apparatus on view and the photographs exhibited.

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THE PRINCIPLES AND PRACTICE OF SUBMARINE MINING.

Read by Captain G. F. Wilkinson, Staff Officer for Engineer Services.

Submarine Mining is one of the means used in warfare to deny to a hostile fleet, entirely or partially, as physical circumstances permit, the use of certain water areas on a coast, as well as a way of ingress to or egress from a harbour.

It is as a deliberate defensive operation applied to defined channels or water areas that the subject is presently dealt with. By this means it will be easier to arrive at a point from which to view its wider applications. Submarine Mining has little offensive action. The mined area requires protection, proximity to guns ashore or afloat is therefore necessary.

The essential element of secrecy is so perfectly realised, that the moral as well as the material effect of this form of defence is tremendous. The moral effect is so strong that the mere presumption that a channel is mined will usually be sufficient to deter a fleet from attempting to pass through; the material effect should a ship be caught within the radius of explosion of a powerful mine would be its certain destruction. If efficiency is absent, moral effect will probably be absent too, as was the case when Admiral Dewey, reckoning
the Spaniard at low value, led his fleet through the mined areas of Manila Harbour. Several mines were exploded by observers ashore, but, owing to defective arrangements, the ships were not located accurately, and so escaped unharmed.

The object, therefore, of Submarine Mining, is to so hamper ships that the effect of their fire may be minimised by the limitations or restrictions placed on their movements. In this way mines and guns mutually protect each other; they are more or less essential to each other. The siting of the mined area is of primary importance; the extent and depth of water, velocity of tide, nature of bottom, and rough, exposed positions, impose limitations more or less important.

The area to be mined having been selected, the distribution of the mines therein is determined, a careful survey made, the actual position for each mine located, and the depth of water noted, so that the subsequent placing of the mines may be an orderly procedure. Methods of fixing positions for mines are matters of survey; but a more than passing reference may not be undesirable, illustrating, as it will, the large amount of preliminary work involved before a water area can be deliberately mined. Admiralty and local charts usually form the groundwork on which the details required are built up.

In Diagram A, methods of fixing positions for mines are illus-

Diagram A.—Methods of Fixing Positions for Mines.
brought into coincidence with the line of point 8 and the distant trig. station.

Submarine Mines are primarily divided into three classes:—
1. Electro Contact.
2. Electro Observation.
3. Mechanical.

The first and second are connected with the shore, and are under control, while the third is not.

In the case of an Electro Contact Mine, the arrangements are such that a blow from a ship is necessary before the mine can be exploded. It usually floats close to, but not at the surface.

An Observation Mine may be floating at a level just below the deepest vessel, or it may rest on the bottom, in which case it is called a “ground” mine. It is so arranged that it can be exploded at will by an observer on shore. This is not so great an advantage as might be thought, because, to ensure satisfactory results, the conditions of observation must be such that the vessel whose destruction is desired must be located with great exactness within the destructive area of the mine. Such conditions are not always obtainable, whereas the use of contact mines is only limited by the range of the protecting guns, weather and other natural conditions being equal.

Mechanical Mines once laid are not under control. They are purely Naval, and will be dealt with further on.

Electro-Contact mines are usually arranged in groups of four for economy of cable and time in laying out the mine-field.

Figures 1 and 2, Diagram B, illustrate methods of arrangement. The governing principle is that a ship should not be able to pass through the mined area without coming in contact with, or being within the influence of at least one mine. If the mines represented in Figures 1 and 2 be moved up into one line, as in Figure 3, it will be seen that a very small interval exists. By increasing the number of rows, so will the intervals decrease until the mines overlap and give a practically continuous line of explosives stretched across the track of a vessel. The actual distance apart ensures immunity from being affected by the explosion of a neighbouring mine.

The following table shows the distance from another mine within which a contact mine should not be placed, in order that the circuit closing arrangement within it may not be affected by the explosion of a neighbouring mine.

<table>
<thead>
<tr>
<th>Contact Mine</th>
<th>Safe Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 lb.</td>
<td>75 feet</td>
</tr>
<tr>
<td>100 lb.</td>
<td>100 feet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observation Mine</th>
<th>Safe Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 lb.</td>
<td>240 feet</td>
</tr>
<tr>
<td>500 lb.</td>
<td>300 feet</td>
</tr>
<tr>
<td>600 lb.</td>
<td>300 feet</td>
</tr>
</tbody>
</table>

From each mine a carefully insulated and protected wire connects, as shown in Figures 1 and 2, to a junction box; within this box, in a water-tight compartment, each wire is joined on to a fuse. From these fuses wires pass on to a point common to all four within the same compartment, and from this common point another similarly protected wire connects to another box, or direct to the shore. The fuse plays an important part in the electrical circuit; as a mine is exploded its corresponding fuse is fired, thus ensuring a disconnection or break in that particular branch circuit. The insulation of the other three cables is thus safeguarded.

It will be seen that one core in the 4-cored cable serves a group of four mines. It is along this single conductor that the testing and firing currents for each mine in the group pass. The number of mines in a group and the number of cores in the main cables may vary, but the typical arrangement shown is found for practical purposes to be the most satisfactory for electro-contact mines.

Electro Observation mines are usually arranged in groups of two, three, or four, seldom more. The mines in each group are laid out in one line and are exploded simultaneously. This class of mine is chiefly used for the defence of a channel or water area (as close as possible to shore consistent with the requirements of safe navigation) through which friendly vessels may pass safely over the submerged mines. This channel is usually known as "The Friendly Channel." Diagram C illustrates a typical arrangement of groups of two.
Diagram C.—Showing Lines of Mines arranged in Groups of Two.

The location of each group as it is laid out is carefully charted by an observer on shore, in order that he may, by means of a suitable instrument, judge when a ship is within easy range of that group. The Instrument is usually known as a “Position Finder.”

Diagram D.—Illustrating Theory of Position Finder.

Diagram D illustrates its principle. Its action depends on the fact that the surface of the water within its reach is sensibly a plane, so that, if the instrument is set at any height above the water and the telescope directed (by moving the slider and vertical rod) on some point (M) on the surface of the water, such as the water line of a ship or pile, a right-angled triangle (ASM) is formed, of which (SM) is the distance on plan from the observer to the point observed, and (AS) the height of the observer above the surface of the water. If
now in the diagram a horizontal line is drawn from the point (P), where the upper end of the slider is supporting the telescope arm, to the vertical axis of the instrument at (C), the triangle (APC) will be similar to the triangle (AMS). If also, the vertical rod and the horizontal arm be graduated to an identical scale (usually 1/250') and the actual distance (MS) be known, by setting the slider to this distance to scale and bringing the telescope to (M) by moving the vertical rod only, the height can be read off the vertical scale. Similarly, if the height is known, and the telescope set accordingly, the horizontal distance can be ascertained.

Further, if a plan to the same scale as the graduations on the instrument is fixed on the chart table so that the position of the instrument on the plan would come in the vertical axis of the instrument, the pointer on the slider will indicate on the plan the position of the point observed. In order to find the position on plan of an unknown point, it is necessary to first set the plan with reference to some known points. It is essential that the pointer (or pencil) shall be exactly in the true vertical plane, and that the distance of the pointer from the vertical axis shall be exactly equal to (PC).

The accuracy of observation depends on being able to adjust the height scale so that (AC) is an equal measure to scale of the altitude of the observer's eye above the level of the water at any moment. This may be done in two ways—

1. By Tide gauge.
2. By Datum marks.

The latter method is preferable. To allow for rise and fall of tide, the instruments must be set frequently by one or other of these methods, as will be evident from the diagram. The point (M) represents the position of an object 400 yards from the observer, when the tide level is (MS). Suppose the tide falls from (S) to (T), so that the point observed is now at (N), if the telescope is brought on the object by moving the pointer, the range of (N) would appear to be about 200 yards only. It is obvious that, to get a correct reading, the height scale should have been raised to (A'), the distance (AA') representing to scale the distance (ST) through which the tide has fallen.

The following table gives approximate destructive range of various mines:

<table>
<thead>
<tr>
<th>Charge</th>
<th>Serious Damage to Engines, Machinery, etc.</th>
<th>Serious Damage to Hull</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 lbs.</td>
<td>20 feet</td>
<td>Shortest distance to Ship's Side measured horizontally from a vertical through the Charge</td>
</tr>
<tr>
<td>500 lbs.</td>
<td>30 feet</td>
<td>Rather greater distances than 500 lbs.</td>
</tr>
<tr>
<td>600 lbs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It will be seen by reference to this table that a vessel of 40 ft. beam could not pass between two 500 lb. mines 100 ft. apart without being damaged by their explosion.

A reference to some details may now be desirable. The complete mine consists of a receptacle or case containing fixed within itself:

(a) The Bulk charge.
(b) Exploding or priming charge.
(c) Detonators.
(d) Arrangements for testing.
(e) Arrangements for firing.

Mine cases, usually of iron or steel, vary in form and size according to the use to be made of them. Ground mines—i.e., those resting on the bottom, are invariably cylindrical, while those floating or buoyant are usually spherical. In buoyant cases, allowance has, of course, to be made for flotation in fixing the size.

(a) The Bulk Charge.—This is securely fixed within the case, and usually consists of gun-cotton wetted with 20 per cent. water by weight. The weight of charge varies—e.g., in a contact mine it seldom exceeds 100 lbs. In an observation mine it is usually 250, 500 or 600 lbs. It is so placed in the case as to completely surround a cylinder, which contains the remaining parts. This cylinder has a flange, by means of which it is bolted on to the opening in the case, and so making there a water-tight...
joint. This cylinder is usually known as "The Apparatus." Into this apparatus, by a simple arrangement of washers fixed on their rubber covering, the wires to be used to convey the electric current pass. Diagram E shows a mine case with bulk charge and apparatus.

(b) The Priming Charge.—This is usually 4½ lbs. of dry gun-cotton, inserted into which are the two—

(c) Detonators, which are exploded from the shore. The detonator used is shown in section in Diagram F. The long shank is filled with Fulminate of Mercury. This is exploded by the ignition of a small quantity of powdered guncotton and gunpowder, caused by the heating of a short length of platinum wire.

Detonators are constructed with extreme care, and a variation of resistance between .3 and .35 ohms is permitted when under test.

Diagram F.

(d) Arrangements for Testing.—Provided water does not gain access to the apparatus or to the copper conductor of the electric cable joining it to the shore, all should be well. The usual method of determining the condition of affairs within the apparatus is to place in the circuit the coils of an electro-magnet, the vibration of a small armature centrally pivoted between the poles of which can be heard by the tester ashore with the aid of an ordinary telephone receiver. By using a weak current, all possibility of premature detonation is removed. The adjustment of this armature, so as to require the application of a definite electric pressure through the coils before it
will vibrate, enables the tester to detect any variations. The coils have a definite high resistance, usually 2000 ohms in a contact mine.

By adjusting the armatures in two mines of a group to vibrate when the testing current is flowing in one direction, and the other two when it is flowing in the opposite, it becomes possible without the introduction of anything further to test two at a time, while an expert tester is usually able to identify the vibrations of a particular armature. Before all the cables are joined on to the common point in the disconnecting junction box before referred to, each mine is separately tested, and its condition and any idiosyncrasies noted. The testing circuit being of high resistance, the possibility of premature explosion by the accidental application of a more powerful current than that for testing is safeguarded against.

4. e) ARRANGEMENTS FOR FIRING.—These essentially consist of means whereby an easier path than that provided by the testing circuit is introduced. In contact mines the blow of a vessel is utilised to cause a spindle or any other arrangement (V) to vibrate or move in such a way as to bring into use a circuit (F) other than the testing. This new circuit is called the firing circuit, and has comparatively no resistance. It practically short-circuits the high resistance testing circuit. The mine is then in a condition favourable for the explosion of its detonators. Diagram G shows the circuit from the shore passing through the detonators before it reaches the point where it divides (L).

In some apparatus an electro magnet with very low resistance coils is introduced in the firing circuit. When the mine is struck, the armature within its field is mechanically pulled within the influence of one of the poles, which holds it, while at the same time, it comes in contact with a point which completes the firing circuit. By reversing polarity, the condition prior to the striking of the mine is restored; in other words, by sending a weak current through the firing circuit, in the opposite direction to the testing or firing current, the polarity of the armature of the firing circuit is reversed. The armature is thus repelled from the position it was pulled into, and resumes its old position. The firing circuit is then broken, and in the condition existing prior to the mine being struck.

This is an advantage should, by any unforeseen means, a mine be struck accidentally by a friendly vessel; but there are disadvantages in that the possibility of derangement of mechanism by one blow may upset further calculations, etc., so it is now recognised that, if a friendly vessel is in the vicinity of the mine-field, its safety is sufficiently guarded by the disconnecting of the firing battery by the operator ashore. E.C. mines are therefore now made automatic—that is, so long as the firing battery or other means of exploding is
connected to the cable leading to a mine, that mine will fire itself when struck by a vessel. Mines are either active or inactive, as the firing battery is, or is not, connected up to the circuit.

Electro Observation mines, on the contrary, are devoid of any mechanism except in the last mine of a group. In this mine the usual arrangement is a polarised relay, with circuits arranged as in Diagram H. In the intermediate mines, there is no arrangement for testing their condition; but that is not required, as a fault in one of them would be indicated by the relay in the end mine. If the faults are serious, the whole lot would require to be picked up in any case.

From the mine let us now go along the cable to the shore, passing as we do the Disconnecting Junction Box, with its water-tight compartment in which the fuses are fixed. Again dealing first with contact mines: The wires from the various groups of mines are each brought into the carefully protected test and firing-room or station. In this room are the various instruments and batteries used for testing and firing. The principal amongst these is the shutter apparatus, which signals when a mine is struck, and at the same time closes the firing circuit so far as the mine is concerned. If the mine-field is active—that is, the firing battery previously connected on to the circuit—the mine would then have fired itself.

The shutter or signalling apparatus (Diagram G) is simply an arrangement by which a soft iron armature (Z) works between the poles of an electro magnet (YY). The action is this: A very weak current (about 1-30th of an ampere), from a small, constant battery is continually flowing out to a group of mines through the coils of this electro magnet. This current is striving to pull the armature towards the left hand pole; but, owing to the high resistance in the mine circuits, cannot draw it completely over; when, however, the mine is struck and the resistance reduced as previously described, the armature is pulled over, and the shutter (X) is allowed to drop between the forked contact point (F) on to the bell (W). This completes the firing circuit, shown dotted and leading towards the point (G). The application of the firing battery is then made possible. On the left of the diagram may be seen the resistance coils for measuring the resistance of the cables; etc., while on the left will be noticed a reversing battery, with its elements arranged in opposition to the firing and signalling batteries, so that when required it may be used to restore, as previously described, the condition of those apparatus fitted with the second armature.

In the case of electro-observation, the arrangements ashore provide for an observing instrument, the principle of which has already been dealt with. The wires from the various lines of mines are brought to, and fixed with suitable connections to metal contact discs. These discs are made to scale to represent the destructive area of the various lines or groups, and are fixed on the chart over the spot which corresponds to the destructive area on the watery plane below. Diagram H shows the circuit from the end mine of a line of three through the observing instrument to the signalling apparatus and firing battery.

Diagram G. — Electric Circuits in a Contact Mine and on Shore.
The methods of joining together the various parts, of conveying them to the sphere of operations, and of laying them out, involve no special principles. With the class of mines described, practically no danger exists in the handling. The mines, previously connected to their branch cables, are placed on the vessel, and by means of the booms and derricks on board, picked up from the deck and placed.
over the side, where they are slung, ready to be lowered into their allotted places. The branch cable is paid out from the steamer, and taken to a smaller boat in which the operation of completing the junction box is performed. These boxes with the cables going to the shore are laid out before the mines are. These smaller boats are known as “junction box boats.” An ordinary half-decked fishing boat is very suitable for the purpose. Telephonic communication is established between the test room and the junction box boat.

Laying Mines—Cable being taken to Junction Box Boat.

The wear and tear of weather and the action of salt water, not to mention the interest of commerce in times of peace, render it imperative that mine-fields be not kept laid down. But all stores must be in such a state of preparation and reliability that their effective use may be arranged at the shortest notice. Mine-fields would not be laid down unless the command of the sea had been lost, except at isolated stations.

Thus briefly have been reviewed the essential factors in Submarine Mining, as applied to Harbour Defence, but no paper on the subject of submarine mining would be complete without reference to the mechanical mines referred to as the third-class of mines.

Mechanical Mines have many advantages over those just described, such as economy of stores, cheapness, speed of laying out, etc., but against these advantages may be placed greater danger to lay out in most cases, and, when laid out, equal danger to friend and foe. Owing to their unreliability, their use for deliberate defence has been abandoned, and they have been relegated to the Navy for use in temporary cases, such as blockading, etc. Perfect mechanical mines should not only be sure in action, but should admit of being
laid down and removed in perfect safety, and should, if they get adrift, automatically render themselves harmless. Many devices have been tried, but so far perfection has not been realised. Methods of ignition by percussion, friction, chemical and electrical action have been tried with more or less success.

So far no information is available as to the means whereby the mines in use in the present war are exploded; but apparently they have shewn all the defects of the mechanical mines of the past. They have broken adrift, and gone floating about on the open sea. They have blown up friend and foe.

Their use by the Japanese at Port Arthur illustrates one of the first actions of a naval force—viz., an attempt to bottle up a fleet, while their use in Pigeon and Talienwan Bays by the Russians serves as an illustration of their application to coast defence as a means to deny certain waters to a hostile fleet where the area cannot be protected by guns from the shore.

In the case of the recent sortie from Port Arthur, when Admiral Togo succeeded in inflicting heavy damage to the Russian ships, another illustration of their use is afforded, when, in an endeavour to compel the Russian fleet to break or alter its formation of "Single Column Line Ahead," torpedo boats darted across the track of the "Czarevitch," laying down mines as they did so.

Before closing, I would refer, in a few words, to the destruction of mines. This is a simple enough operation, but with mechanical mines (as has been seen in the present war) is one fraught with danger. The mines themselves are usually located by creeping with light grapnels, or sweeping with wire ropes stretched between boats. Light boats of small draught are used. When a mine is located, another mine is placed alongside, and both are exploded. It is a slow and costly process, but the result obtained is more than compensatory.

There has been more than one instance of a vessel being destroyed while engaged in removing mines. So far no details are available; but, when the facts are before us, they will probably point to rashness or carelessness. Familiarity breeds contempt.

In conclusion: The future of submarine mining is an exceedingly interesting field for speculation. Even now we have before us the probability of controlling and directing with practical certainty electric energy without the use of conducting wires. It is not probable, however, that a submarine mine-field with its many mines separated from each other by irregular distances, or volumes of sea water, will be found amenable to wireless electric waves such as Nicola Tesla has succeeded in experimentally applying to the management of a submarine vessel.
Author/s: WILKINSON, RUSSELL

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