NOTES

ON

TORPEDOES, OFFENSIVE AND DEFENSIVE.

BY

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PREFACE.

The following pages on the subject of submarine mines have been compiled from the various papers which have been drawn up, and experiments which have been made during the last three or four years in the course of instruction carried on at the School of Military Engineering, Chatham. The object in view has been to put the officers and men instructed in possession of a hand-book, to which they may refer should they, at any future time, be called upon to put in practice what they have learned. The course of instruction has now been so far perfected, in conformity with certain principles deduced from practical trial, that the system taught might at any time be adopted for actual service, and as improvements are made, they may, from time to time, be introduced.

A great deal of valuable information has been derived from Captain Harding Steward's very interesting "Notes on Submarine Mines," which was perhaps the first practical work ever published on this subject. Lieutenant S. Anderson, R. E., assistant instructor in telegraphy and submarine mining, at Chatham, and Lieutenants O. Chadwick, H. Jekyll, J. T. Bucknill, R. F. Moore, and R. Y. Armstrong, R. E., who have been temporarily attached at various periods to the School of Submarine Mining, have been indefatigable in carrying on numerous experiments, with a view to perfecting our system, and to them a great deal of credit is due. Finally, we have had the benefit of the valuable series of experiments carried on, and of the information collected, by the floating obstruction committee, of which Lieutenant-Colonel Fisher, C. B., R. E., and F. Abel, esq., F. R. S., chemist to the war department, were members. These officers have, moreover, contributed personally much valuable information, of which, in carrying on the experiments of the above-mentioned committee, they had become possessed.

Captain W. Dawson, R. N., late secretary to the floating obstruction committee, has very kindly looked over Chapters XIV and XV, on "Clearing Channels of Submarine Mines" and "Locomotive Torpedoes," and Commander F. Harvey, R. N., has been good enough to furnish information for the description of his sea torpedo. Commander Harvey is about to publish a book giving a description of his torpedo, in which any further details concerning it will be found.

The use of submarine mines as military defensive agents has only recently acquired any importance, and progress toward the establishment of a definite system has led to considerable changes since the first of the papers, embodied in this hand-book, was written. It was never considered more than an *ad-interim* publication, and but a small number of copies have consequently been printed. It is now proposed to revise the whole, bringing it up to date, and to reprint it as soon as possible.

R. H. S.

CHATHAM, 31*st March*, 1871.

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For "moving," page 9, 14th line from bottom of page, read "mooring."
For "outworks cf," page 12, 2d line from top of page, read "outworks to."
For "de ense," page 12, margin, read "defense."
For "ha," page 13, 17th line from bottom of page, read "has."
For "ordinary," page 17, 6th line from bottom of page, read "extraordinary."
For "chanel," page 20, margin, read "channel."
For "kilograms," page 28, 8th line from bottom of page, read "kilogrammes."
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For "Figs. 6," page 52, 10th line from top of page, read "Fig. 6."
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After "not," page 112, 3d line from bottom of page, read "quite."
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For “Z,” in equation (12), page 261, read “z.”
For “page 215,” page 265, 21st line from bottom of page, read “page 216.”
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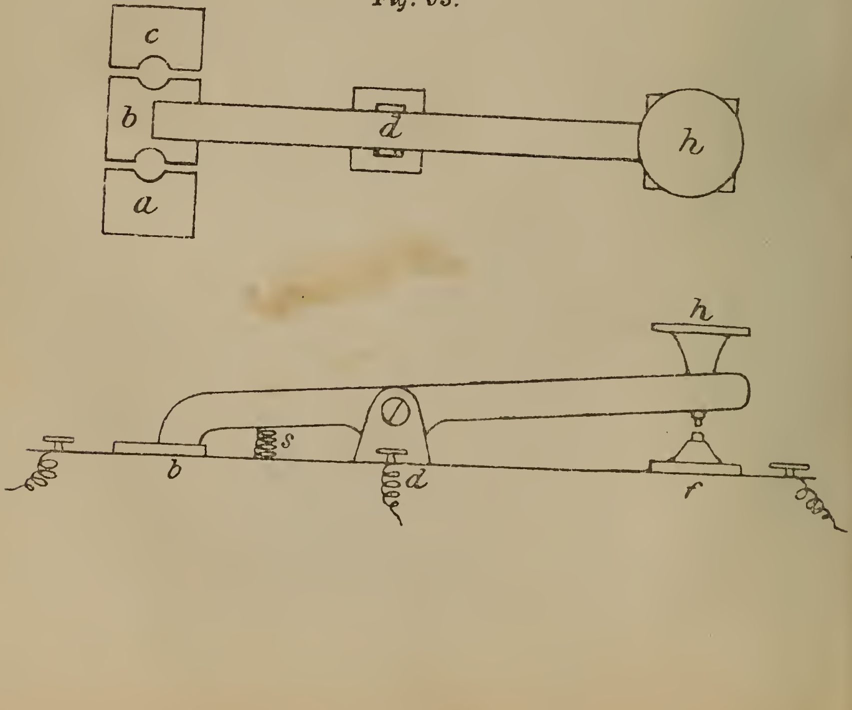
For “to all where,” page 269, 4th line from top of page, read “to all stations where.”
For “as far,” page 272, 18th line from bottom of page, read “so far.”
For “train mortars,” page 273, in marginal note, read “twin mortars.”
For “sluices,” page 291, 20th line from bottom of page, read “sluice.”
For “mushroom anchor,” page 303, margin, read “mushroom sinker.”
For “canvass,” page 289, 7th line from bottom of page, read “canvas.”
For Fig. 93, page 224, substitute cut:

Fig. 93.



CHAPTER I.

INTRODUCTORY.

The term torpedo has been hitherto applied, in a vague kind of way, to all the numerous contrivances which have, from time to time, been devised for producing submarine explosions calculated to act destructively against ships in their immediate vicinity. This term has been used whether these engines have been arranged defensively, the charge being ignited when a vessel is within range of their sphere of explosion, or whether offensively, that is, in a movable form for the attack of a vessel at anchor, or as a means of offense against a vessel in chase of a ship possessing the necessary apparatus, or under whatever circumstances they have been employed.

Definition of a submarine mine.

This term, "torpedo," does not seem applicable to defensive mines, or those which would be used to block up the channel of a river, or the approaches to a fortified sea-port, or in any other similar position; in fact, occupying a site analogous to that of a system of countermines in connection with a land fortress. In the following pages, therefore, I propose to call all contrivances of the above nature, used for defensive purposes, "submarine mines," leaving the term "torpedo" for all offensive combinations, to which it seems to be much more applicable.

Definition of a torpedo.

Under the comprehensive head of submarine mines is included a vast field for research, in which there is ample space for the development of inventive genius, in connection with the defense of fortified harbors, estuaries of rivers, and the coast generally, a most important subject in a military point of view, and which, affecting as it does the attack of such places from the sea, renders it a consideration of the utmost gravity. The introduction of machines of this nature in war cannot be overlooked with impunity by a great maritime power like Great Britain, possessing, as she does, numerous colonies and an immense commercial navy which, in addition to her own coasts, must be defended in the event of war; and as the employment of submarine mines seems to present such a considerable increase in defensive power, there is every reason to suppose that a judicious use of them would, on an emergency, prove of infinitely greater value to us than to a nation possessing less of the maritime element in its composition.

Chinese submarine mines.

Submarine mines have, from time to time, been used in warfare. A very curious Chinese illustrated description of a system of this nature was brought home very recently from that country. The method of ignition of the charges in this Chinese system appears to have been exclusively arranged for mechanical action. Similar contrivances were also used by the Russians in the defense of the Baltic during the Crimean war, without, however, any great amount of success. These seem also to have been designed for mechanical action, as regards the ignition of the charge; but though several of them were fired by contact with the vessels of the blockading fleets, the damage done was insignificant, the charges of powder used being comparatively small in amount. Again, in the recent civil war in the United States of America, submarine mines were extensively used both by the Federals and confederates, especially by the latter, with very much more decisive results. Several of the Federal vessels were sunk, and many were so seriously damaged as, for the time, to be placed *hors de combat.* An excellent description of the means employed during this war has been given by Captain Harding Steward, Royal Engineers, in his valuable pamphlet on submarine mines, which contains much information on the practical working of these machines and of the difficulties necessarily to be encountered therein. A very decided advance in submarine mining is evinced in the arrangements made during this war; the machines used by the Russians in the Baltic were simply allowed to drift, and were fired by mechanical means, thus rendering them equally dangerous to friend and foe, whereas here, we find the confederates mooring their charges in certain positions and firing them, not only by mechanical but, toward the end of the war, by electrical agency—a very decided step in advance, as, in this way, they could at will be rendered perfectly harmless to a friendly vessel, while their chance of acting destructively against an enemy was vastly increased. Another improvement noticeable is the increase in the amount of powder employed in each charge, regulated according to certain rules derived from experiment; the charges were, however, still insufficient.

Russian submarine mines.

Submarine mines, used in civil war in America.

Austrian submarine mines.

The results arrived at during this war were so decided, that the investigation of the subject of submarine mines has since become almost general among civilized nations; and we find them again used by the Austrians, for the defense of Venice, Pola, and the coasts of the Adriatic during their war against Prussia and Italy in 1866. I am not aware that any opportunity occurred of testing the efficiency of the system employed during this war, against an enemy's ship, but the whole was exhibited at Paris in 1867. An examination of this apparatus again shows an advance in the science of submarine mining, for, whereas in the confederate system, everything was to a certain extent tentative and hurriedly arranged, here we have working patterns of all the materials and apparatus on a certain system, and capable of being rendered available for any service required, by a simple reproduction of the number of articles necessary according to patterns which, after numerous experiments, had been decided on. The arrangement and construction of the equipment exhibited shows a considerable amount of ingenuity, and reflects much credit on the designer, Baron Von Ebner, of the Austrian Corps of Imperial Engineers.

Floating obstruction committee appointed.

In this country a committee was appointed, in 1863, to investigate this subject, in combination with that of passive obstructions, and their labors are now concluded. An immense number of experiments have been made under their supervision, with a view to the determination of the details of the apparatus, &c., best suited for the purpose; and many of these experiments have been carried on by the officers and men of the Royal Engineers, at Chatham.

Course of instruction at Chatham.

Instruction in the theory and practice of electricity and its application to the ignition of gunpowder and other explosive agents, for mining purposes, both on shore, under water, and also as required in connection with a system of submarine mine, has for some time been given in the School of Telegraphy, at Chatham. The subject is, however, of such vital importance that it has become necessary to extend the scale of instruction, from the small and make-shift way in which it has been taught, to such a system as would be required on actual service; and for this purpose a moving lighter and a certain number of boats, anchors of various kinds, cases to represent submarine mines, chains, cables, &c., together with batteries, circuit-closers, and other electrical gear have been provided, and with these the instruction is now carried on.

Offensive mines or torpedoes.

Submarine mines may be divided into two great classes, offensive and defensive. The first, the offensive class, which it is proposed to designate by the term "torpedo," hitherto popularly applied to all, falls more particularly to the province of the navy, though its use must not, on that account, be neglected by the military branch of the service. It includes every class of device designed for the active attack of vessels, whether arranged at the end of a spar or boom, in connection with a properly-fitted torpedo-boat, to be used in ramming an enemy's ship or to be carried on board ship and thrown out with a view of acting against a vessel in chase, and exploded by electricity or mechanically, when in actual contact with her, or to be used for the attack of a vessel at anchor. To this class also belong drifting torpedoes, or those propelled by any mechanical arrangement through the water, and of such a form as would be applicable for the attack of floating or other obstructions, or of ponton-bridges, &c. Instruction in such appliances is now regularly conducted on board Her Majesty's gunnery ships Excellent and Cambridge, and a very good practical book, in connection with this course, has been drawn up by Lieutenant Fisher, R. N., who has charge of this duty on board the former vessel. The men of the Royal Engineers should be thoroughly practiced in the use and handling of such contrivances, especially with reference to the attack of ponton-bridges; and it is necessary that they should be well practiced in the demolition, by torpedoes, as well as in the construction of booms and other passive obstructions. As yet, however, but little has been done in this respect, our attention and time having been chiefly devoted to the development of a system of defensive mines. A torpedo-boat has, however, been designed and is constantly used during the course of instruction given on board Her Majesty's ship Excellent.

To the naval branch of the service would seem chiefly to appertain the designing and practical use of the apparatus adapted for searching for and carrying off an enemy's mines, and the defense of vessels against mines of every class, whether stationary or drifting.

We now come to the second great class of these contrivances, viz, the defensive or the submarine mine proper, which I propose so to designate, in contradistinction to the torpedo or attacking implement, and especially the military engine.

Defensive mines, or submarine mines proper.

These seem applicable to almost any circumstances, and may be used with a very great advantage to the defense, in innumerable instances, from that of a first-class sea-coast fortress against a first-class fleet of iron-clads, to that of a fishing village against a small privateer. This assertion seems to be strongly borne out by the experience we have gained, from the perusal of the accounts of the naval operations, during the late civil war in the United States of America. During that war the iron-clad, and even wooden vessels of the Federal fleet, frequently silenced and ran past confederate shore batteries, the latter armed with numerous and well-served pieces of heavy caliber, rifled as well as smooth-bore. For example, Forts Jackson and St. Philip, defending the entrance to New Orleans, and mounting about 100 heavy guns, with the advantages of numerous shoals and a swift current, failed to stop a squadron of wooden ships, which ran past them after a few days' bombardment from their mortar-vessels. Again at Vicksburgh, after a short bombardment, the Federal fleet ran past the batteries commanding the river, with the loss of only a few men, subsequently passing down again with a similar result. On this occasion there were about 30 guns in the shore batteries against 40 on board the ships; some of the vessels were, however, iron-clads.

Again, at Fort Fisher, at the mouth of Cape Fear River, leading to Wilmington, the confederate guns were on two occasions silenced by those of the Federal iron-clad fleet. These are only a few of the numerous instances in which similar results were obtained—in fact the obstructions and submarine mines of the confederates gave much more trouble, and caused much more delay and damage to the Federal fleets, than the batteries. Witness the notable example of Charleston, where, though the guns of Fort Sumter were silenced over and over again, the vessels were kept out for months by the obstructions and submarine mines. Admiral David D. Porter, of the United States Navy, in his very able report on the defensive powers of coast-batteries, states: "The running past a battery is a very easy thing when there is a straight channel and sufficient depth of water; and there is no fort in any of the waters of the North that cannot be safely passed, and (in military phrase) the position turned; and no forts now built can keep out a large fleet, unless the channel is obstructed." And again, "Obstructions and torpedoes are a better defense than our present forts." Such is the deliberate opinion of a very able naval officer, given after an experience of three or four years in the attack of water batteries of every variety; and what has been done once may, no doubt, be done again. Though it cannot be said that shore-batteries may not be very much improved, and their defensive powers against shipping greatly increased, taking them gun for gun as against an attacking fleet, there seems to be sufficient *data* to show that the defensive power of the very best fort that can be built will be much increased by a judicious arrangement of obstructions or submarine mines, or a combination of both. If used in the defense of a first-class fortress, such as Portsmouth, for example, they should be so arranged as to be

Opinion of Admiral Porter, United States Navy.

Defense of a first-class fortress as Portsmouth.

covered by the guns of the forts and floating-batteries, so that while acting as outworks of these latter, they would be protected by them from disturbance by the boats of a hostile fleet.

De ense of a mercantile harbor, as Liverpool.

Another case, in which submarine mines could be effectively used, is that of a great mercantile harbor defended by forts carrying a few heavy guns, as Liverpool, for example. Here we have a few guns in position, which might be silenced by a sufficiently powerful hostile fleet; but if a judicious arrangement of submarine mines were added to these, placed in such a position as to be covered by the guns, and by those of such vessels of war as might be at hand, and, at the same time, advanced sufficiently far to prevent the guns of an enemy's vessels from reaching the shipping in the port, the position as regards the defense would be immensely improved.

In all cases, by a very simple arrangement, to be hereafter described, the channel could be made perfectly safe to friendly vessels, which could run in and out at pleasure, while it could at any moment be made instantly dangerous should an enemy attempt to follow.

Useful in an undefended harbor, as Belfast.

A third case, in which submarine mines could be used with advantage, is that of the estuary of a river leading to a mercantile harbor and not necessarily defended by forts of any sort, as for example Belfast. This important port is situated a considerable distance up an arm of the sea, on a river, and is, or used to be, so nearly undefended by guns that, for the sake of example, they need not be considered as an item in its defense. Under present circumstances Belfast would be open to the attack of a comparatively small fleet of hostile vessels, and its destruction would be a very serious blow in a commercial point of view. If a well-arranged system of submarine mines, however, were placed in the estuary of the river, with one or two gun-boats or a floating-battery, to prevent boats from searching for them, the place would be quite safe from any sudden attack, and would be capable of holding out against an enemy's squadron, with a fair prospect of success, till relieved. Here again the mines must be placed at such a distance as to keep hostile vessels where their fire would be ineffective against the shipping and town. Should no gun-boats or floating-batteries be at hand, a few guns in an earthwork, to cover the mines, would be advisable, but even without them a defense on this system might still be carried on, and it would only be necessary to put down a greater number of mines, so that one might occasionally be fired at a boat engaged in grappling for them, as a deterrent. As a rule they should not, however, be thrown away at small boats, but reserved for more worthy objects.

Another instance in which submarine mines might be advantageously employed, without any combination of protecting guns, is that of a harbor close upon the sea, which could be easily reached by an enemy's guns; such a place as Whitby, for example, which affords a port of considerable importance to the coasting and fishing trade. A few submarine mines laid 4,000 or 5,000 yards to seaward from this place would, by the fact of their existence, deter an enemy's vessels from approaching, as the advantage to be gained would not be worth the danger incurred, while a harbor of refuge would be secured to friendly ships. In such a position as this, it might not be practicable to use them at night or in a fog, unless some means were adopted for signaling the approach of an enemy.

Defense of small harbors, as Whitby.

Again, they might be used for the protection of such a place as Brighton, where no harbor exists, but which is quite open and assailable from the sea, and any attempt to defend which with guns could only end in its destruction by bombardment. In such a case a few submarine mines, placed at a distance of a few thousand yards to seaward, would exercise a salutary deterrent effect. These mines should also be rendered inactive at night or in a fog, to prevent accidents, unless some means of signaling were adopted.

Defense of town open to sea, as Brighton.

Another case in which they might be usefully employed, is that of a flat open beach, on which an invading force might be landed with facility, as, for example, Sandown Bay, in the Isle of Wight. At this point a strong fort ha been built in connection with the defenses of Portsmouth, to prevent such a contingency. A few submarine mines judiciously placed in such a position, and covered by the guns of the fort, would, I imagine, vastly increase the chance of a successful defense, and act as a deterrent against any attempt to land; and probably in many similar positions a smaller fort, only carrying a sufficient number of guns to protect the submarine mines, would answer the purpose.

Defense of a open beach.

One use to which submarine mines may be applied must not be forgotten; it is that by their means an inferior fleet has the power of placing an impassable barrier between itself and an enemy, reserving, however, the power of passing out when required, and of retreating to a strong position at any moment, should it be unable to cope with its adversaries. A fleet of merchant-vessels might also, so to speak, be similarly intrenched.

Protection of an inferior fleet

Defense by submarine mines specially applicable to Great Britain and Ireland and our colonies.

The above are a few of the cases in which it seems that submarine mines could be used with effect, and there are, no doubt, many others which might be enumerated, and even a cursory consideration of the advantages to be derived gives an impression of their importance, to a country with such a great length of coast as that of Great Britain, Ireland, and our colonies to be defended. They seem especially adapted for the defense of colonial ports, many of which, under present circumstances, would be at the mercy of a comparatively small squadron of an enemy's vessels, or even a single iron-clad, which could probably run past or silence the few guns defending them, and bombard or lay the port under contribution. The presence of a few well-placed submarine mines would, however, completely alter the state of affairs and render a different mode of attack necessary. There would then be no alternative but to begin the tedious and dangerous operation of clearing the channel, or to land and attempt to capture the place without the aid of the ships, in which latter case the defenders would stand a fair chance of success in dealing with the attacking force, which would then probably be acting at a disadvantage, or, at best, on equal terms only. Another point gained would be, that each port so defended would become a harbor of refuge into which a friendly vessel could pass freely, but which would be effectually barred against an enemy in pursuit. In case of war it would be no uncommon thing for a friendly vessel to be chased into one of our harbors, as, for example, Melbourne. In such a case a system of submarine mines would be invaluable. Finally, submarine mines may be used in combination with, or without, passive obstructions of every variety.

Moral effect considerable.

The experience of the late civil war in the United States teaches us that the moral effect of a system of defense by submarine mines would be very great. Men will face a known danger readily, but it is not so with a hidden one. The result, therefore, would be a considerable increase of caution in the mode of approach over places where submarine mines were supposed to be lodged, with a corresponding delay and loss of time in the attack, which, in many cases, would enable the defenders to hold out till relieved. Suppose, for example, such a place as Liverpool were attacked by an enemy's squadron, in its present state, protected as it is by a few moderately strong forts, past which iron-clad vessels might run without serious loss; it would be at the mercy of an enemy. If a judicious arrangement of submarine mines were, however, added to the present guns, the same squadron could not get in in this off-hand way, and would probably not think it worth while to incur any delay in attempting to force a passage, as, by the aid of the electric telegraph, it is more than probable that a strong relieving squadron would be off the port before many days had passed.

There is one very important consideration with reference to this question, viz, that the cost of a system of defense, by submarine mines, is comparatively trifling. A channel 1,000 yards wide might, in this way, be defended at an outlay not exceeding that incurred in the purchase of half a dozen heavy rifled guns, to say nothing of the ammunition required for a modern artillery armament, the cost of which is considerable, or of the works in which the guns are placed. Cost comparatively small.

Again, the materials required in the construction of the apparatus are all articles of commerce, easily procurable; the submarine cables, which would perhaps be the most difficult part of the equipment to obtain in out of the way places, may always be kept in store and laid down when required. And finally a system of defense, by submarine mines, can be worked by a comparatively small number of men. All these are important points in connection with a subject which seems capable of such universal application, especially when viewed with reference to the defense of our numerous and distant colonial possessions. Material easily obtainable.

The advantage to be derived from the use of submarine mines is a very considerable increase in defensive power. One important point is that of setting free our fleet to act at sea against that of an enemy; as a very much smaller naval force would be required for harbor defense, and it might consequently be concentrated and used to greater advantage in active operations. Another is the addition, to a very considerable extent, of the defensive powers of our coast batteries and fortresses; that addition being obtainable at a comparatively small cost and with a comparatively small number of specially trained men. A third is the acquisition of a power to defend places which have hitherto been deemed indefensible. A fourth is the power of converting every British harbor into a port of refuge, accessible at any moment to friendly vessels, but absolutely impassable to an enemy. Advantage; great increase in defensive power.

CHAPTER II.

GENERAL PRINCIPLES.

Nature of submarine mines.

We will now proceed to consider, in general terms, the nature of submarine mines. They may be briefly described as charges of gunpowder, gun-cotton, or other explosive agent, of various sizes up to 2,000 pounds of gunpowder, or its equivalent, inclosed in water-tight cases of iron or other material, and placed under water at such depths that, by their explosion, they may sink or seriously damage a vessel passing in their vicinity. They may be classed under two heads, viz: Mechanical, those which depend for the explosion of the charge on mechanical means, such as the simple percussion of a vessel coming in contact with them; and electrical, those which are fired by electrical agency, either by the vessel herself closing the circuit, or at will from the shore. The details of the arrangements in both these systems shall be considered hereafter.

Mechanical submarine mines.

The former class, or mechanical mines, are capable only of very limited use. When once placed in a channel it becomes equally impassable to friend and foe; they are therefore only applicable to certain cases, as, for example, where it becomes necessary to block up a channel completely, that is to say, to render it altogether impassable till the mines have been again removed; for instance, to inclose an enemy's fleet and thus limit its sphere of action, or under any similar circumstances. They might be employed on a flat beach, dry at low water, to cover the flanks of electrical mines defending the navigable channel; in such a case they could be placed in position or removed at low water in comparative security, and the number of electrical cables, &c., required might, by such an arrangement, be reduced. They would not be applicable to the formation of harbors of refuge, as previously alluded to, where merchant-ships could run in to avoid an enemy.

Disadvantages.

It would be absolutely necessary to make some arrangement so that they might be exploded at will, as the most effectual way of getting rid of them when it became necessary to clear the channel, as the process of removal in the ordinary way, by boats, would be far too dangerous an operation to undertake; in fact, it would be difficult, nay, almost impossible, to get men to do it.

They possess the advantages of being capable of being kept in store and made ready for use at short notice; they require no knowledge of electricity in their preparation and management; and they might be used in certain cases with advantage, where electrical submarine mines are not obtainable. Advantages.

Electrical submarine mines.

The second class of submarine mines are those to be fired by electrical agency. These admit of a very much larger field for their employment. They may be fired either at will, (the position of a vessel with regard to them being determined by the judgment of an observer, who himself completes the circuit, so that the charge may be exploded at the right moment,) or the vessel herself may be made to complete the circuit, causing a current to pass and fire the charge.

Disadvantages.

The disadvantages of electrical submarine mines, as compared with those fired by mechanical means, are the multiplicity of wires required, and the necessity of having a certain number of specially trained men; but as the number of such men would be comparatively small, this is not of so much importance.

Advantages.

The advantages of electrical submarine mines are, that they are always absolutely under the control of the observer in charge of them. By simply detaching the voltaic battery used to fire them, which may be done by the removal of a connecting-plug, they become perfectly harmless, and friendly vessels may pass over them with safety, which is not the case with those arranged for mechanical ignition. Again, they can be rendered active at a moment's notice, by simply inserting the plug connecting the voltaic battery.

A safeguard against a surprise.

One great advantage arising from the use of submarine mines is, that no vessel can pass through a channel, protected in this way, at night, or in a fog, without affording a means of indicating her presence, and thus they are a great safeguard against an attack by surprise. In this respect the electrical system has a very great advantage; mechanical mines would no doubt act and be fired when struck, but the electrical need not necessarily be fired, and are capable of being arranged, in a very simple manner, so that without being ignited, they may indicate that a vessel has passed over the charge. Except in ordinary cases, it would not be advisable to throw away a mine in damaging or sinking a small boat, as a gap would thus be made in the line, giving a safe passage to more formidable vessels; taking this into consideration, therefore, there is again an advantage in favor of the electrical system, for the mechanical submarine mine must act, whatever be the size of the vessel striking it, whereas the electrical one may be reserved at pleasure for an object worthy of the expenditure of the charge.

Fresh mines can be added.

Another advantage of the electrical system is, that when a charge has been fired, or become ineffective from any cause, another can be laid down in its place, and the gap thus formed in the line made good, unless an enemy is in such a position as to be able to prevent it. To perform such an operation with safety, it would only be necessary to render the neighboring mines for the time being inactive, so that a boat might pass over them in safety to the point required. Should a break occur in the mechanical system, by the ignition or destruction of a charge, there it must remain; for it would be impossible to get men to risk the chances of being blown up in replacing it by another, and even if volunteers for such a dangerous service could be procured, the chance of creating a greater opening by the accidental explosion of other charges would be so considerable that it would not be prudent to attempt it.

Can be tested electrically.

Perhaps the most important advantage of the electrical system is the power of testing electrically, without going near it, the condition of each separate charge, at any moment after submersion, and of ascertaining, with almost absolute certainty, whether it can be fired or not. If in the electrical system the charges were grappled by an enemy and carried away, the disconnection of any particular charge or charges would be indicated, and the removal of such charge or charges would be at once made known to the defenders by the electrical tests employed. No such power exists in connection with the mechanical system.

Can be raised for examination.

Again, in the electrical system a charge may be taken up at any time for examination with perfect safety, whereas it would be very dangerous to attempt such an operation in the mechanical system.

Captain Steward's improvements in mechanical mines.

In making these remarks, with reference to the disadvantages of mechanical submarine mines, it must not be forgotten that some very important improvements in their construction have recently been suggested by Captain Harding Steward, Royal Engineers, which would make them very much safer to handle and even to raise after submersion, but even with the additions proposed by him, they would not be capable of being as easily and safely manipulated as mines on the electrical system. Captain Harding Steward's system shall be explained in detail hereafter.

Danger in submerging mechanical mines.

During the recent war with Russia many of their infernal machines, as they were called, failed to explode on contact with the vessels of the blockading squadron; this is accounted for by the fact that the men employed to place them in the water were afraid to remove the guards and contrivances arranged to make them safe to handle. This was found to be the case in some of the torpedoes picked up by the boats of the blockading squadron, and with such very dangerous machines it would no doubt occasionally occur. Captain Harding Steward's suggestions would in a great measure obviate the chance of such an occurrence, by reducing the danger to be incurred during the process of submersion very materially.

We will now proceed to consider the positions and arrangements by which submarine mines may most advantageously be made to offer the greatest possible obstacle to the advance of an enemy's vessels.

Project for the defense of Venice by submarine mines and passive obstructions.

In an Austrian work, somewhat corresponding to the Corps Papers of the Royal Engineers, entitled "Mittheilungen über Gegenstände der Ingenieur- und Kriegs-Wissenschaften, herausgegeben vom kaiserlich-königlichen Génie-Comité, Jahrgang, 1867," the following description is given of the method proposed for fortifying the entrance to the port of Venice during the war in 1866, (which arrangement was not, however, carried out.) Three booms, or passive obstructions, were proposed; the outer one, that next to the enemy, to be of light construction, the inner two to be as strong as they could possibly be made; between the two heavy booms a double row, in echelon, of submarine mines, to be fired by the contact of a vessel, were to have been placed, and inside the inner heavy boom what are termed "mines of observation" were to have been arranged; these latter were designed to have been fired at will, and were intended to come into play had any vessel of the enemy's fleet succeeded in passing through the obstructions above described. The light outside boom was probably intended as a protection against drifting torpedoes or ship's boats, which might be sent to attempt to damage the heavier booms and render them less resistant to the passage of large vessels. The whole was covered by the fire of the guns of the place.

Von Scheliha's observations on obstructions and submarine mines.

Count Von Scheliha, of the engineers of the late Confederate States, gives in his Treatise on Coast Defense, published in 1868, an account of several forms of submarine mines and torpedoes used during the late war, and of their effect in certain cases. He is of opinion that submarine mines alone are not a sufficient obstruction against an attacking fleet; that they should always be combined with passive obstructions of the heaviest character possible, and be well covered by guns, to prevent a search being made for them by an enemy.

To close a chanel completely.

In shallow waters he proposes to use passive obstructions of the heaviest nature, resting on the ground. When the water is of such a depth as to preclude the use of passive obstructions resting on the bottom, except at an enormous outlay of time, money, materials, and labor, he proposes to use very heavy floating obstructions securely moored; and he would use his submarine mines for places where, in consequence of the depth of water or the strength of the current, ground or floating obstructions would be either very difficult to make and keep in position, or would be altogether impracticable.

To preserve a free and yet defensible passage.

Where a free channel is required, which may, however, be closed at will against an enemy, he proposes to use electricity as the exploding agent.

Von Scheliha's experience chiefly gained with mechanical mines.

His experience has been gained chiefly with self-acting mechanical torpedoes, and he gives much interesting information on their construction, and advantages, and defects, under various circumstances. Electrical exploding arrangements were not much used by the confederates during the war, but they used mechanical self-acting mines very extensively, both on shore in covering defensive works, and under water for attacking as well as defensive purposes. Since his book was written electrical and other improvements have been made in the construction and arrangement of submarine mines, and in their present form there is no doubt they may be used with advantage in many places, without any combination of passive obstructions. These latter would no doubt prove most useful in rivers and narrow channels, where the force of the current and other conditions may be favorable to their employment, but there are many places, an open roadstead such as Spithead, for example, where it would be extremely difficult, if not impossible, to employ passive obstructions, but where there is every probability that submarine mines could be effectively used.

General rules.

The following general rules must be borne in mind with reference to any system of submarine mines.

1st. They may be used in combination with floating and grounded obstructions, or without them.

2d. They should be placed in such positions that their explosions shall not injure any passive obstructions combined with them, or destroy the electric cables of adjoining mines.

3d. At least two, and, where practicable, more rows of mines should be arranged in echelon across a channel to be defended.

In deep water it is more necessary to employ several lines of mines than in shallow, because in the latter case a vessel sunk by a mine would herself offer an impediment to others following, but in deep water the explosion of a mine leaves a gap, through which there is a safe passage, as far as the line of mines in which it occurs is concerned.

4th. As a general rule submarine mines should be placed in the channels through which large vessels only can pass; the shallower portions being, in all cases where such a course is practicable, rendered impassable by passive obstructions resting on the bottom.

5th. Submarine mines should be placed in the narrowest parts of a channel. The advantages of such positions are evident, as a smaller number would answer the purpose.

6th. Where the depth of water and other circumstances admit of it, a submarine mine should always rest on the bottom; under such circumstances all complications originating in mooring arrangements are avoided; its position is more easily defined, and it is not so easily displaced by accident, or discovered and destroyed by an enemy.

7th. No indication of their position should be allowed to appear on the surface of the water. Under certain conditions it may be impracticable to conceal them altogether, as, for example, where there is a large fall of the tide; under such circumstances the smallest possible indication of their position must be allowed.

8th. Where, from the depth of the water, the charges cannot be placed on the bottom, they should be so moored as to float from 15 to 40 feet below the surface. In places where there is a considerable rise and fall of the tide, special arrangements would be necessary.

9th. The place in which the voltaic batteries and instruments, connected with the ignition of electrical submarine mines, are arranged, should be in those portions of the defensive works which are likely to be held longest, so that a command may be kept over the mines to the latest possible moment in the defense.

10th. Great care should be taken to lay the electric cables in such positions as to render their discovery by an enemy as difficult as possible. The confederates used many devices to conceal the conducting wires of their mines, and among others, that of carrying them in by circuitous routes and burying them under ground, to discover which, the

Federals dug trenches across the courses which they would be most likely to take.

11th. The position of the mines should be well covered by the fire of the guns of the forts or floating batteries of the place to be defended, to prevent their disturbance by boats.

12th. Submarine mines should not be thrown away by firing at small boats, except under very exceptional circumstances, but should be reserved for larger vessels.

General principles of defense of a channel.

The object to be attained, in arranging any system of mines for the defense of a channel, is to place them in such a position that a vessel in passing along that channel must, at some one moment, whatever course she may take, be in such a position as to come within the radius of destructive effect of one of the mines during her progress. In order to attain this end it would only seem necessary to place the mines so that the circles described by their radii of destructive effect may at least touch each other. Theoretically this is no doubt the case, but practically such a system presents difficulties which would prevent its being worked out, and moreover has certain disadvantages inseparably connected with it. Among the practical difficulties is the danger of entanglement between the mooring cables of adjacent mines or their circuit-closers, especially when there is any rise or fall of the tide; when mines are very close to each other it is practically impossible to prevent entanglements of this nature, even with the most perfect mooring arrangements. Again, when mines are very close to each other, the explosion of one is very likely to injure its neighbors, or, where an electrical system of explosion is adopted, to disturb the circuit-closers, electrical cables, &c., connected with them. And the difficulty of paying out the electrical cables and arranging the gear in connection therewith, as well as the grappling for and raising a mine for examination, is much increased by this very close and precise formation. In fact, a certain amount of latitude, so to speak, is absolutely necessary in order to simplify the operation of mooring.

Disadvantages of a single line.

Among the positive disadvantages of such an arrangement is the fact that if a breach were once made in such a line, that breach would, till repaired, afford a safe passage to an enemy's ship. Again, an enemy having once ascertained the position of such a line, could easily define the limits of the area of danger, and take the necessary measures to avoid it. These disadvantages may be overcome by spreading the mines over a certain area, so that while reducing the difficulties of placing in position and preserving for the defenders a certain formation, which secures to them the power of identification with the more precise information and delicate instruments within their reach, the difficulties to an enemy of obtaining a definite knowledge of the area defended may be proportionally increased.

The simplest method in which a system of mines can be arranged for the defense of a channel, is shown in Fig. 1, which also illustrates the general principles on which they Simple distribution of mines for defense of a channel.

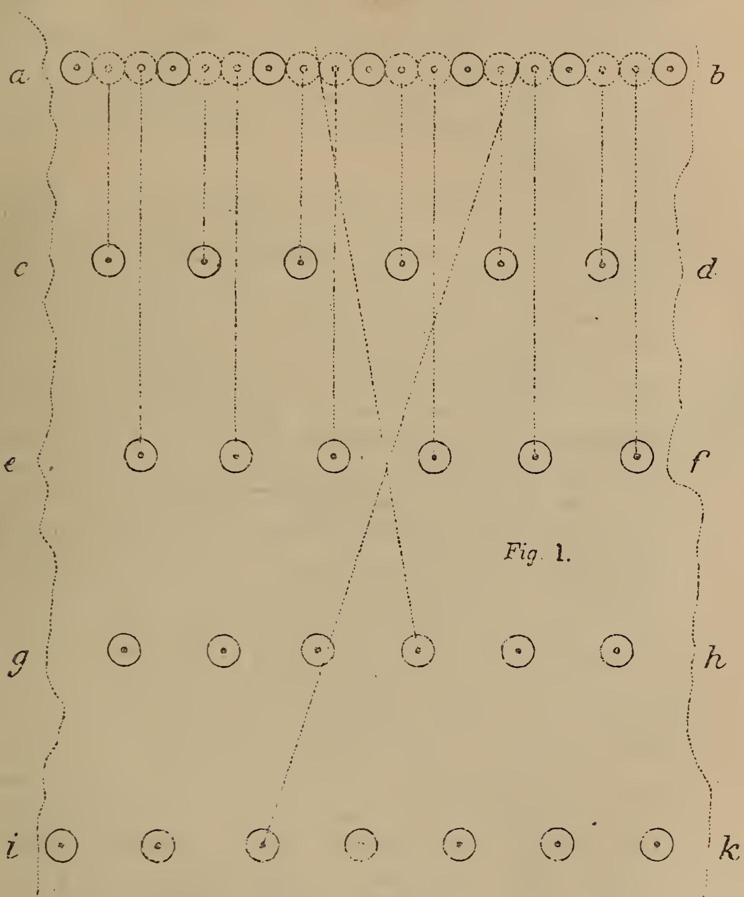


Fig. 1.

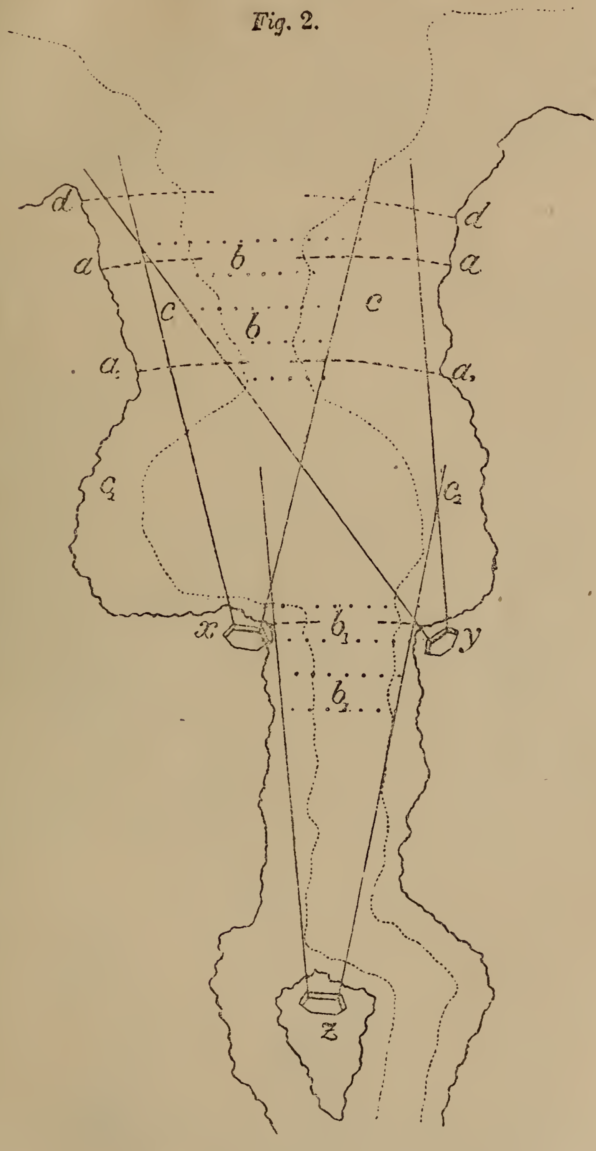
should be arranged in all cases. In this figure *a b* represents the theoretical line required to defend the channel, and it is only necessary to move every second mine back to the line *c d*, and every third to the line *e f*, to secure the objects required. A fourth line *g h*, or even a fifth, *i k*, may be added with advantage, taking care that these last shall cover the intervals left between those in advance of them, in such a way that a vessel passing in obliquely through the intervals of the first three lines, may come in contact with a mine in the fourth or fifth. An arrangement in lines is convenient, as giving the greatest facilities for firing at will by the method of cross-bearings, or for finding the position of a mine in the event of its becoming necessary to raise it for examination. If the lines are so placed as all to converge on a single distant point, say half a mile or more distant, the combination is much simplified, while the actual position of each mine is thereby so little altered that it may without difficulty be made to fulfill all the necessary conditions. The rules regulating the intervals to be left between adjacent charges in a line of mines as well as between the lines themselves shall be discussed hereafter.

Let us now suppose a case in which it would, from the depth of water, strength of currents and other conditions, be practicable and desirable to institute a combined system of defense by passive obstructions and submarine mines, as, for example, an estuary of a river, such as that represented in Fig. 2, defended by three batteries, *x*, *y*, and *z*.

Defense of a channel by a combination of submarine mines and passive obstructions.

The most eligible points, which would be those where the channel is narrowest, or bends where facilities exist for enfilading the lines of obstructions by guns, and which would offer advantages for fixing the positions of the submerged mines very accurately by intersections, or cross-bearings as they are sometimes called, and other places offering local advantages, having been selected, grounded obstructions and booms might be formed, as in the positions $a\ a$, $a_1\ a_1$, in which openings are left in the ship-channel, to allow of free ingress and egress. Across these openings it would be necessary to place several lines of submarine mines, $b\ b$, $b_1\ b_1$, arranged to be fired by electricity, extending so far on each side of the deep or ship channel as completely to cover it, and well protected by the fire of the forts *x*, *y*, *z*, and a light boom, *d d*, might be advantageously placed in advance, to cover the whole system from an attack by drifting torpedoes or boats. The spaces $c\ c$, $c_1\ c_1$ are supposed to be covered by a few feet of water only, and it is assumed that they would be sufficiently protected by the fire of the forts, and by guard-boats provided with proper apparatus for day and night signaling; no mines are therefore proposed in connection with them. The whole of the electrical cables in connection with the mines should be carried into the safest available position, if possible into the fort *z*: but if this is not practicable, those of the outer group *b b* might be carried into either of the forts *x* or *y*, and those of the inner group $b_1\ b_1$ into the fort *z*. The necessity for placing the electrical-room, that into which the electrical cables of any system of submarine mines are carried, in a safe place is very great; on it depends the efficiency of the whole. It would not do to carry the electric cables of the group b_1 b_1 into either of

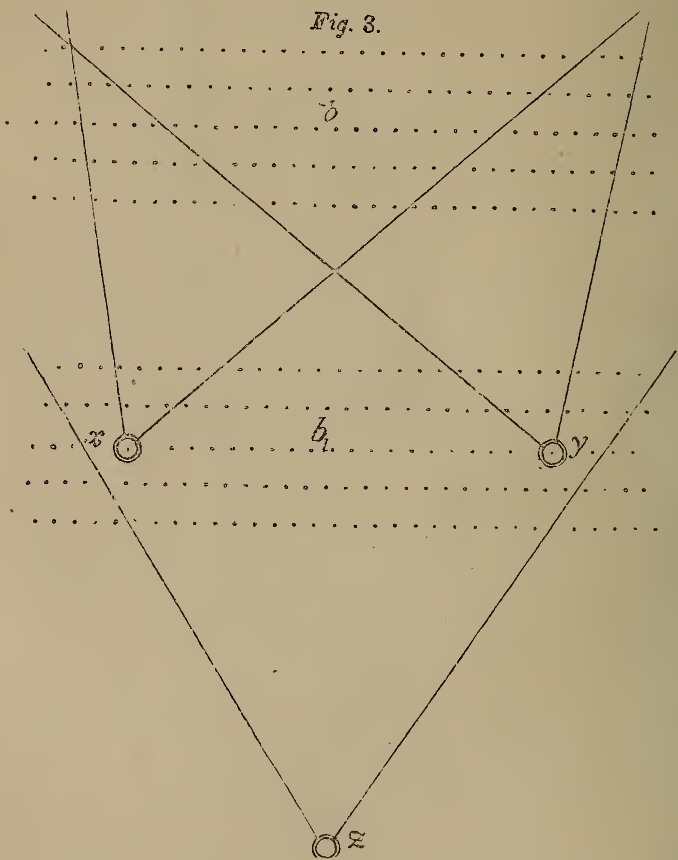
Fig. 2.



the forts *x* or *y*, however conveniently they may be situated as regards the distance. They should be carried into the fort *z*, so that in the event of the forts *x* and *y* being lost, the space between them, covered by the group of mines, would still remain as impassable as ever to the attacking ships. The electric cables in connection with the advanced line of mines *b b* might perhaps be carried into the forts *x* and *y*, if the distance were two great to admit of their being carried into the fort *z*; but those of the group b_1 b_1 should most certainly be carried into the fort *z*. Fig. 3 represents another case, as, for example, an open roadstead, protected by forts in which no passive obstructions of any sort could be used, but where the depth of water is not too great to admit of the employment of buoyant submarine mines. More mines would be required under such conditions, and

Defense of an open roadstead without passive obstructions.

Fig. 3.



they might be arranged as shown in the sketch, the same general rules being observed as to the situation of the electrical-rooms from which the whole system is governed; that is to say, the cables in connection with the group *b* should be carried into either of the forts *x* or *y*, and those of the group b_1 into the fort *z*.

So much depends upon local circumstances, such as the nature of the channel or roadstead to be defended, the probable means of attack at the disposal of an enemy, the draught of water of the vessels of a hostile fleet, &c., that a great deal must be left to the discretion of the officer commanding the defense, and the above must not be considered as stereotyped plans which should never be departed from. They are only intended to convey a general idea of the arrangements necessary to meet the objects in view, which would require much modification to suit the specialties of any particular case.

CHAPTER III.

EXPLOSIVES.

We now come to the consideration of the nature of the explosive agent with which a submarine mine can be most effectively charged.

Explosive agents.

Several substances have been suggested for this purpose, including gunpowder, (of large and fine grain,) compressed gun-cotton, (fired with an ordinary and with a detonating fuse,) nitro-glycerine, dynamite and glyoxyline, (a new explosive material, a combination of gun-cotton and nitro-glycerine, recently invented by F. Abel, esq., F. R. S., war department chemist.)

Gunpowder.

Gunpowder is probably the oldest and best known explosive agent that we possess. Its effects when fired in earth, rock, and masonry have been determined with great accuracy, but we still have much to learn concerning it, when the surrounding substance is water. During the late civil war in America the confederates gave the preference to fine-grain or rifle-powder, under the supposition that it produced a better result for submarine purposes. An experiment, tried in a well in Pennsylvania, seems to bear out this idea. Captain Harding Steward, in his notes on submarine mines, gives the following description of the result obtained on that occasion: "50 pounds of rifle-powder sent up a column of water 250 feet high, while, with the same charge of coarse-grain powder, a column of similar thickness was only driven 70 feet high, and the water was very much discolored, proving the non-ignition of part of the charge."

The French seem to have got hold of the same idea, for, in some experiments recently carried on, they have been trying several varieties of gunpowder, especially manufactured with a view to obtain more rapid ignition.

The Austrians have adopted fine-grain powder, in charges of 168 kilograms, or 369.6 pounds, in some of their most improved forms of apparatus.

A strong case essential when gunpowder is used.

It is probable, however, that when gunpowder is used, the strength of case is of more importance than the consideration as to whether coarse or fine-grain powder should be employed. A case of sufficient strength to secure a proper development of the explosive force of the charge, would be likely to produce a greater increase in that force than would result from a change in the form of powder of which the charge is composed. The experiments made by the floating-obstruction committee seem to prove this to be the fact.

As regards compressed gun-cotton we are somewhat in the dark; but a great number of experiments have been recently made with this substance, fired with an ordinary as well as with a detonating fuse, which throw much light on the subject, and from which its effects, as compared with those of proportionate charges of gunpowder, have been approximately determined. Compressed gun-cotton.

The results obtained from these seem to show a superiority, under certain conditions, for gun-cotton over gunpowder for submarine work; its ignition, at all times more rapid than that of gunpowder, is, when fired with a detonating fuse, immensely quickened, and the damaging effect of its explosion is much increased, both of which properties are in its favor.*

It is to be remarked that the Austrians, who originally used gun-cotton in their submarine mines, appear to have given it up, in consequence of the difficulty they experienced in manufacturing it of uniform strength, and the danger of spontaneous explosion. Mr. Abel's process of making it in a pulp seems to get over these difficulties. He has identified himself with the advancement of the gun-cotton question, and great credit is due to him for the light he has thrown upon that question by long and patient experimental research. Still greater credit is due to him for having discovered and perfected a method of treating gun-cotton, whereby it is rendered non-explosive when burned in the air, but in which the full energy is developed when fired in a close chamber, or with a detonating fuse. The method consists in reducing the gun-cotton fiber to a fine state of division or pulp, as in the process of paper-making, and in converting this pulp into solid masses, of any suitable form or density, under a pressure of 18 tons to the square inch. Abel's improvements in the manufacture of gun-cotton.

* Mr. Abel, who has investigated the action of detonating fuses in developing the explosive power of nitro-glycerine and gun-cotton, states that gunpowder, or any other explosive agent, may be made to exert its full explosive force when only confined in a weak case, or bag, or even when exposed to the air, by being fired through the agency of a sudden and sharp concussion, such as that produced by the explosion of a confined charge of fulminate of mercury. He states that the explosion of powder, by means of a detonating fuse, is decidedly sharper or more rapid than that produced by firing it in a strong receptacle in the ordinary way. Some recent experiments have indicated that more work can be got out of a combined charge of powder by this means than by its explosion in the ordinary manner, under corresponding circumstances.

This method of manufacture is now carried out by Messrs. Prentice, at their works at Stowmarket. To the pulping is mainly due the safety attained, as it insures uniformity in washing, whereby the cotton is thoroughly freed from all acid, and thus every chance of spontaneous combustion is removed. The compression causes combustion to proceed slowly in the open air, owing to the condensed condition of the fibers, which, in the loose state of cotton or rope, burn very rapidly. The gun-cotton is compressed into cylindrical or any other convenient forms, and a density equal to that of powder is given to it, whereby its portability and the explosive force of a given volume are greatly increased. The principle of thus combining safety with force, in a highly condensed form, has produced very valuable results.

Before any definite opinion can, however, be pronounced on this substance as an explosive agent, it is necessary to try some further experiments with large charges. The effect of compressed gun-cotton, fired with a detonating fuse, is marvelous. The power possessed by a detonation of developing suddenly the full explosive force of gun-cotton was discovered by Mr. Brown, of the chemical department, Woolwich; and several forms of detonating fuses, to be fired either by electrical agency or by means of Bickford's fuse, have been constructed by Messrs. Abel & Brown. The electric detonator is a modification of Abel's fuse, a charge of fulminate of mercury being substituted for the powder priming, and the wooden fuse-case being strengthened by an outer tin case, which assists in developing the detonating power of the fulminator. The following summary of the result of some experiments carried on with it and with glyoxyline, under the auspices of the royal engineer committee, at Chatham, on the 6th August, 1868, give an idea of the effect produced:

Experiments with gun-cotton and glyoxyline, fired with a detonating fuse.

Experiments were first made to show that neither of these substances, compressed gun-cotton and glyoxyline, will explode when unconfined and merely fired with an ordinary fuse, either time or electric, but that they require a detonating fuse to explode them under such conditions.

These experiments were most successful; the gun-cotton when ignited with the ordinary fuse only burning, and the glyoxyline being simply blown about without ignition. When the detonating fuse was used, the charges being still unconfined, both substances exploded with great violence, disintegrating the pieces of wood on which they were placed. Five charges were fired successively against a stockade, formed of 1 foot 2 inches square timbers, placed close together and firmly planted in the ground. The piles were chiefly of pine, except those specified to the contrary. The following is the result:

1st. Five pounds of glyoxyline hung in a bag about two feet from the ground. This blew in a hole about one foot in diameter, resembling the effect that would have been produced if a round shot had passed through. Half the timber above the point of explosion was also carried away

2d. Ten pounds of glyoxyline hung in a bag about two feet above the ground. This produces just double the effect of five pounds, the whole of the timber above the point of suspension being carried away.

3d. Ten pounds of compressed gun-cotton laid along the foot of three piles. This cut a clean gap through two whole piles and half the third.

4th. Ten pounds of glyoxyline laid in a train against three timbers, two of oak and one of pine. This cut through all three.

5th. Five pounds ten ounces of glyoxyline and five pounds of compressed gun-cotton. Each charge laid along the ground against three and a half piles, and consequently covering a space of seven piles altogether. The piles were cut half through, with the exception of one which was split completely through, though not severed. The line cut was three or four inches wide.

Experiment against counter-scarp of Saint Mary's front.

A plank being lowered over the counter-scarp of St. Mary's front, to a depth of 10 feet, the total height being 18 feet, the following charges were placed on it: 20 pounds of glyoxyline were laid along 3 feet of plank, and 20 pounds of gun-cotton along 3 feet more by its side. The explosion was extremely sharp, and a partial breach of the following dimensions was formed: 7 feet high, 11 feet wide, and 20 inches in depth. The brick-work was very much shaken for some feet on either side of breach, and pulverized for some inches more in depth.

Result of experiments.

From these experiments it is probable that these substances may prove exceedingly valuable for making breaches in timber and masonry, when portability and rapidity of action is required, as, for example, to breach a stockade or form a lodgment in the revetment of a work. Tamping may be dispensed with, which is a great advantage; but it must be borne in mind that, in order to produce a maximum of effect, absolute contact with the object to be destroyed is necessary, and for this purpose it would be convenient to prepare the charges beforehand, by placing them in bags or tin cases of suitable form, generally cylindrical and very long as compared to their diameter, so as to cover any space required.

Some further experiments were tried on the 5th September, 1868, against the same stockade. The breaches formerly made had been repaired, but certain alterations were introduced in its construction, viz, no earth was raised against the outside, the ground being level there; this earth was moved inside, and, together with blocks of granite, iron guns, and railway iron, was used to strut up the timbers and strengthen the stockade in the interior.

1st. Five pounds of compressed gun-cotton in disks were laid on the ground outside, against one of the logs, (of fir,) forming the stockade. This log was 13 inches square, and was strengthened behind by a block of granite, weighing 9 cwt., and earth. It was also secured to the adjoining logs by a ribbon with 7-inch nails. This charge, fired with a detonating fuse, cut through three-fourths of the log at the foot and forced the block of granite behind 1 foot 6 inches to the rear.

It was the opinion by those present that the ribbon alone prevented the log from falling.

2d. Seven and a half pounds of gun-cotton were now tried under similar circumstances, as in the first experiment, against a log of fir, 14 inches square. This log was only strengthened behind with earth 3 feet 6 inches high by 4 feet at base. The log was cut through and fell forward, the cut end being buried in the earth behind.

3d. Seven and a half pounds of gun-cotton were placed equally on both sides of a corner log (of fir, 15 inches square) of the stockade. This log was powerfully supported on the other two sides by those adjacent to it, forming the stockade. It was cut clean through and the bottom driven out 3 feet, the log leaning in this position against the others.

4th. Seven and a half pounds of glyoxyline were placed loose on the ground against one log of fir 13 inches square, supported behind by small blocks of granite and earth 3 feet high by 4 feet at base. The log was cut completely through but remained standing, the top leaning forward about 2 feet beyond those adjacent to it. The effects of this glyoxyline charge were not so local as those of gun-cotton. With gun-cotton the adjacent logs were not touched; with this charge of glyoxyline, however, the two adjoining logs were much splintered. This difference of effect, between gun-cotton and glyxoxline, was probably due to the different manner in which the two materials were piled against the logs. The cotton, being in disks, was packed close up against the logs. The glyoxyline, being in pellets, was piled loosely against the logs, and therefore the center of gravity was not so close to the logs as in the case of the gun-cotton. It also fell over a little againt the adjoining logs.

5th. A tin cylinder, 3½ inches in diameter, and 3 feet 6 inches long, was loaded with 10 pounds of gun-cotton in disks, which, to lengthen the charge, were separated by ½-inch milled board. The cylinder was laid against three fir-wood logs, 14 inches square each, and which were supported behind by two 18-pounder iron guns and two pieces of railway iron, besides being secured to another by ribbons of wood and iron dogs. This charge was fired with a Bickford's fuse, at the end of which was a detonating arrangement. The explosion, which was very violent, overthrew the two left-hand logs, which fell forward, and very nearly severed the right one at the base, which, however, remained standing, being prevented from falling by the ribbons and dogs securing it to the adjoining logs.

This concluded the experiments against the stockade.

6th. The gun-cotton disks were now tried against some palisades near the stockade. Four disks, weighing 4 ounces each, were placed one under each of four adjacent palisades, their edges being 9½ inches apart. One of the outer disks was then fired, in order to see whether the explosion would ignite those adjoining it. This did not occur; only one was exploded, which cut the palisade against which it was placed clean off level with the ground, but hardly even disturbed the adjoining disks.

Experiments on beams of timber with gun-cotton and detonating fuse.

In order to test the effects of these explosives on beams of timber, some experiments were made on a wooden staging in the ditch, to the west of St. Mary's horn-work. The timber was of fir, but very old and full of shakes.

One of the beams, 10 inches square, composing the staging, was bored with a vertical hole 1½ inches in diameter, into which 2 ounces of gun-cotton was put. This charge completely severed the beam and split it, in several places, to a distance of 3 or 4 feet from the charge.

One ounce of gun-cotton was now tried under similar circumstances. This shattered the beam considerably, and split it so that it could be seen through, but did not sever it.

Large splinters of wood were thrown by these explosions to distances of as much as 20 yards.

Experiment on block of granite with gun-cotton and detonating fuse.

A single disk of gun-cotton, weighing 1 pound 2 ounces, was now placed on the top of a block of granite 3 feet 9 inches by 2 feet 9 inches and 2 feet deep. The block of granite had had several jumper-holes bored in it, which had, however, been tamped up again, but must have weakened it considerably. The result of this explosion was that the block of granite was split vertically all around at an average distance of 2 inches from the outer edges, besides having a hole 1½ inches deep scooped out in the top of it at the seat of the charge. It was also much shaken, and could easily have been picked to pieces. The result of the fracture around the stone was that, in a few days, the part split scaled off and fell away from the block.

The whole of these experiments would seem to prove that gun-cotton, prepared according to Mr. Abel's method and fired by a detonating fuse, is quite as powerful in its action, if not more so, than the mixture of gun-cotton and nitro-glycerine, called glyoxyline.

The average price of the two would be about equal, being (according to Mr. Abel) 20*d.* per pound weight, or 2½ times the price of blasting-powder; but as the effects of one pound of gun-cotton for these purposes appear to be equal to those of 4 pounds of gunpowder, it would in reality be 38 per cent. cheaper to employ gun-cotton. The specific gravity of compressed gun-cotton is the same as that of gunpowder; that of glyoxyline one-third less.

Gun-cotton is more liable to absorb moisture than glyoxyline, though it is not permanently injured thereby. The transportation of nitro-glycerine dissolved in wood spirits, for the manufacture of the latter, is troublesome and expensive and, unless carried about in this way, nitro-glycerine is very dangerous to move, whereas gun-cotton is not so. For actual service, however, the glyoxyline would be manufactured beforehand, and the masses, (grains, disks, &c.,) would be coated with an impervious varnish, which would effectually inclose the nitro-glycerine and protect the preparation from the atmosphere.

Effect of compressed gun-cotton fired, under water, with detonating fuse.

The effects of these explosives are so powerfully concentrated and local, that it can hardly be doubted but that, if sufficient quantities were used, iron plates of considerable thickness could be pierced by them, especially under water.

A few charges of compressed gun-cotton have also been fired, with a detonating fuse, under water with the following result:

1st. A charge of 3 pounds 0¼ ounce was fired at our experimental target, (the squares of which are of fir, 14 inches square and 1 inch thick,) at a distance of 20 feet from the target and with 7 feet six inches immersion; this broke 22 squares.

2d. Three pounds 0¾ ounce, 30 feet distant from the target, and with 7 feet 6 inches immersion broke 10 squares.

Twenty pounds of powder, at a distance of 20 feet, produced less result than this charge of gun-cotton at 30 feet.

With both these experiments the shock experienced was most violent. The sprats and small whiting, for a considerable distance above the point of the explosion, were killed and drifted past in great numbers.

The above two experiments were made to test the comparative strength of the explosion of gunpowder and its equivalent of gun-cotton.

Comparative effect of powder and gun-cotton fired with detonating fuse, under water, on a muddy bottom.

3d. Charges of 15 pounds of powder and 3¾ of gun-cotton were placed on the mud and fired at high water, at a depth of 10 feet. The charges were fired together, and the columns of water were observed to be about equal, but more mud was intermixed into the column of water thrown up by the powder.

The craters were examined at low water, when they were high and dry.

Each crater was found to be 9 feet in diameter, the gun-cotton crater was 2 feet deep, and the gunpowder crater 4 feet deep.

It would appear from this that the shock of the gun-cotton explosion only compressed the mud in a downward direction, and the mud so compressed afterward recovered to a certain extent its original position.

In the gunpowder crater the mud was less violently but more thoroughly thrust aside, and thus a deeper hole was made.

The lateral effect, which was really what we wanted to arrive at, was about equal, the charges of powder and gun-cotton being as 4 to 1.

Against an air-backing, which would be the condition presented by a ship's side, a decided superiority for the gun-cotton is shown in the first and second experiments.

Before any definite conclusions can be arrived at, experiments on a larger scale must be undertaken. It may, however, be laid down as an established fact that the local action produced by a charge of gun-cotton, ignited by a detonating fuse, is enormous; that this effect is quite independent of tamping, except in loose or soft material, such as earth, and that the instantaneous explosion produced is in no way affected by a want of absolute contact or by a small interval between the disks, rings, or masses composing the charge, as shown by the fifth experiment of the 5th September, 1868; or, in other words, that no compression is required at the moment of ignition. This in submarine mining is a very great point gained, as it does away with the necessity for considering the strength of case, as far as the development of the explosive force is concerned; a thoroughly water-tight envelope, of sufficient strength to resist the pressure of the water at the depth to which it is required to be submerged, being alone required. The certainty of immense local action being, as already stated, established, it only remains to be proved that the radius of destructive effect is at any rate equal, with equal weights, to gunpowder, to relieve us from many difficulties to which submarine explosions are at present liable, and it is to be hoped that this very desirable result may be arrived at.

Relative values of gunpowder, gun-cotton, and nitro-glycerine, examined theoretically and chemically.

In a very carefully written article which appears in "Engineering" of the 12th February, 1869, the relative mechanical forces generated by the explosion of gunpowder, gun-cotton, and nitro-glycerine have been determined theoretically and chemically, the pressure of the atmosphere being taken at 15 pounds on the square inch, to be as follows: 1 grain of gunpowder, when fired, produces a pressure of 200 pounds on the square inch; 1 grain of gun-cotton produces a pressure of 1,204 pounds on the square inch;* and 1 grain of nitro-glycerine produces a pressure of 1,167 pounds on the square inch.

It is probable that these values are not far from the truth, provided the explosion takes place under exceptionally favorable circumstances as to strength of case and completeness and rapidity of ignition, but such conditions would very rarely occur in practice.

A maximum of effect probably obtained by firing gun-cotton with a detonating fuse.

Perhaps the nearest approach to such perfection of ignition is obtained in the case of gun-cotton or glyoxyline, and also with gunpowder, fired with a detonating fuse; and if this theory is true, we may assume that the explosive effect of a charge of either of these substances, when fired with this particular form of fuse under favorable conditions, approaches very nearly to a maximum, or, in other words, to the effect which would be produced by the same charge fired with an ordinary fuse, and contained in a case, the strength of which had been calculated to a nicety, so as just to exert the proper pressure to develop the maximum force at the moment of ignition, and yet not so strong as in the smallest degree to reduce that force by the pressure required to burst too strong a case.

Gun-cotton non-explosive when wet.

One great advantage of gun-cotton is that, if ignited in a free open space, it simply burns without explosion, and that, in order to render it incombustible, it is only necessary

* This result is based on data derived from the forms of gun-cotton originally manufactured as to density and consequent weight, viz, 11 pounds to the cubic foot. Compressed gun-cotton weighs considerably more; nearly as much as gunpowder.

to wet it. This wetting does not injure it in the least degree, and when dried again it is as good as ever. A drowned charge may consequently be restored to a perfectly *efficient state.* This property, together with the greater security for storage and manipulation consequent theron, gives it a great advantage over gunpowder.

Toward the close of the late civil war in the United States, a good deal of gun-cotton was sent out to the confederates, but it does not appear to have ever been used by them.

The third explosive alluded to is nitro-glycerine. Some experiments, with a view to testing its capabilities for submarine work, were made by the United States Government, but with what result I am unable to say. Our experience of it, derived from experiments made at Chatham, is, however, such as to lead us to discard it for the above purpose. Its advantages are the very compact form in which charges might be arranged, its greater explosive effect, weight for weight, as compared with gunpowder, six of powder being about equivalent to one of nitro-glycerine, the peculiarly damaging effect of its explosion, and that leakage of water does not prevent its ignition; but it is extremely dangerous to store, and its effects upon those working with it seem prejudicial to health. Further, it seems to require much care in arranging the charge for ignition, and we found that, unless confined in a strong vessel, such as a shell, for instance, there was no certainty that it would be fired by an Abel's fuse, specially prepared for the purpose; it seems to require a large amount of compression, or to be submitted to concussion the moment of ignition. This latter failing might possibly be got over, but its other disadvantages are quite sufficient to condemn it as an explosive agent for submarine mines. Nitro-glycerine.

Another substance which might be used for submarine mining purposes is "dynamite." This may be described as a mixture of nitro-glycerine and silica, by which the former is said to be made as safe to handle as ordinary gunpowder. Its discovery is due to Mr. Nobel, a German engineer. The question of safety in carrying, storing, and manipulating this substance, requires further testing; if it is simply a painting over, as it were, of the particles of silica, it is possible that the shaking necessarily encountered in carriage, or even long storage, might have the effect of settling or running the nitro-glycerine together, under which circumstances it would become as dangerous as nitro-glycerine unmixed. The following experiments with submarine Dynamite.

mines filled with dynamite, made in September, 1868, at Carlskrona, Sweden, give some idea of its effects:

Experiments with dynamite against hull of a 60-gun frigate at Carlskrona.

The target was the hull of a 60-gun frigate, which had been built in 1844; her timbers and planking were quite sound; timbers of oak, about 13 inches square, 1 inch apart; planking of Swedish pine, 5½ inches; bottom strengthened inside with wrought-iron diagonal bands, 6 inches by 1¼ inches; inside planking running half way up to the battery deck of oak, 6 inches thick. The hull had been "*razé*" down to the battery-deck, and the copper removed. The chief object was to ascertain the effect of dynamite, in a contact-mine, against a strong wooden vessel, as well as against a double-bottomed iron vessel; and, with this object in view, a quadrangular opening had been effected on the port side and filled with a construction representing a strong double iron bottom, firmly fastened to an oaken frame that had been put on inside, on the four sides of the opening, and with through-going bolts, 1 inch in diameter, to the timbers. The mines were arranged as follows:

Starboard side No. 1, about amidship, 7 feet below water-line, with the center of the mine 2 feet 2 inches from the bottom of the ship; charge, 13 pounds of dynamite in a thin iron case, ($\frac{1}{12}$-inch plate.) The mines, although representing contact-mines, were placed some little distance from the ship, on the supposition that they would or might be pushed to some distance away from the striking ship before they exploded.

No. 2. About 40 feet from stern, 7¾ feet below the water-line, center of mine, 3 feet from the bottom of the ship; charge, 16 pounds of dynamite in a glass vessel.

Port side No. 1. About 30 feet from the stern, 5¾ feet below the water-line, 2 feet from the ship's bottom; charge 16 pounds of dynamite in an iron case of $\frac{1}{12}$-inch plate.

No. 2. About 40 feet from No. 1, 6½ feet below the water-line, 2 feet 2 inches from the ship's bottom; charge, 10 pounds of dynamite in a case as above.

No. 3. 2 feet 2 inches from the center of the iron bottom, 7 feet 4 inches below the water-line; charge, 13 pounds of dynamite in a case as above.

These five mines were fired at the same moment, the hull was lifted about a foot, and sunk in 1½ minutes.

The wreck having been docked, the effect of the different mines were found to be as follows:

Effect of the mines.

Starboard No. 1. Timbers broken and thrown inside, into the hold, on a space of about 15 feet by 8 feet, leaving a hole of those dimensions; three more timbers on one side of the hole broken; inside oak planking rent off on a length of 14 feet; two iron bands torn up and bent, one of them broken in two places; outside planking off on a space of about 21 feet by 12 feet; several planks, still higher up, broken.

No. 2. Timbers blown away on a space of about 8 feet square; inside planking off on a length of 20 feet; two iron bands broken, and torn up and bent; outside planking off on a space of about 19 feet by 12 feet.

Port side No. 1. Timbers blown away on a space 10 feet 6 inches by 12 feet at one end, and 6 feet at the other; inside planking off for a length of 14 feet; one iron band torn up, one broken; outside planking off on a space of 18 feet by 25 feet and 15 feet.

No. 2. Timbers blown away on a space 4 feet in length and 16 feet in height; on the sides of this hole, 10 timbers were broken; two iron bands torn up, one broken; inside planking off for a length of about 20 feet; outside planking off for a space of about 20 feet and 23 feet by 10 feet and 13 feet.

No. 3. The gas sphere had hit the middle of the outside plates on one of the angle-iron ribs. This rib was torn from the timbers and bent up, nearly two feet in the middle, but not broken. There was an oval hole in the outside plates 4 feet by 3 feet between two ribs, which ribs, with the plates on edge riveted to them, were bulged out about 5 inches. The inner plate, one large piece, was blown up in a vertical position, after having cut all the bolts and rivets, 60 of 1 inch, and 30 of $\frac{3}{4}$ inch, save those that fastened the lower side to the oaken frame and timbers. On a length of about 30 feet and height of about 20 feet the bottom, on all sides of the iron construction, had been bent inwards; the greatest bend was about 5 inches; three deck-beams above had been broken.

By the joint effect of all the mines, almost all the iron deck-beam knees had been rent from the side, and there was an opening between deck and hull on both sides for a length of about 130 feet.

The last and newest explosive agent is glyoxyline, recently invented by Mr. Abel, chemist to the war department. This is a compound of gun-cotton and nitro glycerine, prepared by soaking the former, in a granulated state, or in the form of disks or pellets, in the latter, of which it will take up nearly its own weight; the masses are then coated with a varnish, which perfectly excludes air and incloses the nitro-glycerine; when thus manufactured, it is said to be as safe to handle as ordinary gunpowder. Its explosive Glyoxyline.

effect, when fired with a detonating fuse, is very similar to that of gun-cotton fired with the same fuse, and as the latter is very much safer to handle, it is consequently greatly to be preferred, unless future experiments develop any peculiar advantages to be derived from the use of glyxoyline.

It is of importance to keep in view the necessity of using an explosive substance for submarine, or indeed for any mining purposes, which, though powerful in its effects when required to act, and of a nature suitable to the work to be done, may yet be safely stored and manipulated when ordinary care is used; and we may on this account at once put aside the many compounds which, though at first sight presenting advantages, are liable to explode unless handled with extreme care. Picrate of potassium is an example of this class, and the fearful explosion of this substance which recently occurred in Paris, is enough to condemn it.

Size of charge.

The next point to be considered is the amount of the charge, of powder or other explosive, to be employed in each mine. On this subject we have still a good deal to learn, and, before we can bring the calculation of charges for submarine mines to the same degree of certainty which has been attained as regards those for ordinary earth, rock, or masonry, much remains to be done.

The points to be determined are the depth at which a given charge is most effective; the lateral and vertical range at which a certain charge may be relied on to produce a given result, and what that result would be on the bottom of a vessel as strongly built as a modern ship of war.

Experience of confederates on size of charge.

The experience of the confederates on this point is described by Captain Harding Steward, R. E., in his notes on submarine mines, as follows: "With submerged torpedoes, as employed by the confederates, the regulation of the charge depended on the depth of water, the nature of the bottom, and structure of the ships to be expected, except in the case of small torpedoes, moored a little below the surface and arranged for contact. With these the proximity of the charge to the object altered the conditions. The following scale of charges, suitable to depths from two fathoms and upwards, was made for use in the James River, where the bottom is very soft. It is based on *data* obtained from the destruction of wooden vessels of 800 tons, by the confederates; also from experiments, and is suitable to strongly built wooden vessels up to 1,000 tons:

Charges for a soft bottom for 1,000-ton vessel.

2 fathoms........................ 300 pounds of powder.
3 fathoms........................ 600 pounds of powder.

4 fathoms	900 pounds of powder.
5 fathoms	1,200 pounds of powder.
6 fathoms	1,500 pounds of powder.
7 fathoms	1,800 pounds of powder.
8 fathoms	2,400 pounds of powder.

With hard bottoms the charges could be diminished, for the waste of powder is not so great. In the case of a rocky bottom, as much as 25 per cent. may be deducted, according to the American experiments, because the rebound of the portion of the gas that acts downward is almost coincident with the upstroke of the rest. These charges, even considering the objects in view, appear excessive, but it must be remembered that the confederates used only one fuse for ignition. With a proper arrangement for igniting the charges at several points a reduction might have been made amounting to 40 per cent. As I have before mentioned, the employment of large charges was made with a view of controlling a large area, and destroying the vessel through the commotion of the water, when beyond the direct action of the charge. This plan may be a good one with small vessels; but the worst feature of the system is the fact that, as in some cases, the result depends upon the lifting powers of the charge, the quantity of powder must necessarily be increased in proportion to the size of the vessels expected. A progressive increase of one third of the amount given in the foregoing scale, for every extra thousand tons of measurement, was considered by the officer superintending the mining operations in the South as the least that could be done in the case of large vessels. This is no doubt true, but with vessels of 3,000 to 4,000 tons it brings the charges to quantities too large for proper arrangement."

Smaller charges for a hard bottom.

Charges increased for larger vessels.

As regards this scale of charges recommended by the confederates, it seems to be somewhat fallacious to go on increasing the charges without limit, according to the depth, and we may therefore safely assume some point beyond which the charges should not be increased. Probably 2,000 pounds might for the present be assumed as a maximum, which ought to be sufficient to break the bottom of any vessel, however strongly she may be built, if fired in a proper position with reference to her. As the tonnage of a vessel increases, so generally does her strength ; but so also does her draught of water, and, consequent upon the latter fact, if the charges were always kept as deep as possible, a larger vessel would always find a larger charge in proportion to her size, in close proximity to her, wherever there was sufficient water to allow her to pass. On the contrary the large charge would probably reach a smaller vessel, and as effectually damage her notwithstanding the cushion of water intervening.

In the sixteenth volume of the Professional Papers of the Corps of Royal Engineers, a description is given by Lieutenant W. A. J. Wallace, R. E., of the means adopted for blowing up some wrecks of vessels in the river Hoogly. Lieutenant Wallace's conclusions as to the size of the charges to be most advantageously employed, as derived from these experiments, are as follows:

Size of charges used in destruction of wrecks in the Hoogly.

"The size of the charges when they cannot be placed inside or under the wreck should, in my opinion, be regulated by the depth of the water. In from four to nine fathoms, 450 and 500 pound charges were found to answer very well, but I think they might have been increased with advantage at the latter depth.

"Between three and four fathoms, 250 and 300 pound charges are generally the most economical; a larger quantity simply throws the water to a greater height without producing a corresponding increase in destructive effect."

It is to be remarked, however, that these charges were, in every case, arranged to be in actual contact with the vessel, and were intended simply to break up the wreck in such a way as to clear the channel, and, especially at the greater depths, they would be found much too small for use as submarine mines.

Charges in confederate drifting torpedoes too small.

The charges used by the confederates in their drifting torpedoes were usually about 100 pounds of powder, and were productive of comparatively small results; this is in a great measure accounted for by the fact of their explosion occurring at, or very near, the surface of the water. The charges they employed in the attack of vessels with their torpedo boats were 50 pounds of powder, which proved ineffective in many cases, and I think may be pronounced too small for the purpose required.

Experiments made at Chatham for floating obstruction committee.

A great number of experiments have been made at Chatham for the floating obstruction committee, with a view to determine the depth at which a given charge is most effective, as well as the radius of explosive effect, or distance from such charge at which a vessel would be destroyed. This series is not yet completed, as it will be necessary to fire some larger charges than those with which experiments have hitherto been made. The results as yet obtained give us the following information, which, though it can only be regarded as approximately true, must be our guide until the subject is further investigated: first, that 100 pounds of powder is most effective at a depth of 10 feet—that is to say, that as it approaches nearer to the surface much of its energy is lost by the escape of the gas toward the air, and the lateral effect is reduced proportionally. Actually on the surface the lateral force of explosion would be at a minimum, which would in a great measure account for the small amount of damage caused by the confederate 100-pound charges in the mechanical contrivances already alluded to. Again, if the charge be lowered the explosive effect seems to be smothered, so to speak, by the increased pressure of the water and the lateral effect consequently diminished. When further experiments have been made the depth at which larger charges are most effective will be determined; secondly, from the observation of the results of certain experiments made with charges of known sizes, fired on the bottom with different superincumbent depths of water, it has been found that when a charge is immersed to that depth at which it is most effective the radius of explosive effect may be derived from the equation

Radius of explosive effect.

$$R = \sqrt[3]{8\,c},$$

where R = radius of explosive effect in feet, and c the charge of gunpowder in pounds. Where gun-cotton fired with an ordinary fuse is used, the value of c would have to be multiplied by 4 and the equation would stand thus:

$$R = \sqrt[3]{32\,c},$$

and so on for any other explosive substance used, the proportionate effect as compared with gunpowder having been obtained. The relations expressed in this equation are completely borne out by the result of an Austrian experiment on a large scale, in which precisely the same effect was obtained, in proportion to the size of the charge employed.

When the results of the larger charges have been obtained, it is possible that the deductions arrived at may be somewhat modified, but in the mean time they seem to be sufficiently near the mark to be adopted for any calculations we may have to make.

Experiment on Her Majesty's ship Terpsichore.

In an experiment tried at Chatham on Her Majesty's ship Terpsichore, a charge of 150 pounds of fine-grain rifle-powder, placed in 22 feet of water, on the bottom of the river Medway, at a distance of 12 feet below the keel of the vessel and 2 feet horizontally clear of the side, made a hole at a distance of 19 feet, in a direct line, and nearly in a vertical direction, of such a size as to sink the ship in a few minutes.

We learn from the result of this experiment that the explosive force of a charge acts most strongly, whatever the depth may be at which it is submerged, in the direction of the line of least resistance, which in this case was through the bottom of the vessel, precisely at the point where the charge broke through.

Experiments on Her Majesty's ship America.

In the spring of 1866, a number of experiments were tried at Portsmouth, by firing several charges of various sizes, suspended at different horizontal distances from the sides of Her Majesty's ship America, and at different depths of water. No very decisive results were obtained from these experiments, but the fact that the destructive effect of charges, in a horizontal direction, diminishes rapidly as the distance increases is to be remarked.

Von Scheliha's experiments.

In his Treatise on Coast Defense, recently published, Colonel Van Scheliha gives the result of several experiments which he made himself. Some of these results are very anomalous, and do not at all bear out preconceived notions. They, however, confirm the idea, of which there can be now no doubt, that the explosive effect of a charge acts most strongly in the direction of the surface, or line of least resistance, whatever may be the depth of the water.

General conclusions as to the effect of a charge fired under water.

The destructive effect would appear to be limited to the area from which the gas of the exploded charge drives away the water. The first effect of the explosion would be the formation of a globe of gas, exerting a pressure equal in all directions. Water being practically incompressible, the effect in the direction of the sides is a force which is instantly communicated horizontally through the water as a shock, for a considerable distance; but in consequence of the ready transmission of this shock, in all directions horizontally, there is but little damaging effect. The effect of the gas in a vertical direction, is no doubt much enhanced by its very low specific gravity as compared with water, but its expansion, originally due to the great heat which caused its production, is immediately checked by the cooling influence of the surrounding water. The gas then, in the first instance, would appear to lift bodily a column of water immediately overlying the primary globe of explosion; as soon as this column of water is set in motion the gas commences to force itself through it, and we have a column of spray, or a mechanical mixture of gas and water, ejected above the surface of the water. In the event of a ship being immediately over the charge, if the strength of her timbers were greater than the resistance of the depth of water on each side, the line of least resistance would evidently be to the right and left of the vessel, and the greatest effect of that charge would be just clear of the ship's sides. But, as in the majority of cases, when a charge is exploded near the bottom of a ship, the resistance of the timbers against an upward blow would be less than that of a column of 18 or 20 feet of water; it would take effect in that line of least resistance, or through the ship; in such a case there would probably be no indication of an explosion on each side of the ship, except a slight disturbance on the surface of the water. In this case the water in all directions except between the charge and the ship, acts as a most sufficient tamping, or an incompressible medium. That this water-tamping is most effectual would be best exemplified by first exploding a charge placed on the surface of the water against a ship's side, noting the effect, and then exploding a similar charge against the ship's side, but immersed 10 or 15 feet. In the first case, however, the explosive effect of the powder would be in one respect greater, owing to the absence of cooling of the gas, the explosion being principally in air. The difference of strength in the side of a ship at the water-line and 10 feet below the water-line, must, in such an experiment, be taken into consideration, as it is presumed that in a modern ship of war, a greater strength will always be provided at the water-line than under the quarter.

There is an additional amount of water ejected in the explosion of a submarine mine, due to the pressure of the atmosphere forcing the surrounding water to fill up the vacuum caused by the explosion, and a considerable portion of the water is consequently drawn up in the wake of the original column overlying the charge.

Approximate rule for determination of sizes of charges.

As already stated, we are still far from being able to give any fixed rule by which the sizes of charges may be calculated; but as it is better to be above than below the mark, we may assume, till a definite rule is established, that no charge should be less than 500 pounds of powder, which should be used in all cases up to a depth of 20 feet. As a limit in the other direction, we may assume 2,000 pounds of powder as a maximum charge to be adopted, to be used at a depth of not less than 40 feet of water. This latter size is not too large to handle with comparative ease. In considering the series of charges given by Captain Harding Steward, as the result of the confederate experiments, we find that the square of the depth in feet gives very nearly the sizes of the charges of powder in pounds for depths between 20 and 40 feet, for mines laid on hard bottom, and if we add one-fourth to the sizes of charges thus obtained, for soft muddy bottoms or buoyant mines held by moorings, we shall have a tolerably accurate means of approximately calculating the charges required between depths of 20 and 40 feet. This relation of charges, as the squares of the depth, though not derived from any mathematical relationship between the forces existing, is a rule easily remembered, and which seems to give a result sufficiently near the mark for practical purposes. Charges of the sizes above mentioned would seem to be sufficient to sink any vessel passing fairly over them. The ships would draw more water in proportion to their size and strength, and, bearing in mind the rule that where practicable the mines should always be laid on the bottom, they would find increased charges opposed to them in proportion to their draught of water.

The force required to break through the bottom of a vessel, so strongly built as a modern man-of-war, has yet to be determined, and may lead to considerable modifications in the strength of charges here suggested.

Proportion, as compared with gunpowder, of other explosives to be used in calculation of charges.

In the event of any other explosive than gunpowder being used for submarine mines, as, for example, if it is found that gun-cotton, fired with a detonating fuse, produces better results, it will only be necessary to discover the relative proportionate value due to the force generated thereby, as compared with gunpowder, and apply it to the approximate rules given, in order to obtain similar information for the particular form of explosive used. There are again many places where gunpowder only may be obtainable and its use becomes a necessity, there being no choice in the matter.

Interval between mines in a line.

The next point to be considered is the interval to be allowed between two adjacent charges in the same line of submarine mines, so that the explosion of one shall not injure those next to it, or disturb the arrangement of their electrical cables, and yet that the chance of a vessel, running between any two, and thus escaping injury, may be reduced to a minimum.

This is a point on which nothing has yet been definitely determined, but is of so much importance that a series of experiments should be made as soon as possible, with a view thereto.

The interval between any two mines, which would place one at such a distance from the other as to secure safety in the event of either being exploded, manifestly depends upon the size of the charges employed, or, in other words, the distance at which any given charge is calculated to act destructively. This may be approximately calculated, when gunpowder is used, from the equation

$$R = \sqrt[3]{8\,c},$$

(see page 33,) where R is the radius of destructive effect. If then we place our mines in line at central intervals of six times R, our present experience goes to show that they will be safe from the explosion of those adjacent to them. To find the safe interval for gun-cotton, or any other explosive used in a system of mines, it will only be necessary to multiply by the co-efficient, derived from actual comparison of the effect with that of gunpowder, to determine the value of R due thereto, and to arrange the mines in line at intervals of 6 R as before. This necessary interval between the charges in line is one reason which renders the employment of two or more lines of mines essential to a proper maintenance of the defense. It also sufficiently explains the objects to be attained, in placing them in such a way that the charges in the second line shall cover the intervals in the first, and that those in the third shall cover the intervals in the second, and so on.

Interval between each line of mines.

Again, with regard to the distance to be allowed between any two lines of mines, it is easily seen, by reference to Fig. 1, page 15, that just in proportion as we move our second and third lines back, we increase the chance for a vessel to pass safely through; it is, therefore, desirable to keep these lines as close together as the other conditions of the case will admit. These other conditions are, first, the necessity for allowing a sufficient distance between the lines of mines, to enable the electric cables to be laid in a safe position midway between them, in carrying them to the electrical room from which the system is to be worked. Second, the necessity for placing the lines at such intervals that there shall be no confusion in determining the position of each mine, by intersection, after they have been submerged. This is absolutely necessary in case it is required to fire the mines by judgment, the position of a vessel being determined by intersection, or cross-bearings, as it is sometimes called. It is also necessary to facilitate the discovery of a mine, in case it is required at any time to take it up for inspection And third, the average length of a large ship of war is an item which must be taken into consideration in determining the distance above required. Keeping these conditions in view, the intervals between the lines may be approximately determined and, as a general rule, they should never be at

Experiments required to determine distance of safety.

less than 100 yards or more than 200 yards apart, unless such an arrangement is incompatible with the peculiar circumstances of any particular position to be defended.

It would be very desirable to make a few experiments, with a view to the more definite determination of this question of distance, at which one charge would be safe from the effect of the explosion on another; till this is done the above general rules may be adopted.

Experience of Lieutenant Wallace, R. E., as to distance of safety.

In the record of the destruction of wrecks in the river Hoogly, by Lieutenant Wallace, R. E., he mentions that one of two charges of 450 pounds each, placed 55 feet apart and at a depth of 48 feet of water, was destroyed by the explosion of the other, probably stove in; it is not said how damaged. This distance of 55 feet is manifestly far too little for safety with a charge of that size; it is, however, mentioned here as the only experiment which I have been able to find which in any way touches on this point.

CHAPTER IV.

FORM AND CONSTRUCTION OF CASE.

The next point to be considered is the form and construction of the case to contain the charge of powder, or other explosive.

Let us first enumerate the several conditions which it is necessary that this case should fulfill.

1st. It must be very water-tight to prevent damage to the charge by leakage. Conditions to be fulfilled.

2d. It must be sufficiently strong to bear handling, without danger of becoming leaky by straining, and must be able to sustain the external pressure due to the depth of water at which it is to be placed.

3d. When gunpowder, or gun-cotton fired with an ordinary fuse, is used, it must be sufficiently strong to hold the charge together, as it were, for an instant at the moment of ignition, so that its full effect may be obtained by as thorough a combustion as possible of the charge. When gun-cotton, fired with a detonating fuse, is used, our present experience seems to indicate that the case need only fulfill the conditions, as regards strength, enumerated in paragraphs 1 and 2.

4th. In the case of a buoyant mine, it must be capable of being arranged with a large excess of flotation, so that when moored it may remain as stationary as possible at the required point.

5th. It should be of such form as to be capable of being handled and moored conveniently.

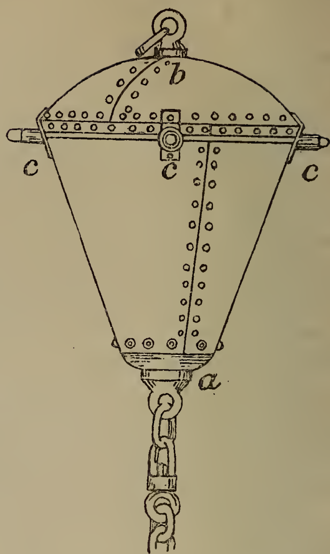
6th. It should be of such a form as to secure a thorough ignition of the charge with the smallest possible number of fuses.

7th. It should be of such form as to be easy of construction and not too costly.

First, with reference to the form of case. Those hitherto used seem to have been either conical (see Fig. 4) or cylindrical. The former appear to have been used by the confederates as the general shape for their self-acting mechanical torpedoes. The apex (a) of the cone forms a convenient point to which the mooring-cable may be attached, while the base, terminated by a curved portion, (b,) serves as an air-chamber, giving the necessary buoyancy to keep the mooring-cable taut, General form of case. Conical form for small mechanical self-acting mine.

and hold the mine in a comparatively stationary position in a current or tide-way. This seems a very good form for self-acting mechanical mines, giving a good salient position on which to place the bosses to be struck by a passing vessel, as at *c*, *c*, *c*.

Fig. 4.



Cylindrical form best for larger charges fired by electricity.

The cylindrical form appears to have been used by the confederates, where they allowed their charges to rest on the bottom. The cylindrical shape admits of the charge being stowed in a very convenient form, and, for large charges, possesses advantages, as far as the ignition is concerned, as will be hereafter described.

The Austrians have adopted a cylindrical shape for their buoyant charges, and those exhibited by them at Paris were of the forms shown in Figs. 5 and 6. These mines were

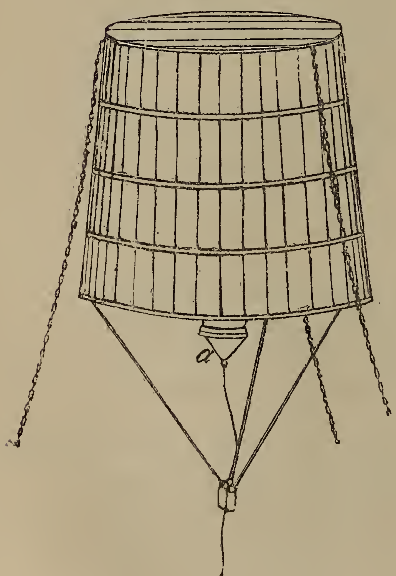
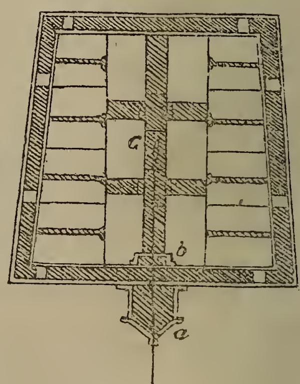


Fig. 5.



arranged to be fired by electricity, and, all things considered, the cylindrical form seems the best adapted for the size of charges recommended by them, viz, 370 pounds of powder, whether arranged to be laid on the ground or to be floated from moorings at any required depth.

It is impossible at present to lay down any definite rule as to the form of case best suited for submarine mines; before this is done some experiments must be made with large charges of powder. All that has hitherto been done seems to point to the cylindrical as the best practical form, except for the case already mentioned, where comparatively small charges, to be fired by mechanical self-acting means, are to be used. A spherical form would be theoretically the best, supposing a single point of ignition only to be used, because every part of the outside would be equidistant from that center of ignition; but the construction of a case of this shape would be comparatively costly, and a cylinder, the height of which approaches nearly to its diameter, is sufficiently near in shape to a sphere for practical purposes.

Next, as regards the material of which the cases may be most advantageously constructed.

Several substances have been suggested and tried for this purpose, such as wood, iron, and vulcanized India rubber. The confederates appear to have used wooden barrels for their smaller charges, and cases of boiler-plate iron for their larger charges. Materials of which cases may be composed.

The large charge of 1,750 pounds which destroyed the Commodore Jones in the James River, and that of similar size which so narrowly missed the Commodore Barney, were both in cases of boiler-plate iron; these charges were both fired by electricity. A charge of 5,000 pounds of powder in an iron boiler, arranged to be fired by electricity, was placed at a distance of 1,500 yards from Fort Sumter, at Charleston; at the critical moment, however, it failed to ignite from some unknown cause, which was probably either a defect in the insulation of the electric cable, or a bad fuse. This charge had been four months under water before any attempt was made to fire it, and the art of testing fuses and insulation was not then known as it is now.

The following is a description of the construction of the cases for submarine mines, exhibited by the Austrian war department, at Paris, in 1867.

The form and arrangement of the charge of a gun-cotton mine in a wooden case is shown in the accompanying sketch, Fig. 5, which gives an elevation and section. It consists of two strong wooden cases, one within the other; the inner one covered with zinc and the space between them filled in with tar. They are of the shape of a truncated cone, but the diameter of the bottom is very slightly greater than that of Forms of case used by the Austrians.

the top. The inner one has a mean diameter of about 4 feet, and is about 4 feet in height; it is calculated to contain 4 hundredweight of gun-cotton, made up in coils and packed with plenty of air space, as shown in section, Fig. 5; in this section the air-space is shown dark. Abel's compressed gun-cotton affords great advantages over that in coils, as applied by the Austrians. The size of a given charge of cotton is thereby reduced from three times that of powder to nearly an equal bulk, weight for weight. Figs. 6 shows an elevation and section of an iron case, cal-

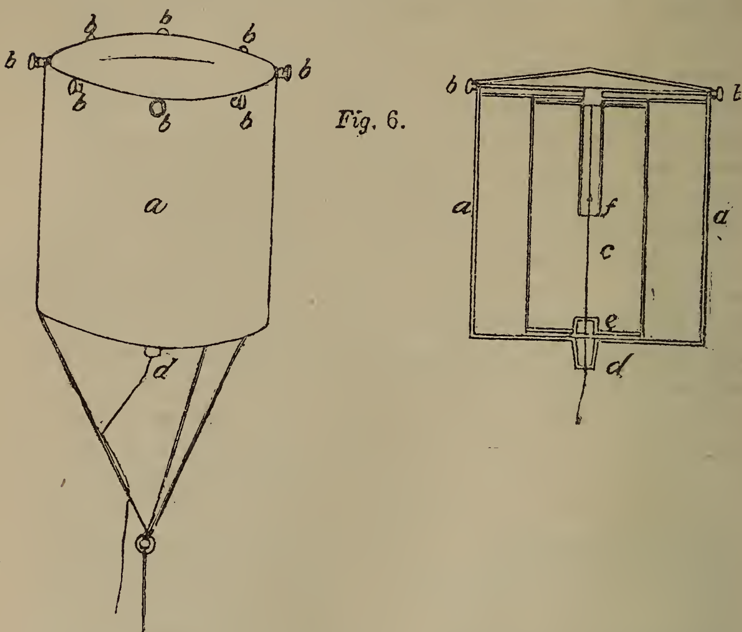


Fig. 6.

culated to contain about 3 hundredweight of gunpowder. It consists of an outer cylinder, (*a*,) at the top of which is a series of projecting buffers, held in position by strong springs, by the contact of which the circuit from the firing battery through the fuse is completed by a vessel passing over the torpedo. These buffers are shown in the sketch at the points *b*, *b*, *b*. Within the inner case a second iron cylinder (*c*) is placed to contain the charge of powder, a sufficient air-space, to give the requisite buoyancy, being allowed by the difference in size of the cases. The outer case is about 4 feet in diameter and 4 feet in height.

Captain Harding Steward's suggestions as to the use of India-rubber bags.

Captain Harding Steward, R. E., has suggested placing the charge in an India-rubber bag, the bag being furnished with an outer covering of iron. This outer covering need not be necessarily water-tight, and is only intended to protect the India rubber from injury by friction against rocks, &c., and to give rigidity to the whole apparatus, so that it may be easily handled, and, when required, moored by means of anchors in the usual way. In some experiments tried by the confederates it was found that a large charge of powder inclosed in an India-rubber bag did not produce the same amount of explosive effect as the same charge in an iron or wooden case of considerable strength. It is probable that the envelope was burst by the first explosion and a portion of the charge wetted before the whole of the powder had been ignited, and in order to obviate this result, Captain Steward proposes to ignite the charges at a great many different points, so that the whole may be fired as it were simultaneously, and the drowning effect thus partially obviated. This is done by a single fuse placed at the extremity of a metal tube, passing through the charge, and the tube being perforated at intervals, the flame and gas of a small priming charge is driven into the body of the main charge at a large number of points simultaneously. A more minute description of this arrangement will be given in treating of the several modes of ignition applicable. It is to be remarked that the confederates only used one fuse in their charges, whatever their size might be, and this is quite sufficient to account for the non-ignition of the whole of the powder in a large charge when inclosed in an India-rubber bag only. The advantages of Captain Steward's system are the comparative cheapness of the case, and that it is not dependent on the iron outer covering for keeping the charge dry; this covering may consequently be made by a comparatively inferior workman.

India-rubber bags used in connection with operations on steamer Foyle.

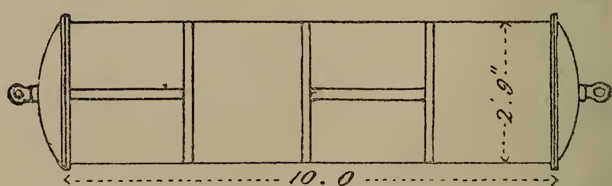
In removing the wreck of the steamer Foyle, sunk in the Thames at Barking Reach, which service was performed by the officers and men under instruction in the School of Submarine Mining, Chatham, the charges were all inclosed in vulcanized India-rubber bags, within an outer casing of half-inch boiler-plate iron. It was intended that the outer iron coverings should have been water-tight, but by some accident one of these cases leaked considerably; the charge was, however, saved by the India-rubber bag, and performed its work apparently as well as any of the others. This leak was attributed to the fact that the iron case had been left, for some time before it was filled with powder, in a hot sun; in fact, the air inside felt very hot to the hand. When subsequently submerged, it was supposed that the cooling and consequent contraction of the air had caused a considerable increase of external pressure, and that the water had forced its way through some weak place. All the iron cases used had been tested by hydraulic pressure, and were apparently sound before immersion, yet the fact of the water having got into the case is indisputable. One lesson learned from this occurrence is, the advantage of using two water-tight cases for submarine mines, an inner one to hold the charge, and an outer one to withstand the pressure of the water and to secure the necessary amount of flotation, when the mine is required to be buoyant. Assuming that the leak was occasioned by the cause above specified, it is necessary to keep iron cases out of the sun, and fill them with the air inside at a temperature somewhat similar to that of the water in which they are to be placed; and again, when it is necessary to store them, especially in positions where they may be subjected to considerable changes of temperature, the screw-plug or man-hole should be left open to allow a free ingress and egress of air. As a matter of precaution, this should be made a general rule whenever it becomes necessary to store these cases; this course is adopted with regard to large iron buoys.

Mines should not be loaded or kept in the sun or at a high temperature.

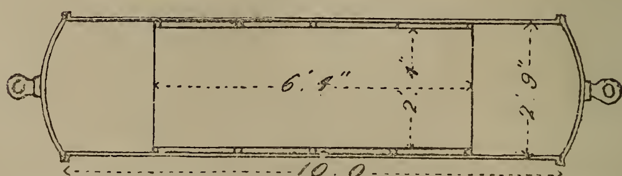
Report of Lieutenant Chadwick, R. E., on boiler-plate iron for submarine mine cases.

The following report by Lieutenant Chadwick, R. E., on the subject of boiler-plate iron, as applicable for use in the construction of submarine mines, possesses considerable interest.

Fig. 7.



Section.



The results of Lieutenant Chadwick's investigations are, that envelopes for submarine mines should be double, an exterior wrought iron case, and an internal tin or India-rubber case, to contain the powder, leaving an air space of 1½ inches to 2 inches between the two, and kept apart by wooden battens. The general form of case is shown in Fig. 7. This air-space is to prevent the interior case, containing the powder, being damaged by any slight leakage, or by the deposition of moisture produced by change of temperature. In buoyant mines a considerable air-space is required to give the necessary flotation.

For a buoyant mine it is recommended that the case should be of B B boiler-plate iron throughout, the sides $\frac{1}{4}$ inch, and the ends $\frac{3}{8}$ inch thick, fixed together by rivets, bolts, and nuts of the same material and quality. The size for a buoyant mine to contain a charge of 1,000 pounds, might be 10 feet long and 2 feet 9 inches in diameter. This gives an amount of buoyancy as determined by the following calculations:

1. To find the displacement: Displacement.

Volume = length × area of base, (taking no account of the curved ends.)

$$= 10' \times \frac{121'}{16 \times 4} \times \pi$$
$$= 10' \times 5'.939$$
$$= 59'.39 \text{ cubic feet.}$$

Displacement = volume in feet × weight of 1 cubic foot of water.

= 59'.39 × 62.425 pounds = 3707.42 pounds in fresh water; or 59'.39 × 64.05 = 3793.93 in salt water.

2. To find the weight of the mine:

Area of skin = length × circumference.

$$= 10' \times \frac{11''}{4} \times 3.1416$$
$$= 10' \times 8.639$$
$$= 86.39 \text{ square feet.}$$

Now $\frac{1}{4}''$ plate weighs 10 pound per square foot, (Rankine;) therefore weight of skin = 86.39 × 10 pounds = 863.9 pounds.

Weight of three joints each 3″ wide:

$$= 3 \times \text{circumference in feet} \times \text{width} \times 10$$
$$= 3 \times 8'.64 \times \tfrac{1}{4}' \times 10$$
$$= 64.8 \text{ pounds.}$$

Weight of 4 joints, (longitudinal,) $= 4 \times 2\frac{1}{4} \times \frac{1}{4} \times 10$

$= 22.5$ pounds.

Weight of 2 circles of angle-iron, 3′ in diameter at 4.2 pounds per foot, running:

$$= 2 \times \frac{9}{4} \times 3.1416 \times 4.2$$
$$= 59.38 \text{ pounds.}$$

Each end is a segment of a hollow sphere, the diameter of the base being 2 feet 9 inches, and the height 6 inches. The thickness of metal is $\frac{3}{8}$ inch.

Using the formula for the surface of a segment of a sphere:

$$S = \pi . d . h$$

we find the surface of the two ends $= 2 \times 3.1416 \times \frac{11'}{4} \times \frac{1}{2}'$

$$= 8.64$$

$$\text{weight} = 8.64 \times 15 \text{ pounds}$$

$$= 129.6 \text{ pounds.}$$

Weight.

Summary of Weights.

	Pounds.
Skin	863. 90
3 joints	64. 80
4 joints, (longitudinal)	22. 50
2 rings, (angle-iron)	59. 38
2 ends, (domed)	129. 60
Charge	1, 000. 00
Case for do	150. 00
Total weight	2, 290. 18

Flotation.

3d. To find the flotation:

	Fesh water.	Salt water.
Displacement	3, 707. 42	3, 793. 93
Weight	2, 290. 18	2, 290. 18
Flotation	1, 417. 24 lbs.	1, 503. 75 lbs.

This may appear unnecessarily large, but it is well to have an excess of flotation power, as it can easily be diminished by using a slightly larger charge.*

The dimensions given above are sufficient to resist any tendency to collapse from external pressure.

Let l = length in inches.
d = diameter.
t = thickness.

Collapsing pressure.

q = collapsing pressure per square inch.

Then $q = 9672000 \frac{t^2}{l. d}$ nearly; (see Rankine's Applied Mechanics, page 307.)

Therefore, in the present case, $q = 9672000 \frac{\frac{1}{16}}{120 \times 33}$

$= 152.6$ lbs. per square inch,

which represents a pressure of about 350 feet depth of water. This calculation is made without regard to the covering plates over the joints, which would probably quadruple the strength,

* The amount of flotation necessary depends on the strength of the current in which a buoyant submarine mine is moored, as will be explained hereafter.

as three such joints would exist, the case being conveniently formed of four plates, and consequently l, the length for calculation, would become 30 instead of 120.

The strength to resist internal bursting pressure is given by the equation

$$\frac{t}{r} = \frac{p}{f} \quad \text{(Rankine.)}$$

Bursting pressure.

Where t = thickness.
r = radius.
p = bursting pressure.
f = tenacity, which may here be taken as 34,000 pounds per square inch. (Rankine.)

$$\text{Then } \frac{\frac{1}{4}}{16.5} = \frac{p}{34000}$$

or, $p = 515$ pounds per square inch.

Therefore bursting pressure is nearly 520 pounds per square inch. To develop the whole force of the powder, when fired in the ordinary manner, a much greater strength would probably be necessary; but to obtain it, the thickness of the case would have to be increased to so great an extent as to render it unmanageable. It would appear, therefore, that to produce a given effect it would be better to employ an excess of powder, ignited by several fuses, than to attempt to produce a maximum effect from the charge by increasing the thickness of the case. It might be well to try, on a considerable scale, the effect of inclosing the powder in a loosely-woven bag of gun-cotton, with the object of igniting the charge from the exterior, by which the dispersion and loss of part of the charge might be prevented.

There is no doubt that, under ordinary circumstances, we should use a cylindrical case, more approaching in form to that adopted by the Austrians, and shown in Figure 6, than to that given by Lieutenant Chadwick, shown in Figure 7; this latter was designed to be moored fore and aft, as would be necessary in a very strong current. Our present experience goes to show that, in a three or four knot current, a single mooring-hawser will answer every purpose, provided plenty of buoyancy is given to the mine.

We have as yet no sealed pattern of an approved form of case for submarine mines, and till one is determined on, it is only possible to deal in general terms with the subject.

Result of experiments on strength of case, by floating obstruction committee.

A good many experiments have been tried by the floating obstruction committeee, to ascertain the requisite strength of case to fulfill the necessary conditions already enumerated, and the following appears to be the result of their investigations, so far as carried out:

"These experiments lead to the general conclusion that the effect of a charge of gunpowder exploded under water is enhanced in a very great degree by the strength of the case in which it is inclosed, seeing that even with so small a charge as 4 pounds the maximum effect of the force is not attained until a case is provided of ⅛-inch iron, and which will stand a gradual pressure from within of 330 pounds per square inch.

"It may therefore be assumed that the manageability of a charge will alone determine the maximum weight or strength to be given to a torpedo, and that all the strength which it may be found necessary to give to the case, in order to resist the pressure of the column of water under which it is submerged, will tend to increase the effectiveness of the charge, there being no risk that such extra strength of case will involve an expenditure of force, in its rupture, at all approaching in extent to the advantage gained by its resistance, and the consequent increase of time afforded for the development of the explosive force of the charge."

A corroboration of this opinion appears in the account of the experiments on board the Excellent, where the effect of 5½ pounds of powder in a shell approximated to that of 25 pounds in a barricoe.

Experiments with large charges required.

It only now remains to continue the series of experiments with large charges, of such size as would be used on actual service, to enable a definite conclusion as to the form and strength of case best suited for the purpose, to be arrived at. The charges hitherto used in the experiments carried out have been small, as the apparatus would not admit of large charges being fired in connection with it. A continuation of this series of experiments, in connection with an apparatus of similar form, but on a larger scale, under the direction of the royal engineer committee, is now being carried on, from which more definite results will no doubt be obtained. These experiments are not, however, sufficiently advanced to warrant any decided conclusion upon the results obtained from them.

Cylindrical form of case recommended.

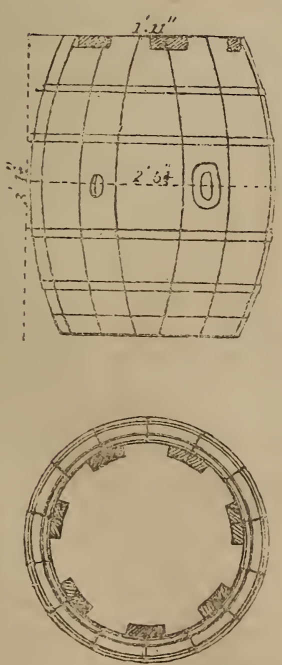
As far as we yet know, I think we may say that a cylinder of a more or less elongated form seems to fulfill the required conditions best, but whether it should be of India rubber, protected as described, of boiler-plate iron, or of any other material, has still to be determined. Should, however, boiler-plate iron be decided on, I think we may safely assume that a thickness of ¼ inch of metal (the bursting pressure for which, on an elongated case, of the dimensions shown in Fig. 7, calculated to contain 1,000 pounds of powder, would be 515 pounds on the square inch) will give a sufficient resistance to the bursting effect of the explosion for the size of charge recommended.

Barrels may be used as a make-shift.

In all cases, the most approved form of envelope to contain a charge of powder for submarine mining purposes, may not always be at hand, and it may be necessary to use ordinary barrels, or any other available articles. Barrels are very readily obtained anywhere, and, when properly strengthened, are a tolerable substitute for the more approved form of case; they are, moreover, made of sufficient size to contain a considerable charge of powder.

In blowing up wrecks in the river Hoogly, as reported by Lieutenant Wallace, R. E., in Volume XVI of the Professional Papers of the Royal Engineers, page 116, barrels were used. These were of different sizes, viz, hogsheads, half-barrels, and kilderkins, holding respectively 500, 300, and 150 pounds of powder. Lieutenant Wallace tried several methods for strengthening the two larger sizes, which he found necessary, and that employed by Sir Charles Pasley, in his operations upon the wreck of the Royal George, and shown in the annexed Fig. 8, was found to be the most effectual. It consists in strengthening the ends of the barrels with wood. The projecting tops of the staves of the original barrel were half cut away, and the strengthening of wood arranged to break joint with them, while at the same time filling up the spaces cut away. This done, the whole barrel was well payed over with pitch and tar, and, when required to remain a considerable time under water, the whole was sewn up in a stout canvas covering, also well saturated with the same composition of pitch and tar. Lieutenant Wallace found that, in a strong tide-way, a charge of 500 pounds of powder required a weight of 400 pounds to sink it, whereas in slack water, less than half that weight was sufficient.

Fig. 8.



All cases must be very water-tight.

As in submarine mines the charges must generally remain a considerable time under water before explosion, it is most necessary to make the case, whatever it may be, very water-tight, and with this view the inside of a barrel might be lined with a coating of marine glue or cement. In the experiments carried on by the floating obstruction committee, the latter was found to give a perceptible increase of explosive effect, when used as an external coating to X X tin cases for small charges, by giving an increase of time for ignition. An internal case of X X tin would also, I imagine, prove a very effective means of keeping the charge dry. In using it care should be taken to fix it firmly inside the barrel, as any independent motion might disturb the connections of the electrical conducting wire or destroy its insulation. An internal India-rubber bag, as recommended by Captain Harding Steward, placed inside a barrel would also afford a ready means of preserving the charge in a dry state.

An internal tin case or India-rubber bag recommended to keep the charge dry.

If greater flotation than that afforded by the barrel, when loaded, is required, in order to fit it for a buoyant mine, it must be given by buoys or corks attached to it.

A steam-boiler a good make-shift.

Another make-shift which may be used for submarine mining purposes is a steam boiler, and any other envelope presenting the necessary requisites of strength, to resist the external and bursting pressure at the moment of ignition, in a sufficient degree to insure a good explosive effect, and also possessing the property of being very water-tight, would answer the purpose. In all cases it would be necessary to use the same precautions in the preparations of these articles as recommended for the barrels, and which indeed are the essential points to be attained in any envelope for submarine mining purposes, whether of a make-shift character or constructed especially for the purpose.

A strong case essential with gunpowder or gun-cotton fired with an ordinary fuse—with gun-cotton fired with a detonating fuse it is not so essential.

These remarks, with reference to the strength of case necessary to develop the explosive effect of any given charge, have reference especially to gunpowder; and as circumstances may occur in which gunpowder alone is obtainable, they must not be omitted in considering the organization of any system of submarine mines. If any other explosive be used, the necessity for employing a case of sufficient strength, with reference to the peculiarities of that explosive, must still be kept in view. Compressed gun-cotton fired with an ordinary or with a detonating fuse is the most likely agent to be employed. If fired with the ordinary fuse it would still be necessary to take the strength of case, to develop the full explosive effect of the charge, into consideration, and the conditions would be very similar to those of gunpowder, bearing in mind that, where an equivalent only is used, a case of proportionately smaller size will be sufficient. If fired with a detonating fuse, we may probably omit the consideration of the strength of the case as far as the development of the explosive effect of the charge is concerned. The other conditions to be fulfilled, viz, capacity to keep out water, sufficient strength to bear handling without danger of fracture, &c., enumerated in the beginning of this chapter, must, however, be kept in view.

It is impossible as yet absolutely to say that gun-cotton, fired with a detonating fuse, is our best explosive for submarine mines; but it possesses many advantages, not the least of which is this ability to dispense with all consideration of the strength of case necessary to the development of the maximum explosive effect.

CHAPTER V.

MOORING.

The next point to be considered is the mode of mooring a submarine mine when it is to be floated up from the bottom and not actually laid on it.

The question of mooring seems at first sight a very simple matter; practically, however, it has been found to be one of the most difficult problems to be solved in connection with a system of submarine mines. In order to possess a maximum of efficiency, no indication of the position of a mine should appear on the surface of the water,* and yet the spot to within a few feet where it is deposited must be known to the defenders of the position in which it is used. It has been found that the least current, or even a moderate breeze, renders the placing of even a single mine in a definite position a matter of very considerable difficulty. When a series of mines are to be moored in proper relative position, this difficulty is much increased, and it is again considerably augmented in proportion to the depth of water. Under certain conditions, therefore, special means, to be hereafter described, must be employed.

Objects to be attained.

The objects to be attained in mooring are as follows:

1st. That the charge should be kept as nearly as possible stationary at the point where it is required to act. This is particularly necessary where there is a tide which, flowing first in one direction and then in another, tends to cause the mine to shift its position, and is indispensable in the case of mines to be fired by judgment.

2d. The mooring should be so arranged that there shall be as little twisting as possible, which might break or injure the insulation of the electrical cable.

3d. The anchors or heavy weights used should be suited to the nature of the holding ground or bottom.

4th. Mooring-cables should be so arranged that they may not be likely to become twisted together or entangled.

Buoyant submarine mines may be moored by one or more cables, according to the different circumstances of the case,

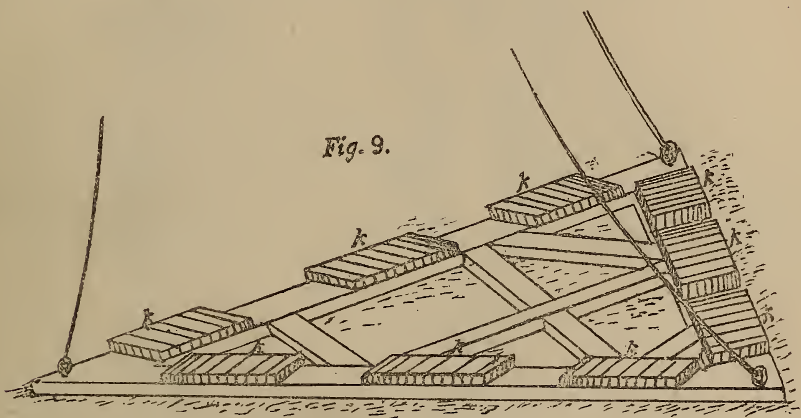
* In certain cases it is impossible totally to conceal the position of a system of mines, as, for example, when there is a considerable rise and fall of the tide. When such is the case the very smallest indication possible should be allowed to appear on the surface of the water.

and several modes of mooring have been suggested and adopted.

The following is a description of that used by the Austrians during the war in 1866, and exhibited by them at Paris in 1867: Austrian mode of mooring.

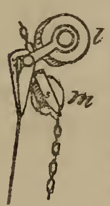
In the Adriatic, where there is almost no tide or current to disturb submarine mines or cause them to revolve and twist up their mooring-chains, a very simple arrangement for keeping them in their required positions has been found effectual. This is shown in sketch Fig. 9, which gives the

Fig. 9.



form employed with the original gun-cotton charges which were arranged to be fired at will. It consists of a simple wooden platform of triangular form, on which heavy weights, marked (*k*) in sketch, are placed at intervals; this platform is attached to the submarine mine by three wire ropes, in connection with its angles, which are fastened to three chains holding the charge at any depth below the surface of the water required, by means of arrangement shown in sketch Fig. 10. This consists of a pulley (*l*) attached to the extremity of the wire-rope of platform, through which the mooring-chain of the charge is passed and fastened by a key or catch marked (*m*) at the required length by means of a self-acting arrangement shown in Fig. 11. This key is of considerable weight, and consequently slips down as the charge is hauled into its place, but the moment the chain is slackened the two arms (*a*, *a*) shown in dots which are made to allow the latter to pass through in one direction only, catch into a link of the chain and hold the charge firmly into its place. The ap-

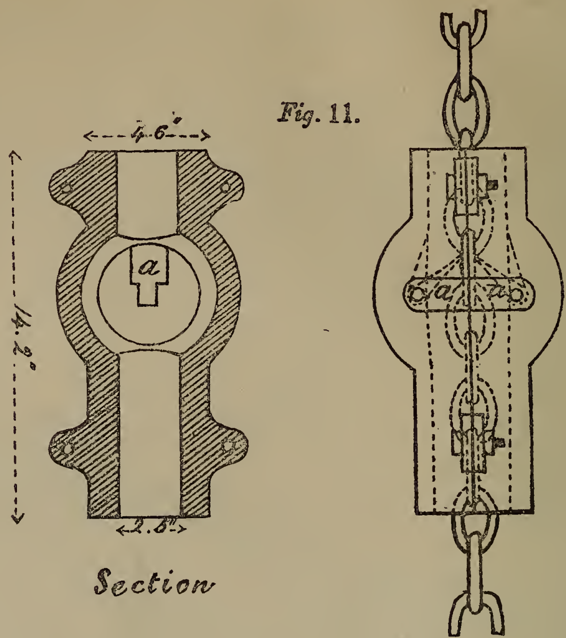
Fig. 10.



Austrian catch.

paratus is so constructed as to allow the chain to be passed freely through it, and is provided with nuts to admit of its

Fig. 11.



being separated, in order to disconnect it from the chain when required. In our mooring experiments an apparatus of this nature, weighing $60\frac{1}{2}$ pounds, has been used in connection with a half-inch chain with good results.

Austrian mushroom anchor.

In connection with the self-acting submarine mines more recently adopted, a mushroom anchor has been used. This mode of mooring is said to have been quite effectual in the still water of the harbors of the Adriatic.

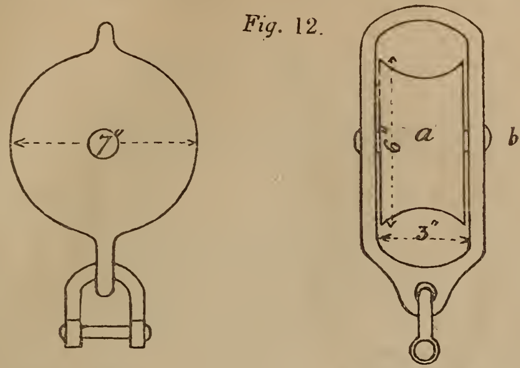
Block and pulley.

The details of the block and pulley used in connection with this key are shown in Fig. 12. The sheave (*a*) is made of cast iron galvanized, and the remainder of wrought iron. The sheave (*a*) and axle (*b*) were, in the first instance, made of gun-metal, but the electric action, set up between this and the iron of which the remainder was constructed, had the effect of decomposing the latter very rapidly, and the apparatus in consequence soon became useless. Experience teaches us that no two metals between which electrical action is likely to occur should be placed in contact in sea-water, as the latter is quite sufficient to induce voltaic action, to the detriment of one of the component parts, and destroy the apparatus. An ordinary shackle is attached to the block to enable it to be fastened into a link of a

Metals between which electrical action occurs not to be placed in contact in sea-water.

chain or thimble when required; when convenient it may be fastened directly into the eye of the mushroom anchor,

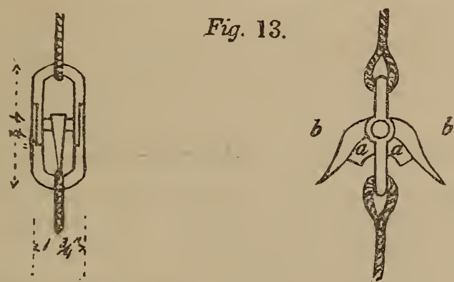
Fig. 12.



which, under certain conditions, would simplify the arrangements very much. The dimensions shown are adapted for a ½-inch chain. When new it works very well, but rust soon renders it stiff.

Fig. 13 shows another description of catch by which a charge, which has been hauled down, may be held in its place. Barbed catch.

Fig. 13.



It consists of a simple pair of barbs, (*b b*,) working on an axle and held open by an India-rubber spring, (*a a*,) capable of being compressed; if pushed away from the India rubber they simply press against each other, shoulders being provided on each, close to the axle, to sustain any pressure exerted against them. To use this apparatus it is only necessary, after measuring the depth of water at the point where the mine is to be submerged, to insert the catch at the required distance in the mooring-cable below the charge, and haul down through a thimble or eye on the mushroom anchor or moorings, when the mine will be retained at the required depth below the surface.

It possesses the advantage over the Austrian arrangement, Fig. 11, that it can be used in connection with a hemp or wire cable, whereas the Austrian can only be used with a chain.

Catches of this kind have been used in our mooring practice with very good results when new. When they have been some time submerged the rust makes the joints very stiff. And they then become hard to pull through the ring or thimble in connection with them. The Austrain catch possesses the same defect, becoming very stiff from rust; in fact, any iron apparatus must necessarily be injured in this way, and, for the reasons already specified gun metal is inadmissible in close proximity to iron. The rusting is not perhaps of any very great importance, as, when once down into position, a mine would seldom be required to be moved.

A series of experiments in mooring were carried on at Chatham during the autumn of 1867, and the following extracts from the reports of Lieutenant O. Chadwick, R. E., who had immediate charge of these experiments, throw some light on the difficulties to be encountered in submerging charges.

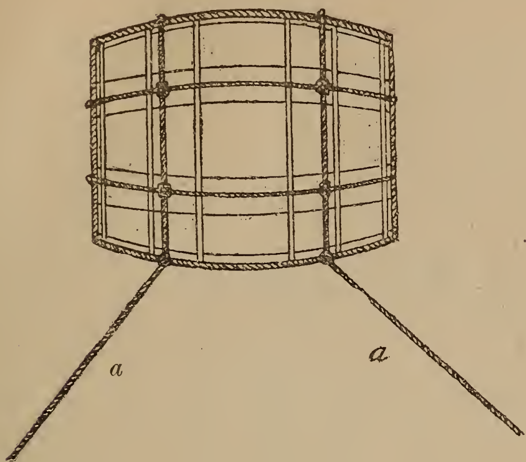
Experiments in mooring in Medway, near Upnor Castle.

"When the depth of water is so great that a submarine mine, if placed on the bottom, would require for efficiency an excessively large charge, it must be floated up from the mooring to which it is attached. This introduces great complication in the arrangements and also increased chance of derangement, either by accident or by the operations of the enemy. For still, tideless waters, the Austrian method would no doubt answer. In any current, however, the case would be liable to spin round and entangle the conducting wire with the moorings and produce kinks in these, unless indeed the size of the triangle were inconveniently large. It is also easily grappled and taken up; indeed one placed in the Medway at Upnor was, after a few hours, hooked by an anchor of a barge or steamer and carried away."

Faulty arrangement of mooring cables.

While on the subject of methods of mooring when there is any current, the following must be avoided: Fig. 14 shows an ordinary cask with two mooring cables (*a a*) underneath. The object of using two cables is to keep the mine in a perfectly stationary position, but our experience, derived from experiments carried on in the Medway, is, that unless the attachments of these cables to that mine are kept well apart they are certain to become twisted round each other when there is a current, and especially in a tide-way where it runs first in one direction and then in another. It is clear, too, that if, in the process of lowering or by any other chance, the mooring cables get a single turn around each other, the effect of their having been originally arranged apart is completely lost, and they become as free to revolve as if both cables have been attached to the same point. Practically it was found that with a current of about three knots an hour, as in the Medway, barrels arranged as in Fig. 14

Fig. 14.

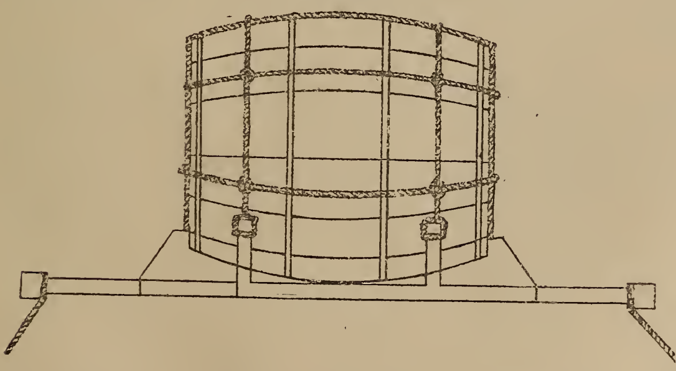


invariably became twisted up in such a way that an electric conducting wire, connected with the mines to which they were attached, would inevitably have been much kinked and probably injured.

To obviate such a result Lieutenant Chadwick proposes, with small charges and at moderate depths of water, to lash the mine on a spar on which a rough frame-work to fit the form of the barrel had been arranged, and attach the mooring-cables to the extremities of that spar as shown in Fig. 15, thus securing the necessary distance between the points

Small charge moored on a spar.

Fig. 15.



of attachment to prevent the chance of entanglement. In order still further to secure this, the anchors to which the cables are attached should be placed well apart, and plenty of

Ladder moorings.

buoyancy allowed to keep the cables tight. In certain positions it may be inconvenient to place the anchors far apart, and when this is the case, a ladder arrangement may be effectively used.

Fig. 16.

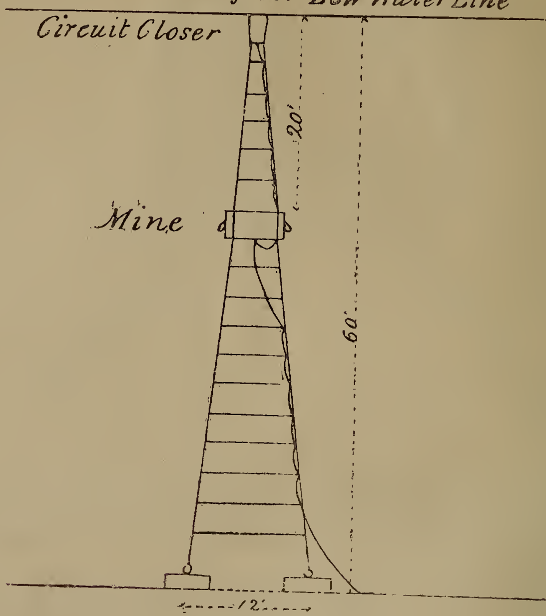


Fig. 16 shows a combination of this sort, somewhat similar to that tried in connection with experiments on board Her Majesty's ship Cambridge.

The following report by Mr. Charles Cockran, gunner, Royal Navy, extracted from the report of the committee on active obstructions, published in 1868, gives the results obtained:

"A buoyant torpedo, consisting of a 27-gallon iron oil-cask, containing 15 gallons of water, and a strongly buoyant nun-buoy to represent the circuit-closer, were fitted with two mooring-ropes from the circuit-closer to the torpedo and thence to the mooring-ballast, the ropes being separated by wooden rounds or spreaders, one to three feet long, to resist the tendency to twist. This arrangement, with two insulated wires connecting it with the electric battery, was placed in position on the 18th of April, 1868, in 10 fathoms water in a part of the Hamoaze liable to strong eddy tides; and at the end of 24 days it was removed. While it was in position the arrangement was twice examined by divers, who reported the mooring-ropes and conducting-wires to be clear of turns;

and that, when taken up, a round turn was found in the mooring-ropes close to the ballast, but the whole of the upper portion of the ropes and the insulated wires were clear. This means of employing hemp-rope, in the absence of wire-rope, in a manner calculated to resist the revolving tendency of the circuit-closer, appears to have proved successful. It is, however, to be observed that the rounds or spreaders are liable to lodgments of sea-weeds or other objects, which might sink the circuit-closer; and that the plan does not therefore recommend itself for adoption, except when wire-rope is not procurable.

"The buoy-rope, which had been attached to the ballast for recovery after experiment, repeatedly took several turns around the mooring-ropes, though cleared by the divers at each examination."

In Fig. 16 rather more spread is shown than was used in the Hamoaze experiment. This would no doubt decrease the tendency to twist, but the broader spreaders would afford a greater space for the deposit of sea-weed, &c. In deciding, therefore, on the particular dimensions to be employed, local circumstances, such as the quantity of sea-weed or other floating matter, the strength and direction of currents, their steadiness or eddying qualities, and all similar difficulties, should be carefully considered so as to insure, as far as practicable, a minimum of evil in the form adopted.

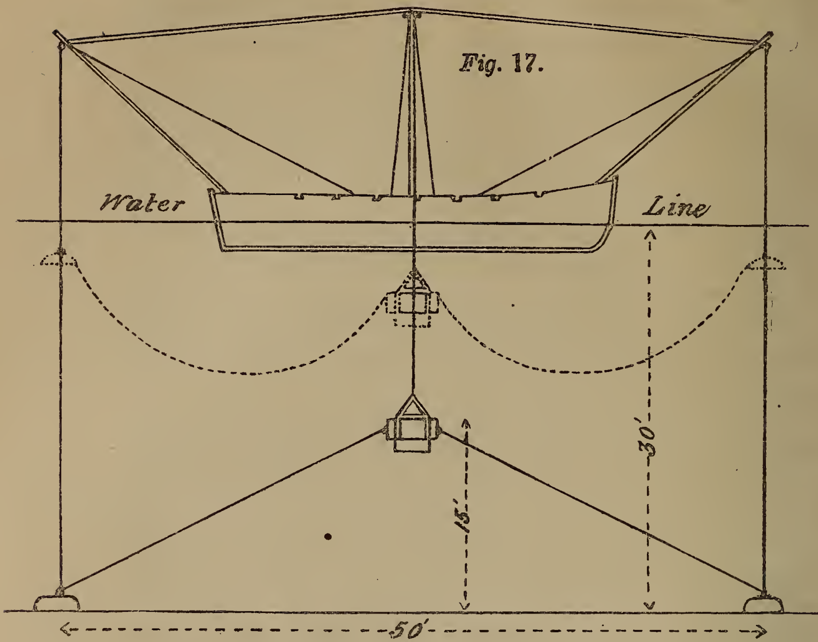
Mooring fore and aft.

In a tide-way where there is a current of more than five knots an hour, two anchors may be advantageously used, placed up and down stream at a considerable distance apart, depending on the force of the current and the height from the bottom at which the mine is to float. At first, considerable difficulty was experienced in placing the anchors at a correct distance apart, but by the following method small charges have been laid down successfully and have maintained their positions when so placed.

The following arrangement, designed by Lieutenant Chadwick, R. E., was tried in the river Medway during the autumn of 1867, and moorings with a charge attached were thereby successfully lowered into position without much difficulty.

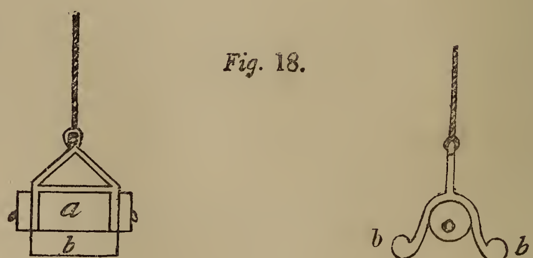
A derrick, Fig. 17, was rigged at each end of a boat, the distance between the ends being that which the moorings were to have when on the bottom. To these the mooring-anchors were suspended, being attached to the ropes by nippers which released them when on the bottom. The charge itself was made to sink by means of a heavy saddle, Fig. 18, placed over it, and thus its upward tendency did not draw the moorings together; (*a*) shows the mine, (*b*) the weighted saddle.

Fig. 17.



The length of the mooring-cables having been previously adjusted according to the depth of water, when the moorings were placed on the bottom the saddle was drawn up, and the charge rose into its proper position.

Fig. 18.



Small charges, of the size of 18 to 36-gallon casks, were successfully placed in this manner with a 30-foot gig, ponton-baulks being used to form the derricks.

The larger kind of ship's boats, such as a 42-foot launch, are provided with a windlass placed across the boat, in the center of its length. Under this are two hollow trunks fixed water-tight over holes in the bottom; through these ropes may be passed to the windlass, and in this manner a heavy object may be carried under the bottom of the boat. A load of from two to three tons may be safely carried in this manner.

In order to place a large buoyant charge, of 1,000 pounds to 2,000 pounds, for example, three of these larger boats would be required to carry it and its anchors, one for each anchor or mooring-block, and one for the charge itself. They would be connected by a rope, which, if kept stretched, would insure the anchors being placed at the proper distance apart.

In some cases ponton-rafts, with triangle guys erected on them, might be used, but they would be difficult to manage in a current.

Some further experiments were subsequently made in the Medway opposite Chatham dock-yard, where there was no chance of the apparatus being carried away by passing vessels, as was supposed to have been the case with those placed in the river opposite Upnor Castle. The following is the result of these experiments as reported by Lieutenant O. Chadwick, R. E.: (Mooring experiment off Chatham dock-yard.)

"Two large casks (36 gallon) were moored in the river with mushroom anchors of 10 cwt. each. Their total buoyancy was about 10 cwt., and each contained a weight of 5 cwt., representing the charge, so that there was an upward strain on the mooring-rope of 5 cwt. The length of the rope was 15 feet, so that the top of the barrel was about 20 feet from the bottom of the river. (Mooring by a single cable.)

"The depth of water at low water was, in one case, 20 feet and in the other 8 feet.

"A clip-hook was first used to release the mooring from the tackle by which it was lowered; but this was found not to answer, from the twisting of the rope when lowering, which caused the tripping line, in connection with the arrangement, to wind round the parts of the tackle.

"The next plan used was a double rope, passing through a double block on the sheers erected on the raft and through the eye on the mushroom anchor. This arrangement also gave great trouble, from the twisting of the ropes together, and it was found impossible to clear the rope from the moorings when a single mooring cable was used."

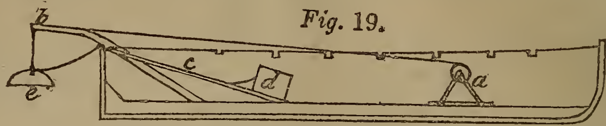
Lieutenant Chadwick, in conclusion, recommends the following mode of lowering mines into their places to be adopted:

"The mines, with their moorings attached, should be carried to the place where they are to be submerged, in a barge or lighter, provided with a derrick or crane, for taking them in and out.

Ship's launch fitted for mooring purposes.

"For lowering them into position a ship's launch might be used, provided with the fittings shown in Fig. 19. In the center, or perhaps rather more forward, a crab-capstan, *a*, might be placed. Over the stern are two davits, (*b b*) with

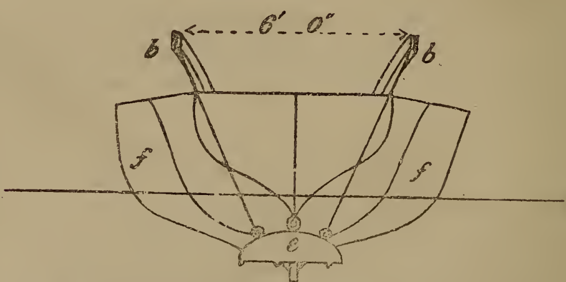
Fig. 19.



sheaves, their outer ends being about 6 feet apart. Between them is an inclined plane (*c*) on which the case (*d*) containing the charge is placed.

"The mushroom anchor (*e*) is lowered by means of two ropes, attached to two eyes in its sides, as shown in Fig. 20.

Fig. 20.



Each of these ropes leach through the sheaves in the end of a davit, and thence to the crab-capstan. By thus separating the ropes it is hoped that twisting may be avoided.

"The mine should be placed on the inclined plane, and the mushroom anchor between the davits, by means of the crane in the shore lighter. This done, the boat is ready to be towed to the destined position of the mine. The anchor should then be lowered gradually down, and the mine launched over the stern. To detach the ropes by which an anchor has been lowered, common marline-spikes, well greased, and which are arranged to hold these ropes by being passed through a double heart-knot, may be used. These marline-spikes having been withdrawn by means of lines, (*f f*) attached for the purpose, the anchor is thus released."

A 32-foot pinnace is sufficient to lower an anchor or mooring-lump weighing 20 cwt.; but for larger weights a larger boat would be required.

Results of experiments in mooring with pinnace fitted on Lieutenant Chadwick's plan.

A 32-foot pinnace having been fitted up as recommended by Lieutenant Chadwick, a series of experiments were made with her during the summer of 1868. The result of these experiments showed that, though this system answered remarkably well for lowering a mushroom anchor or mooring-lump into position, and there was no twisting or difficulty in detaching the ropes by which it was so lowered, there was still an immense amount of care required in handling the charge and circuit-closer in connection with it, in order to prevent damage to the electric cable and disarrangement of the mooring-gear, and that even with a depth of only six or seven fathoms, at which the experiments were tried, and a three or four knot current, such as that of the Medway, it was so difficult to get a mine into any required definite position as to be practically impossible. The conclusion consequently arrived at has been that in most cases, and especially in deep water and with large charges, it will be necessary to lower the moorings first into the required position and haul the charges down to them, in order to insure that accuracy of position which is essential when a mine is to be fired by judgment; and in order to obviate, as far as possible, the great strain on the anchor, which necessarily occurs during the process of hauling down, the mine should be weighted, the weights being subsequently removed when the operation of submerging is complete. The bottom at the point where the apparatus was placed was soft mud, and consequently very favorable to the mushroom form of anchor. The current runs about three knots an hour at the point where the experiment was tried; the top of one barrel was just awash, while the mooring-cable of the other allowed several feet of slack, at dead low tide. The mooring-cable used was a 3-inch wire cable composed of a strand of No. 20 galvanized iron wires, and manufactured by Messrs. Newall & Co. The result of this mode of mooring was most satisfactory; there was no twisting of the barrels and consequent torsion of the mooring-cable; that barrel which was moved so as to be just awash at low water, seemed simply to turn a little, as indicated by a vane arranged to show above the water, but never to make even a single whole revolution, and almost immediately turned back again. The position of the barrel altered but little, whether the tide was running in or out, probably not more than two feet either way from a central point. There was, of course, more motion with the other barrel which had a considerable amount of slack cable at low water. The wire cable was a great improvement on the ordinary hemp cable, with which the barrels, in the first experiments, were moored, and the mushroom anchor did its work remarkably well.

Soft muddy bottom very favorable for mushroom anchor.

The conclusions arrived at from these experiments seem to be as follows: that a single cable should be used whenever possible, and that a wire rope is superior to a hemp

Conclusions arrived at derived from above experiments.

one, being less likely to twist, kink, or wear from friction; that a mushroom anchor is the best form for a soft muddy bottom. On a hard rocky bottom, the dead weight of the moorings must be depended on to keep a mine stationary, and, if a very heavy mushroom anchor is used, its edges should be furnished with toes or points, as shown in Fig. 20, to catch in the crevices of the rocks. Plenty of buoyancy should be given to the case to keep the charge stationary; buoyancy about equal to the weight of the charge will suffice in a current of four knots an hour, but it might be increased with advantage on a stronger current. With a current up to four knots an hour a single iron wire cable, with an anchor which holds sufficiently, will answer every purpose; but where the current is very strong, with a rise and fall of tide, it will probably be necessary to moor with two cables, one from each end of the case, and two ordinary anchors. When two cables are used, they should be placed as far apart as possible, and the anchors well spread out, and the buoyancy should be sufficient to keep the cables very taut. From the experiments made at Chatham, it has been found that, two cables attached to a case close to each other, twist together immediately, and the case is by this means soon drawn down out of position. When anchors are not obtainable, heavy blocks of stone or pigs of iron ballast, or any heavy weight, may be used to replace them for moorings.

The following suggestion by Lieutenant Jekyll, R. E., is worthy of consideration, and would no doubt be found practicable in many cases, if not with very large, certainly with charges of moderate size:

Mooring to a heavy chain suggested by Lieutenant Jekyll, R. E.

"Submarine mines used defensively will generally, if not always, be moored in straight lines.

"In practice, the greatest difficulty is experienced in mooring any object in a particular spot, especially when two mooring-chains are required, as will sometimes be the case, to prevent twisting. I suggest that, instead of anchors, a heavy chain cable be employed to moor the mines.

"A section of the channel to be defended having been made, the line assumed by a chain could be laid down to scale. The positions of the mines and their distances apart, depth from the surface, &c., having been arrived at by calculation, could also be laid down on the section. The points where the small mooring-chains of each mine meet the large chain would appear on the drawing, and the distance of each point from either extremity having been measured off the scale, could be marked on the chain.

"Before sinking the heavy chain, the small mooring-chains should be rove through the links at the places marked, and the ends buoyed, sufficient length being allowed for the buoys to reach the surface.

"The conducting-wires could next be laid, and the ends attached to the same buoys which support the mooring-chains. In this way everything could be prepared, the cables tested, &c., before the mines were required at all; indeed, if the operation of fixing the same were practiced beforehand, it could be left out until there was considerable probability of the mines being required for use. By keeping the mines ready loaded in suitable magazines, and having the cables frequently tested, the probability of injury would be greatly diminished.

"The great advantage of using a heavy chain would be the absolute certainty of having all the mines in their proper places; it would also simplify the moorings by doing away with a multiplicity of anchors and anchor-buoys.

"A 2½-inch chain cable weighs 400 pounds per fathom. The mines would probably never be nearer than 70 or 80 feet apart, so it is evident that the chain would be quite heavy enough to counteract any flotation which would in practice be given to the mines."

In a current of any strength, it would be necessary to use two parallel chains across the current, to prevent the mines swinging with the change of tide, but the same advantages would hold good.

This idea is quite compatible with the system of hauling down the mines to previously placed moorings, as it would only be necessary to supply a pulley, of the form already described, shackled on to the chain cable at proper intervals, and with the necessary tackle rove through them.

Placing moorings in connection with a directing hawser, suggested by Lieutenant Bucknill, R. E.

A modification, suggested by Lieutenant Bucknill, R. E., on Lieutenant Jekyll's plan, has been tried in the Medway, in 7 fathoms of water, and been found to answer very well. The arrangement used was as follows: A strong hempen cable was laid out across the river, from the mooring-lighter at Catness, the outer extremity being anchored. Previous to immersion, this cable was marked at intervals, at the points where it was intended subsequently to lay down the line of mines in connection with it. In this state it might have remained at the bottom of the river for a considerable time without injury, the slack having been taken up in order to keep it in a fair and even line, and prevent unnecessary movement. To place the moorings in position the following course was adopted: A mushroom anchor, with gear attached, having been attached to one of the davits of the pinnance, the directing-hawser was slacked off sufficently to admit of its being underrun, and was passed over the bow of the boat at the fore row-locks; she was warped along to the position required, as indicated by the mark previously made in the hawser. One end of a branch hawser was now bent on at this point, and the other extremity made fast to one of the eyes on the mushroom anchor, the necessary amount of slack being left to allow the anchor to be passed into its proper position. For small charges up to 100 pounds of powder, a distance of 30 feet, or a little more, from the directing-hawser would probably be sufficient, and, when no greater distance than this is required, it only remains to cut away the spun-yarn lashings securing the cable which retains the mooring at the extremity of the davit, and, thus set free, the anchor falls into its required place. On actual service, however, much larger charges than 100 pounds would be used, and it would be necessary to place the moorings at a greater distance than 30 feet from the directing-cable; to do so, it is only necessary to veer out the branch cable, thus letting the boat drop down to the position required, and cut away the lashings as before. The anchor having thus been got into position, any further arrangement for attaching the charge, electric cable, and circuit-closer, may be carried on without difficulty.

Favorable weather necessary while placing moorings in position.

Favorable weather, and a proper direction of current, especially in a tidal channel, are very essential to success when the operation of getting moorings into position is undertaken, the difficulties being much increased by a fresh breeze and rough water. It must be borne in mind that, in order to insure a maximum of efficiency, the position of the moorings must be defined within very narrow limits.

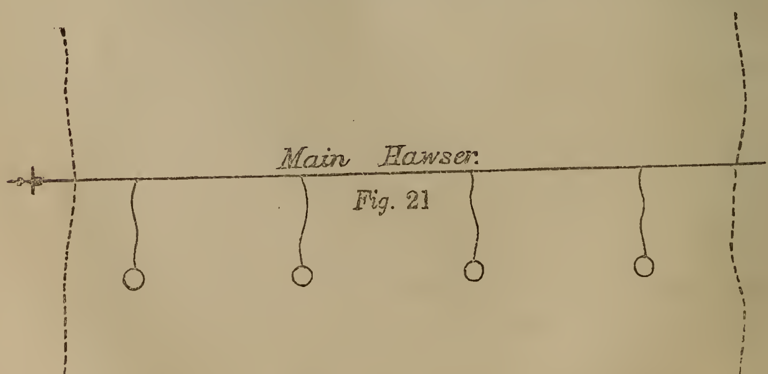


Fig. 21

One or two lines of mines may be laid on this principle in connection with a single heavy hawser or mooring-chain.

The general arrangement of a single line so constituted is shown in Fig. 21, and that of a double line in Fig. 22.

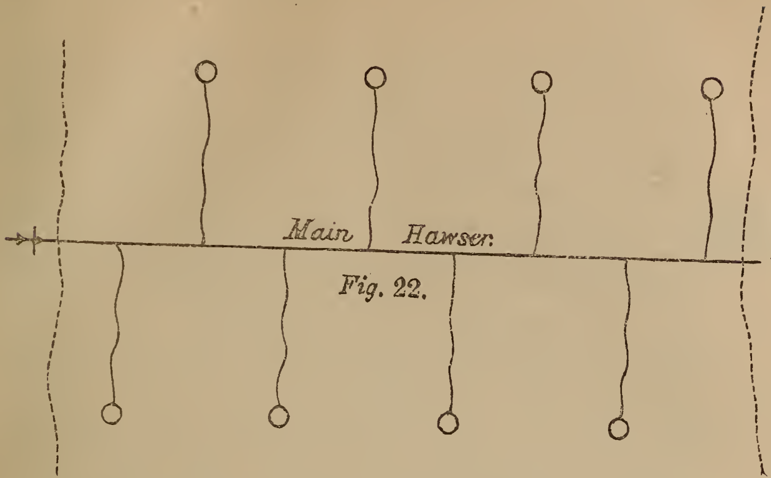


Fig. 22.

This plan affords considerable facilities for the examination of charges after they have been submerged. In order to reach any particular charge it would only be necessary to underrun the main hawser till the required branch was reached, by it to raise the mooring-anchor, and with it the mine to be examined. In the event of the main hawser being broken, it would not be a very difficult operation to grapple it and bring it to the surface for repair. When the main hawser is not in use for any of the purposes above mentioned, all slack should be taken in to prevent unnecessary motion. This system appears to answer very well up to a depth of seven fathoms, and it would be very desirable to try it in very much deeper water. Examination of submerged charges.

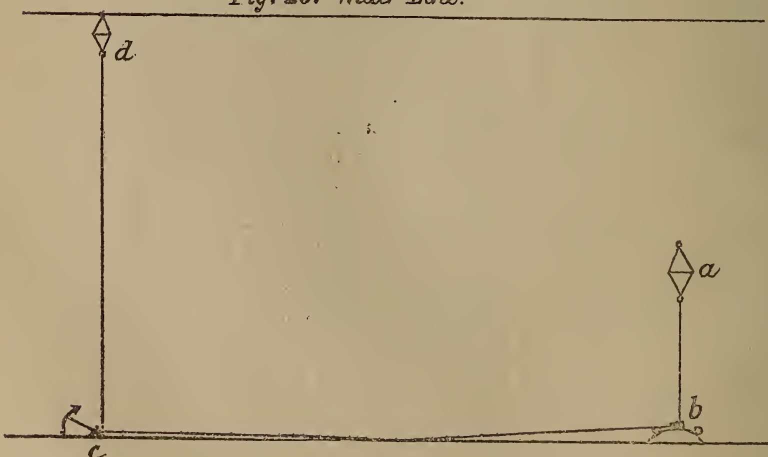
The fact that the exact position of a mine, within a yard, must be known to the defenders, must be always kept in view; and in order to simplify identification as much as possible, an arrangement in lines, directed on some given point, will generally be best. This would seem to be an additional reason for placing the moorings first in correct position, and afterward hauling the mines down to them, and would seem to be the easiest and most practical course whether a single mooring cable is used or whether a mine is moored fore-and-aft to resist an extraordinary current, as, for instance, an unusual rise and fall of tide. In a broad channel and with deep water, as, for example, at Spithead, the difficulties of arrangement in lines would be increased, and probably in such a case it would be necessary to anchor a couple of large vessels fore-and-aft, and, after hauling them into the exact line, to connect them by a hawser, by which latter the boats engaged in lowering the moorings would be guided.

It would, in many cases, be not only desirable but necessary to place the moorings in position at leisure in time of peace, and thus the most difficult and tedious part of the operation being done, a channel could, on a threatening of hostilities, be very rapidly put in a state of defense.

Power of working the running-gear of any hauling-down arrangement must be retained.

When an anchor has been placed in position it is necessary to retain the power of working the running-gear, in connection with the hauling-down arrangement, in a practical form, and for this purpose the arrangement shown in Fig. 23 is suggested. In this arrangement a buoy (*a*) is placed in connection with one end of the cable, rove through the pulley (*b*) shackled on to the eye of the mushroom anchor, while at the other end an ordinary anchor (*c*) is attached. This latter is cast at such a distance from (*a*) that there is no chance of entanglement between the cable attached to the latter and that in connection with the anchor-buoy, (*b*.) By this arrangement it is manifest that, by weighing the anchor, (*c*,) both ends of the line rove through the pulley or loop (*b*) may be obtained at any moment with facility, and there is no chance of the two parts of the mooring-cable becoming twisted round each other, however long they may have remained submerged. It is essential to efficiency that there should be no such winding round each other of the

Fig. 23. Water Line.

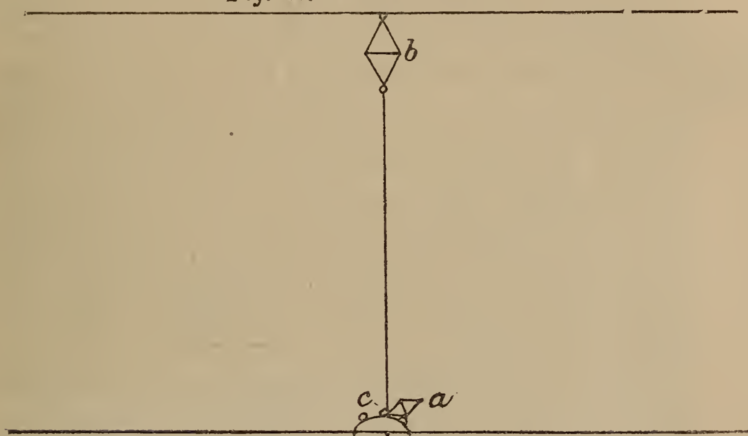


two parts of the cable, as even a single turn would destroy the action of the running-gear through the pulley. If the buoy (*d*) cannot be conveniently used, the anchor (*c*) may be deposited in position without it, and, should it be necessary to weigh it, the line (*b c*) could be easily grappled and brought to the surface, sufficient slack being allowed for this purpose. An ordinary weight of any sort, sufficiently heavy to counteract the upward pull of the buoy, (*a*,) might be used instead of the anchor, (*c*.) The buoy (*a*) should be kept some distance below the surface, as well to prevent injury to it by vessels striking it, as to keep its position, which would indicate that of a future submarine mine secret.

Arrangement of running-gear suggested by Quartermaster-Sergeant Mathieson, R. E.

A modification of this plan, shown in Fig. 24, has been suggested by Quartermaster-Sergeant J. Mathieson, R. E. It consists in simply arranging two buoys, one at each end of the running-gear, passing through the pulley

Fig. 24. Water Line.



or loop (*c*) in such a way that the buoyancy of one of them, as (*b*,) shall considerably exceed that of the other, (*a*,) and the latter, having been hauled down close to the moorings, would be held there till required to be moved. In such an arrangement care must be taken to make the buoy (*a*) sufficiently strong to resist the continuous pressure of the water at the depth at which it is required to remain. It possesses the advantage over the system first described of greater simplicity, but is more easily disarranged, for if the buoy (*a*) rose slightly, from any depression of the buoy (*b*,) there would be a certain amount of slack in the cable, and a consequent capability of entanglement by twisting around that part of it attached to (*b*,) which would at once destroy the efficiency of the combination. It has, however, been tried practically in the Medway, in five or six fathoms of water, with considerable success.

Whichever of these plans is adopted, the utmost care is required in keeping the cables and buoy-lines clear during the process of lowering the moorings, as well as in subsequent manipulation, as any entanglement would be fatal to success, and more care is necessary with the second method than with the first. When laid down, too, they should be examined at intervals to see that the running gear is in working order.

A mine on the bottom must be so heavy as to remain stationary.

Where a charge is to be laid on the bottom, it should be of sufficient weight to insure its remaining stationary. Lieutenant Wallace, in his account of the demolition of wrecks in the Hoogly, gives his experience as follows: "Sometimes, in a strong tide-way, a charge of 500 pounds of powder required a weight of about 400 pounds to sink it; whereas in slack-water less than half that amount was sufficient." These weights, of course, refer to charges arranged in barrels, as used by him, and in all cases the weight of any particular form of case must be taken into account.

Mode of placing a charge in position.

The next point to be considered is the best mode of lowering a heavy charge into its position at the required depth below the surface, and, when lowered, of attaching it to the anchor. Two modes have been described by which this may be effected; either by first measuring the depth of water by sounding, then attaching the anchor, with the necessary amount of cable, and lowering both together, or by lowering the anchor first and drawing the charge down to it, and, when it has reached the required depth, there fastening it securely.

The first plan is so simple that it requires no explanation. Our experiments have, however, proved that when it is required to place a mine in position, the limits of which are defined, it is practically impossible of execution, except with small charges, very moderate depths of water, and favorable circumstances of weather and current. By the second method a mine may be placed much more accurately in position, and it is practically much more easy of execution.

Barge used by Austrians for mooring submarine mines.

The Austrians employed a large boat or barge, on which a derrick was erected, by which the anchor or mooring arrangement was first lowered into its place. To this anchor was attached a certain amount of wire cable, to the upper extremity of which was fixed a pulley, Fig. 10, already described. Before the anchor was lowered into the water, an iron chain attached to the case was passed through the pulley, and by it the charge was drawn down to any required depth and there held by the self-acting arrangement previously alluded to, Fig. 11.

When the heavily-weighted wooden platform, also used occasionally by the Austrians for mooring purposes, was employed, the charge was held down to the required depth by three mooring cables, one attached to each angle of the platform, and the only difference was that three pulleys and keying arrangements were required instead of one, as used with the anchor. The Austrians, however, carried on their operations where there was no tideway, but it is probable that a charge, moored by three cables in this way, might twist and be drawn down if acted on by a current, unless the three points to which the cables were attached were placed very far apart.

We have now had some experience in placing charges in position, by the method of hauling down to an anchor already laid, and keying by the Austrian and other catch described, and it is certainly not only quite practicable, but in many cases preferable to any other plan that we have tried.

In our experiments at Chatham the apparatus at first used for placing the charges in position was composed of any materials that could be obtained on the spot; and we have since gone into the question of the special apparatus and arrangements best suited for the purpose. Some of the charges moored in the earlier stage by a single mushroom anchor were lowered from a ponton-raft by means of a derrick erected thereon. A raft of this nature forms a tolerably good platform from which to carry on such an operation in smooth water. It possessed one serious disadvantage, however, namely, that there being no gunwale, small stores were frequently pushed overboard and lost. If, therefore, a ponton-raft is ever used as a make-shift for such a purpose, it would be desirable to add a temporary gunwale to it. Our experience in mooring submarine mines may be summed up as follows: When possible, place the moorings in position at leisure, and be very careful to get them into the exact sites previously decided on for the mines.

Ponton raft used for mooring purposes.

Experience derived from experiments at Chatham.

Arrange the running-gear in the simplest form, and try it at intervals to see that it keeps in good order.

When a channel is to be put in a state of defense, bring the charges to the required point, and haul them down into position.

With a current up to four knots an hour, a mine may be efficiently moored with a single wire-cable, provided plenty buoyancy is given.

With a current of five knots an hour or more, charges, to be held in a defined position, should be moored fore and aft. For this purpose a double line of moorings is required, and in hauling down it is necessary to take care that the top is horizontal when the mine is in position.

Mode of mooring with a considerable rise and fall of tide.

There is one problem, with reference to submarine mines, which has still to be solved, namely, that of mooring in a spot where there is a considerable rise and fall of tide, so as to show no indication, or at least a minimum of indication, on the surface as the depth of water decreases. Many suggestions have been made with a view to the solution of this question, but none can be said to be completely successful.

Mode of mooring suggested by Quartermaster-sergeant J. Mathieson, R. E.

Quartermaster-Sergeant J. Mathieson, R. E., has suggested the use of a small buoy, just sufficient to give that amount of flotation necessary to keep a circuit-closer always suspended at a given distance below it, the circuit-closer itself being slightly heavier than its bulk of water. The arrangements of this plan were found to be too delicate to be practically useful; the slightest leak in the small buoy at once disarranged the efficiency of the combination; any lodgment of sea-weed or other floating matter was also equally fatal, as it increased the weight and consequently disarranged the very delicate balance necessary to successful working; and the small buoyancy of the whole combination rendered it liable to be acted on by a comparatively small current and thrown out of position, which, for reasons already given, would be a serious objection.

Mode of mooring suggested by Lieutenant W. E. Peck, R. E

Lieutenant W. E. Peck, R. E., has suggested the use of a compressible buoy, arranged to act, through a pulley, so that as the water fell and the pressure was consequently reduced, it would expand, and, by the increased flotation thus acquired, draw a charge, in connection through a pulley with it, down. An India-rubber buoy might no doubt be made to fulfill the necessary conditions as to compressibility, but there would be great difficulty in getting any combination so nicely balanced as that suggested must necessarily be, to work automatically through a pulley which had been submerged even for a comparatively short time; the friction occasioned by oxide has been found, under such circumstances, to be very great.

Mode of mooring suggested by Lieutenant R. F. Moore, R. E.

Lieutenant R. F. Moore, R. E., has suggested hauling a line of mines or circuit-closers down mechanically, by means of a cable connected therewith made fast at one extremity and passing through a fixed pulley to a windlass at the other. The fixed extremity of this regulating cable and the pulley, through which it passes to the windlass, must both be below the lowest level to which it is necessary to haul down the mines, and consequently below the surface of the water. In order to raise or lower the mines thus arranged it would only be necessary to slack out or haul in the cable, by means of the windlass as required, and it is easily seen that a comparatively small amount of cable taken in or let out would effect the necessary difference of level in the mines. In such a combination the mines should have plenty of buoyancy.

In this system it is to be feared that the friction, inseparable from the use of pulleys submerged for any length of time, would act prejudicially. This combination has still to be tested; it seems, however, worth trying, and if successful might probably be used in certain positions with advantage, especially if the number of mines attached to each cable is not very great.

Stationary arrangement of moorings for a channel with considerable rise and fall of tide.

In the absence of any reliable system of mooring, to fulfill the necessary requirements with a considerable rise and fall of the tide, and for the present we cannot lay down any definite rules on this point, it would be necessary to arrange the mines to float at such permanent levels as to be sufficiently near the surface at high water to act effectually, and yet not so near as to be visible at low water. By the use of large charges, with a proportionately large radius of explosive effect, this might probably be done except in extreme cases; and where it would be impossible to keep them absolutely out of sight, the mines and circuit-closers might be covered with sea-weed, or disguised in any suitable way, in order to conceal to the utmost their real nature.

When necessarily visible circuit-closers, &c., to be disguised.

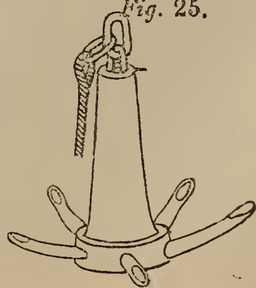
Use of dummies.

In all cases, and in this especially, dummies should be freely used to perplex an enemy and conceal the position of the real mines. These dummies should bear a close resemblance to the real article, should only be sufficiently conspicuous to attract attention, without revealing their real character, and might be placed in any convenient position, or even occasionally shifted at night, so as to increase the delusion and perplexity.

Extemporized moorings.

A mushroom anchor is in most cases, and especially on a soft muddy bottom, the form which seems best adapted for mooring submarine mines. Such articles may not, however, always be at hand, and it may become necessary to use some extemporized arrangement. That shown in Fig. 25, and consisting of a strong heavy wooden shaft with a number of wooden arms or flukes was, after experiment, considered a very good form by the authorities of the United States of America. This might easily be made wherever hard-wood timber is available.

Fig. 25.



Again, the wooden weighted platform of the Austrians is one that might be easily constructed in many cases. It seems particularly applicable where a charge is to be moved over a rocky bottom or bad holding-ground, where it must be kept in position by the dead-weight of the arrangement. The wooden platform affords a broad space on which any number of heavy weights can be conveniently placed and the materials of which it is formed, viz, wood and iron, are procurable everywhere. The system of mooring by these cables seems objectionable, as, with a current, they would be very likely to become twisted together; but there is no reason why a single cable from the center should not be adopted if proper precautions to strengthen the connection of the central point, to which the cable would be attached with the outside by means of iron stays, or in some other manner, were used.

Ordinary anchors.

It is unnecessary to describe how ordinary anchors may be used for mooring submarine mines.

Large stones, pigs of ballast, &c., for mooring purposes.

Large stones, pigs of ballast, or any heavy weights may be used where the more appropriate forms of apparatus cannot be obtained. These must necessarily be sufficiently heavy to hold a mine in position by their simple dead-weight.

Weight of moorings.

A very important point for consideration, is the weight of the anchor or mooring apparatus necessary to hold any given size of charge in position. This will depend on its buoyancy, and the strength of the current in which it is to be moored, and also on the nature of the bottom or holding-ground.

The Austrians recommend very heavy moorings—as much as seven times the weight of the charge of powder in certain cases.

This was necessary, because the Austrians always hauled a buoyant charge down to its proper position after its moorings had been placed. The large excess of weight acted against the strain in hauling-through the block, which was, of course, equal to that of the buoyancy on each portion of the rope, or double on the whole. Without a considerable excess of weight, we have found that, during the process of hauling down, the moorings are very liable to be drawn out of position.

Calculation of weight of moorings.

As, however, the tendency to move depends on the amount of buoyancy, the pressure exerted by the current, and the tenacity or otherwise of the holding-ground, the weight of anchor or mooring apparatus necessary to overcome that tendency to move may be calculated as follows: Let B be of the buoyancy, or excess of flotation over weight of a charge of a given submarine mine; let P be the pressure exerted by any given current on the same mine when moored to the bottom and floating freely therein, it is evident that the resultant of these two forces, or $\sqrt{B^2 + P^2}$, gives the force tending to move the mine out of its position. Now, suppose a case where the water is absolutely still, P becomes nothing, and the force tending to move the mine would be simply equal to B, the buoyancy, and that force would be exerted in a vertical direction. To balance this we should require an effective weight exactly equal thereto, and taking into consideration the necessity of providing an excess in order to keep the mine stationary, it would be necessary to at least double such weight in practice. In calculating the weight to be opposed to the flotation in order to keep a given mine from drifting out of position in consequence of the action of a current, the effective value of the anchor or moorings must be taken as its weight, minus the weight of water displaced by it. The loss of weight by immersion would, of course, depend on the bulk of the mooring apparatus to which the mine is attached, and, when this bulk is considerable, it becomes a most important consideration in the calculation; when a simple iron mushroom anchor is used, it is probable that its weight, if double the buoyancy, would be amply sufficient in perfectly still water. Again, let W be the weight of mooring required; if the foregoing conclusions are correct, we should then have

$$W = 2\sqrt{B^2 + P^2}$$

In still water, where $P = O$, W would be equal to 2B, or double the buoyancy as already assumed to be sufficient.

Where it is intended to haul a mine down to moorings previously placed, more than double the buoyancy would be necessary, for the reasons already given.

Amount of buoyancy.

A very important element in the above is the amount of buoyancy necessary to be given to a buoyant mine, and here again we must start from some kind of assumed basis, and, from the experience we have had in mooring operations in the Medway, it would seem that, even in still water, the buoyancy should not be less than the weight of the charge; and where a current exists it should not only not be less than the weight of the charge, but should be not less than three times the force exerted in the form of lateral pressure by that current. For example, if it were required to move a 500-pound charge in still water, it ought to have a buoyancy of 500 pounds as a minimum. Now, suppose it to be subjected to a lateral pressure due to a current of four knots an hour, which, on a cylindrical curved surface, may be put down roughly at 300 pounds for the size of case which would be required for a 500-pound charge, it should then have a flotation of not less than 900 pounds. In calculating the pressure exerted by a current on a cylinder, assuming the curved surface to be presented to it, half the pressure which would be exerted on a flat surface equal to its greatest sectional area may be taken; this will be near enough for the purpose. We have assumed the buoyancy, in the case where a current exists, as equal to three times the pressure exerted by that current, in order that the mine may not be moved far out of a central position, vertically over its moorings, such motion being limited by the direction of the resultant of the two forces acting on it; when the mooring-cable is very short, however, this buoyancy may be considerably reduced. In any case when a buoyant mine is to be retained within certain limits, when moored with a given length of cable and acted on by a known current, it is a very easy matter to calculate the buoyancy necessary to produce the required result.

Excess over calculated buoyancy necessary.

An excess of buoyancy over the calculated amount is always necessary to obviate the ill-effects of slight leakage or any other disturbing cause which might tend to reduce efficiency. It is probable that an addition of one-fourth would be sufficient in cases where the conditions are favorable, but more may be added where imperfect or makeshift arrangements are employed.

Muddy bottom favorable for mooring operations.

The deductions to be derived from the above statement are applicable only to cases in which the bottom is hard, and the mine must be held in position by the simple dead-weight of the anchor or mooring apparatus to which it is attached. When the bottom is soft this weight may be considerably reduced, and in an extremely soft muddy bottom like the Medway, it is probable that three-fourths of the weights, calculated as above, would be sufficient, especially where an anchor of the mushroom form is used, this form being very applicable to such situations.

A 10-cwt. mushroom anchor, left for three or four weeks at the bottom of the Medway, was found to have sunk completely into the mud, and it required very strong tackle and a mooring-lighter to weigh it.

To facilitate search by a diver for an anchor at the bottom of a river, it has been found a good plan to paint it white.

Calculation of lateral pressure.

In order to calculate the lateral pressure exerted on any mine by a given current, the following formula may be used:

$$P = 4.085 \times V^2$$

where V = velocity of the current in miles per hour. From this equation P will be found in terms of pressure in pounds per square foot of flat surface, which is, as already stated, nearly double that on the curved surface of a cylinder.

CHAPTER VI.

MODE OF IGNITION.

Having determined on the form of case, size of charge, and mode of placing submarine mines in position, it next becomes necessary to decide how they shall be ignited so as to do as much damage as possible to an attacking ship. This may be done either mechanically or by electricity.

First with regard to the mechanical mode of ignition. Mechanical ignition

Several arrangements have been tried, with more or less success, by which charges of powder may be ignited by mechanical action. In several of the confederate torpedoes, which were raised from the bottom of the James River at Richmond, and the drawings, and some of the originals of which I had an opportunity of seeing, through the kindness of Brigadier-General Michler, of the United States Engineers, a simple gun-lock and percussion-cap were used. These may be considered as among the most primitive contrivances of this nature, and, from various circumstances, such as oxidation or incrustation in the metal in the more delicate parts, perhaps the least likely to act at the right moment. An improvement in this was the simple percussion system, by which a charge was ignited by the vessel herself striking directly on a cap containing a detonating mixture; the most delicate of these, mentioned by Captain Harding Steward in his notes on submarine mines, appears to be Brook's fuse, which was arranged in the form of a nipple projecting from the case containing the charge, formed of copper of different thicknesses, according to the amount of sensitiveness to be given, and primed with fulminate of silver. The details of this fuse are given in Captain Harding Steward's paper already referred to, and need not therefore be repeated here. Several other forms of detonating fuse were also tried by the confederates, both for land and submarine service. An account of several ideas for mechanical ignition, devised from time to time, may also be found in the report of the committee on active obstructions.

Simple gun-lock.

Brook's fuse.

Another mode of mechanical ignition used by the confederates, and previously by the Russans in the defense of the ports in the Baltic, is the well-known sulphuric-acid fuse, formed on the principal of ignition by sulphuric acid dropped upon a mixture of equal parts of chlorate of potash and loaf sugar. The sulphuric acid was placed in a small

Sulphuric acid or chemical fuse.

glass globule, which was so arranged as to be broken by a blow which would be given on touching the side of a vessel, and the acid set free, falling on the mixture of chlorate of potash and loaf-sugar, produced the required ignition.

Captain Harding Steward gives an account of the attack of the United States frigate Minnesota by the confederate torpedo-boat Squib, in which Captain Davidson, who was in charge of the latter, attributes the partial failure of his attack to the slow ignition produced by the chemical fuse (sulphuric acid, chlorate of potash, and loaf-sugar) used; he supposes that, in consequence of this comparatively slow ignition, the torpedo-boat had recoiled 3 or 4 feet before the actual explosion took place.

Improved chemical fuse.

There is no doubt that ignition by the sulphuric-acid fuse is comparatively slow—that is to say, slow as compared with that of gunpowder; but it may be very much improved by the addition of a small quantity of ferro-cyanide of potassium or sulphuret of antimony. From experiments made in the chemical laboratory at the School of Military Engineering, Chatham, it has been found that an addition of one-third of ferro-cyanide of potassium to the mixture of equal parts of chlorate of potash and loaf-sugar, produces an ignition as rapid as that of gunpowder.

Sodium or potassium fuse.

Another very simple mode of producing ignition has been suggested by Captain Campbell Hardy, of the Royal Artillery; it is simply caused by dropping water upon the metal sodium, when ignition takes place. Potassium would also answer the purpose, but is inferior to sodium, the latter having a greater affinity for oxygen. Captain Hardy made several experiments with this substance at Halifax, Nova Scotia, with good results; the only fault he found with it was its comparatively slow ignition, which, however, he thinks might be improved by piercing the body of the sodium with small holes. It would be well worth while making a few experiments with this substance, for even if the results obtained from it are not so good as those of the more approved form of chemical fuses, it is so safe to handle that it presents many advantages which might be brought into use where other forms are not obtainable. The metal sodium can now be procured almost everywhere, in the form of a paste, which is easily cut and manipulated. It must, however, be preserved in naphtha or some substance containing no oxygen, or it would soon absorb oxygen from the air and become useless as an explosive agent.

Abel's torpedo-primer.

The following description of an adaptation of the sulphuric-acid fuse, arranged by F. Abel, esq., F. R. S., chem-

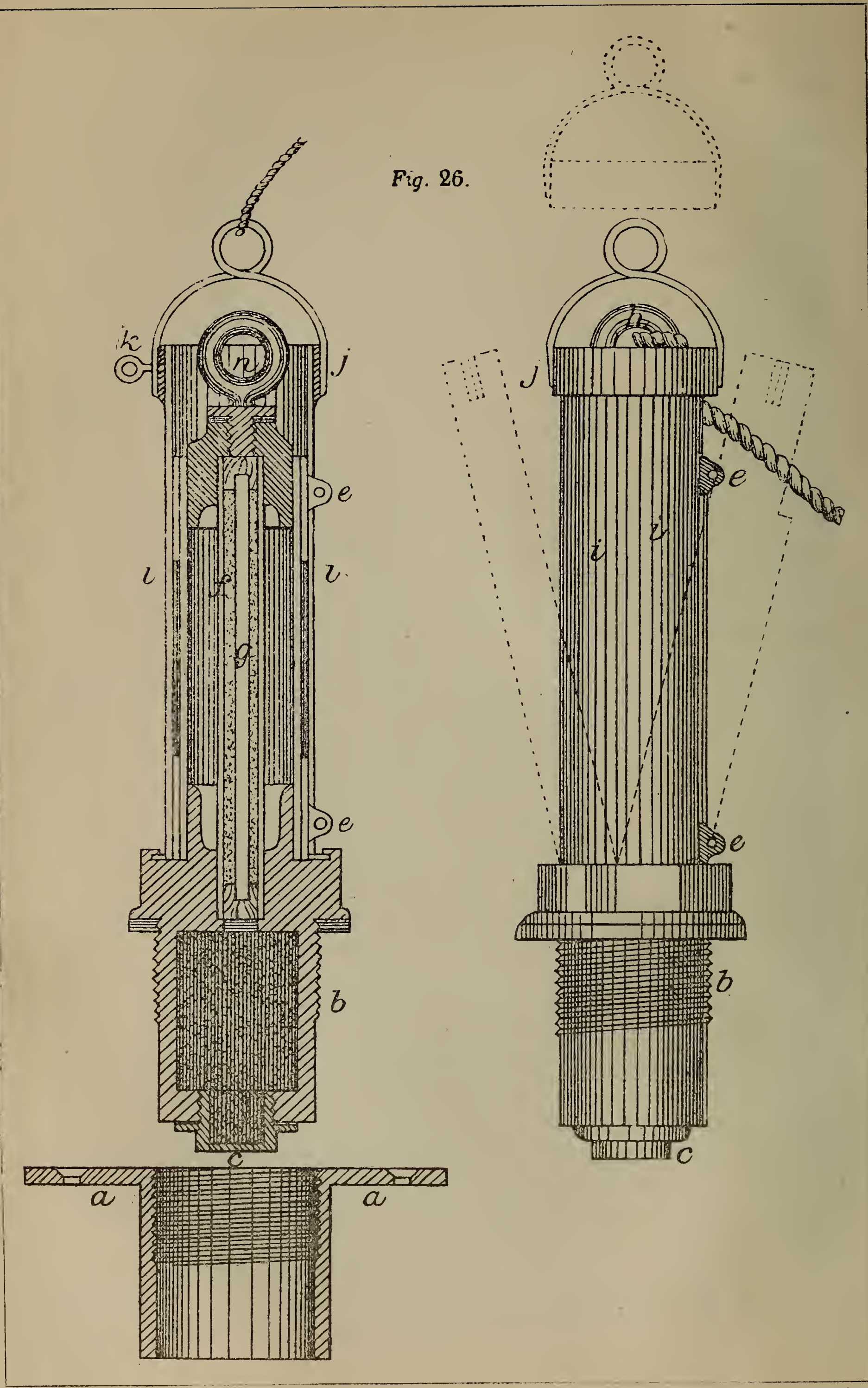


Fig. 26.

ist to the war department, has been approved by the floating obstruction committee, and is extracted from their report :

"In Fig. 26, (*a*) shows the socket to receive the primer, which is arranged to be fixed firmly on to the case containing the charge, as shown in Fig. 27; (*b*) is the powder-chamber to hold the priming charge; (*c*) is a screw-nut closing the powder-chamber; (*d*,) Fig. 27, a flexible India-rubber tube; (*e*, *e*) are screw-bands; (*f*) a lead tube containing the explosive mixture; (*g*) a glass tube containing oil of vitriol; (*h*) eye to receive the firing line; (*i*, *i*) guard in segments; (*j*) guard ring, (*k*) a screw pin."

"Before the charge is placed in position, a cord or wire is attached to the eye of the guard-ring (*j*), and the screw-pin (*k*) in the side of the guard-ring is removed. When the primer is to be rendered active, after it has been placed in position, the guard-ring (*j*) is removed by pulling the cord attached to it. When this has been accomplished the guard (*i*, *i*) will fall away from the primer, leaving it active. The safety-guard of the primer is on no account to be removed until the mine has been placed in the position assigned to it. When a sufficient strain is put upon the eye (*h*) the lead tube (*f*) bends and the fraction of the glass tube (*g*) is thus determined, whereupon the primer is fired."

The socket (*a*), Fig. 26, which is to receive the primer, and which accompanies it in the packing-case, is fixed by means of screws or rivets into the opening of the vessel which is to be converted into a submarine mine. The usual precautions are to be taken to make the junction between the socket and the case water-tight. A piece of iron-rod, about twelve inches long, is bent at the end into the form of an eye; the other end is then screwed or driven into the case, in such a position that the rod is parallel to the primer when the latter is inserted in the socket, (as shown in Figs. 28 and 29.) In this operation, care is necessary to prevent the rod being so driven or screwed into the case as to cause leakage under the pressure of water after submergence. The distance between the rod and the primer should be about six inches, and the eye of the rod should be about two inches lower than that of the primer. The nut at the base of the primer (Fig. 27) is removed, and the powder-chamber (*b*) is filled with gunpowder. The nut is then replaced and screwed down tightly by means of the spanner provided for that purpose. The charged primer is screwed down as tightly as possible upon the washer by means of the spanner. The position of the fixed primer is shown in Fig. 27. The firing

Primer-socket.

Fair lead.

Charging primer.

Firing line.

line is passed thorough the eye of the rod, and is then firmly attached to the eye of the primer, (h,) as shown in Fig. 28. For this purpose the line must be passed through the hole in the guard provided in it, in order that the guard-ring may be pulled away after the charge is under water. The connection of the firing line with a jack-stay or with the line of another mine, may be accomplished either before or after it is attached to the primer. A wire of copper or iron, or a small line coated with wax or pitch, sufficiently long to reach to the surface of the water, after the charge has been placed in position, is attached to the eye of the guard-ring. The loose end of the wire should be attached to a small float, so that it may be recovered at any time. When the mine is ready to be submerged, the small pin (k) in the side of the guard-ring is removed. This pin is not essential to the security of the guard, and may, therefore, if thought advisable, be removed earlier. It is only provided to prevent the guard-ring being removed by persons who may be needlessly meddling with the primer. If it is intended to leave the guard upon the primer some considerable time after it has been laid down, it will be advisable to lubricate the bearings of the guard upon the ring. For this purpose the screw-pin is removed, the lubricating agent (grease or oil) is applied between the guard and the ring, and the latter is then twisted round two or three times, so as to insure the lubrication of the bearings. This should be done, in every instance, before employing the primers, if they have been in store for some considerable time. Whenever it is intended to render the mine active, the guard-ring is removed by pulling the cord or wire attached to it; the guard will then fall away from the primer. By bringing the guard-ring to the surface the operator will, therefore, know that the mine is in working order.

Lubricating guard-ring.

Removal of guard-ring.

Different modes of arrangement for use with a mine.

This primer may be arranged for the ignition of a mine at will from the shore, as shown in Fig. 30; or by the contact of a passing vessel, as shown in Fig. 28 and 29.

This form of fuse is now an article of military store, and may be issued on requisition.

Defects of mechanical fuses.

The great defect of all forms of self-acting mechanical fuses, is the danger, almost inseparable from them, of accidental ignition; a blow given by accident in handling these affairs may produce a most disastrous explosion, and there is consequently a considerable amount of danger to be incurred in placing them in position, and still more in clearing them away. In the form recommended by the floating obstruction committee, security is to a certain extent ob-

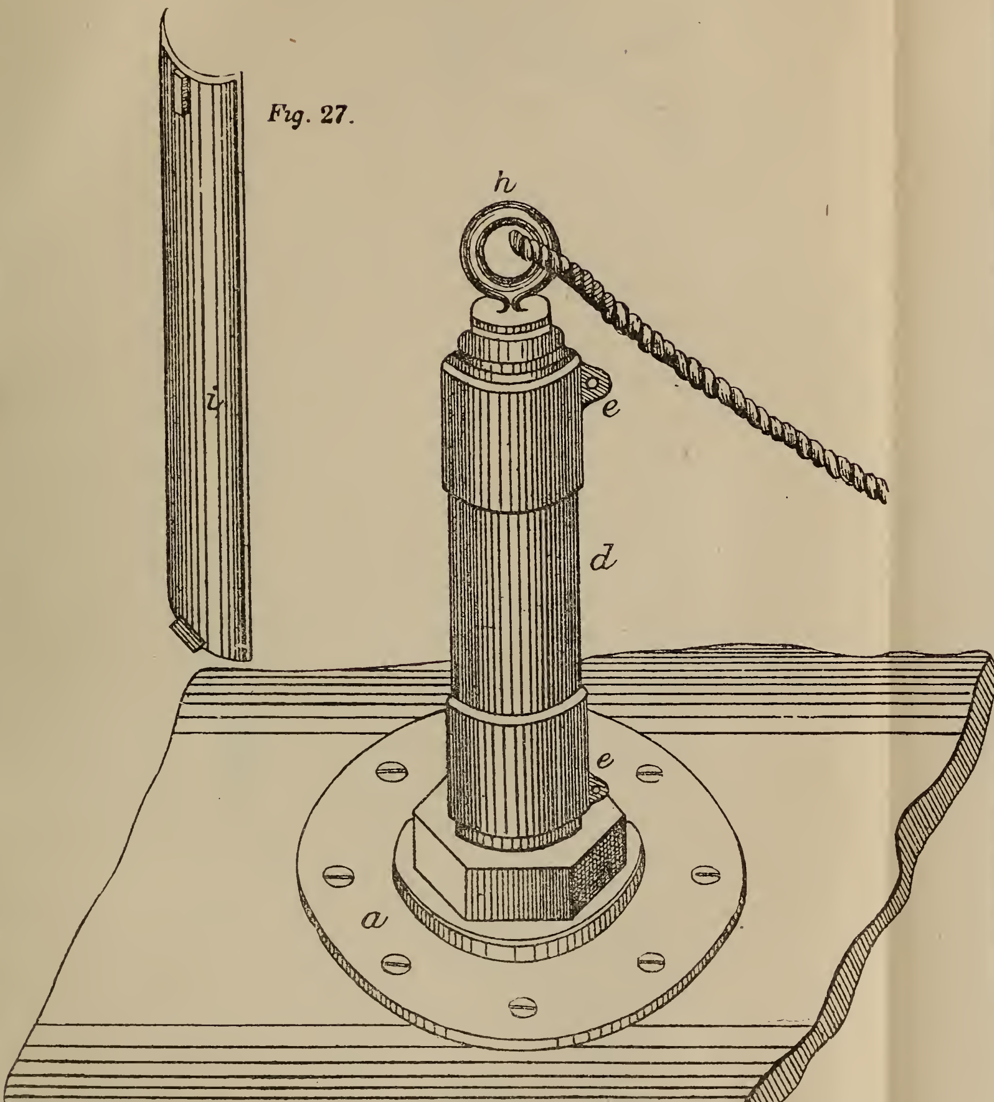


Fig. 27.

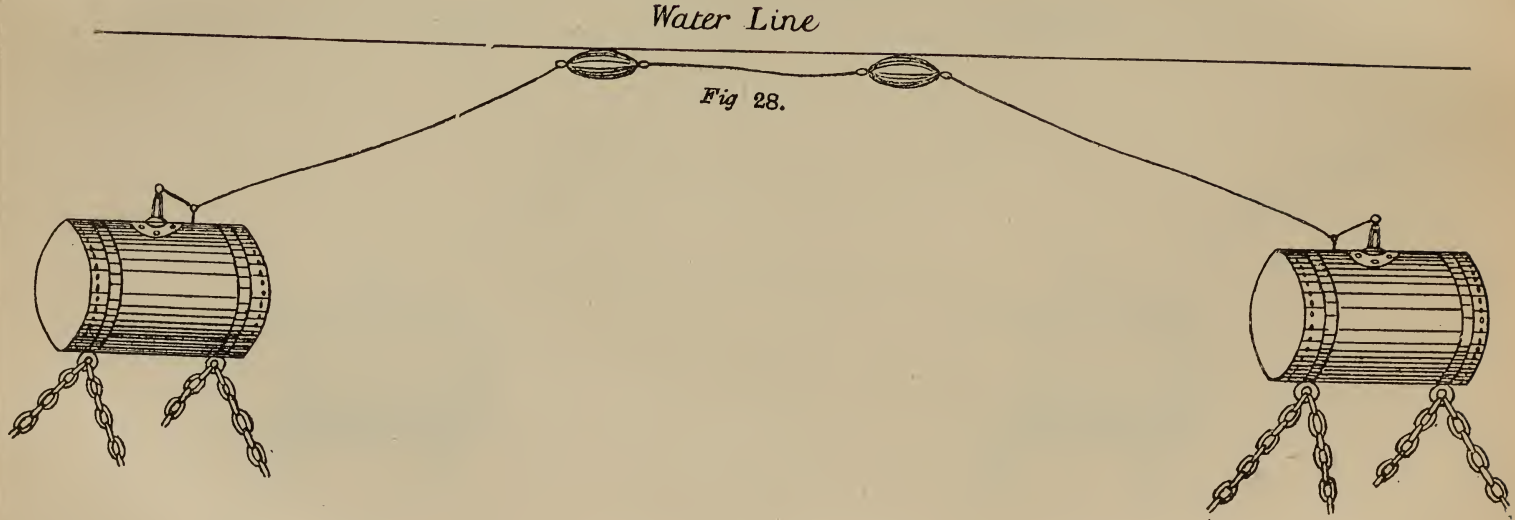


Fig 28.

Water Line. **Fig. 29.**

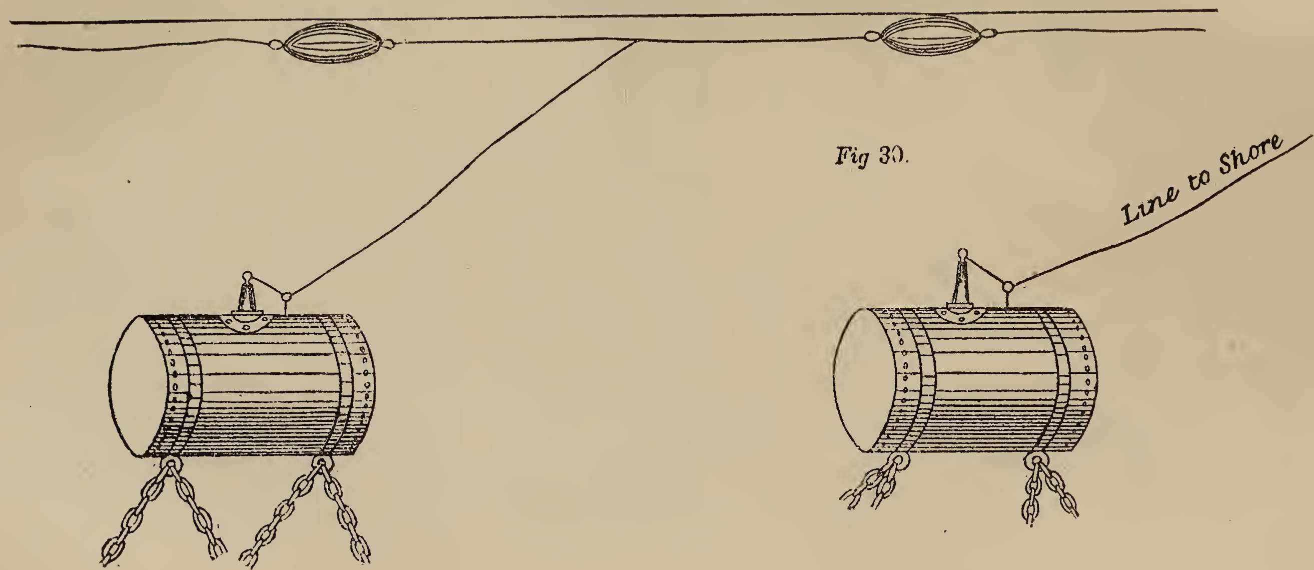


Fig 30.

tained by the metal coverings, which are not removed till the charge is actually in its place. Another method by which this very desirable object is to a certain extent attained, has been suggested by Captain Harding Steward, R. E., of which the following is a description:

Captain Harding Steward's safety stop-cock for mechanical sub-marine miner.

"It consists in the introduction of a stop-cock (*k*), Fig. 31,

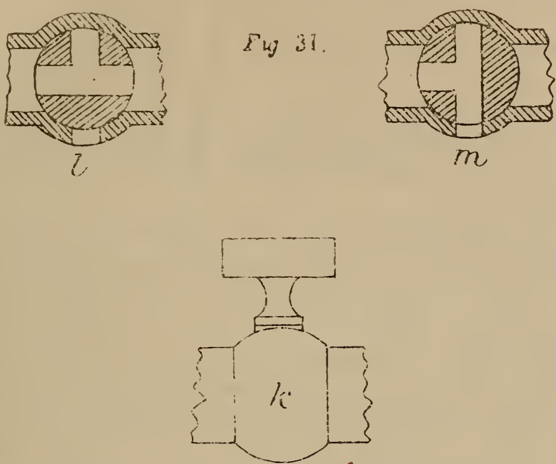


Fig 31.

at the head of the tube, between the fuse and the charge. This is so arranged that when the cock is turned in the direction of the tube, as in section (*l*), the gas, on formation, can pass freely through and fire the charge. When the cock is shut off, the gas, on a fuse exploding by accident, is made to escape by the side as at (*m*), a cut at right angles to the main cut in the cone being provided for that purpose."

Destruction from leakage of water is one of the chief dangers to which this arrangement would be liable, when the stop-cock is turned off. It is to be observed, however, that it would only be turned off when at or near the surface of the water, where the pressure is least, and turned on when submerged and the water-pressure greatest, the chance of leakage being, however, least under corresponding circumstances. In order to prevent the leakage in question, Captain Steward has made the following provision:

"The cone, in connection with the stop-cock, should be ground to fit very accurately, in order to prevent leakage of water; and in addition, Captain Steward proposes to cover the escape-hole with a small water-proof plaster, which at a moderate depth, where the pressure of the water was not too great, would keep the water out, while at the same time it would offer no material resistance to the exit of the gas if the stop-cock were turned off for safety.

"It is presumed that mechanical submarine mines would have guards or covers of some sort to protect the fuses, and, with the stop-cock in addition, which guarantees cutting off the priming from the charge, a detonating mine, however delicate, could be transported in a boat to the point of deposit, buoyed on the surface, and the moorings properly regulated for submerging without incurring any danger of an explosion. The fuse-guards would probably have to be removed prior to launching the mine over the side of the boat, but the stop-cock could be left turned off till everything was ready for submerging; until then no greater mishap than the destruction of a fuse could occur, even if accidentally struck."

A few experiments have been made in the School of Submarine Mining at Chatham with this arrangement, and it was found to cut the gas off from the charge quite efficiently in every case.

Captain Steward's mode of mooring mechanical miner.

Captain Steward suggests, as a further preventive against accident, that "three moorings should be used for buoyant mechanical submarine mines. If two moorings were, in the first instance, established at low water, the case might be allowed to float, as shown at (*a*), Fig. 32; a third mooring should then be laid out in the direction of the current, and the mine drawn down thereto, which would bring it into the position shown at (*b*), Fig. 32." It is to be observed that this mode of mooring (with three cables) is not so objec-

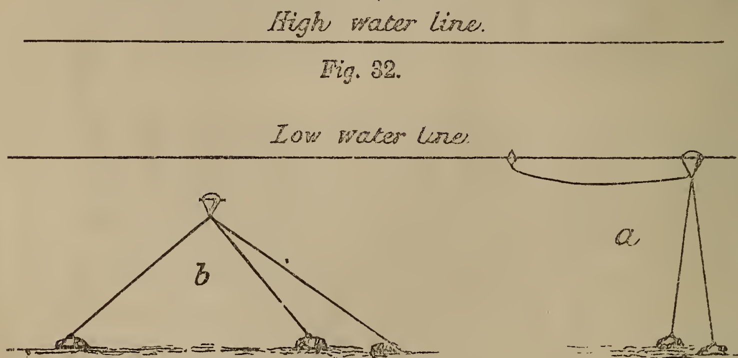


Fig. 32.

tionable with a mechanical mine as it would be with one fired by electricity. There being no electrical cable in connection with it, to be wound up or injured, no necessity exists for preventing it turning to any extent, and it might be supplied with a swivel at its apex to admit of its turning, as is often done with ordinary buoys.

"To raise a mine thus deposited the case could be brought to the surface, at low water, by raising the stream mooring and bringing it forward a little."

On raising a mine it might be made quite safe by simply turning off the stop-cocks the moment it came to the surface.

This arrangement for shutting off, as it were, the fuse from the charge of powder, is applicable to almost any form of mechanical ignition that may be devised.

Electrical ignition.

Passing from the mechanical we now come to the electrical mode of ignition, in which a very important matter for discussion is the fuse.

Platinum-wire fuse.

Several forms of electrical fuses have been devised and used for the ignition of gunpowder, gun-cotton, &c. The confederates used the platinum-wire fuse and Grove's or Bunsen's battery in many of their mines, which were arranged to be fired by electricity. This form of fuse, in connection with the first-named battery, has for a long time formed a part of the engineer equipment of the British army for land-mining operations, and the result of some experiments with it, in connection with submarine mines, have been so successful that it is to be hoped that it will satisfactorily fulfill the necessary conditions for the latter purpose.

Advantages of the platinum-wire fuse.

There are numerous advantages to be derived from the use of the platinum-wire fuse, of which the following are the principal:

1st. Great facilities are afforded for testing the circuits.

2d. It does not deteriorate by climate, &c., and can be stored for any length of time without damage.

3d. It can be very easily improvised, and the materials of which it is composed are simple.

4th. It does not require the very high insulation in the conducting cable which is necessary when a fuse, fired by a current of high tension, is used; and it may be fired through a cable in which a comparatively large fault exists.

5th. There is no danger of an accident during the process of testing, for which purpose more powerful batteries may consequently be safely used. Considerable care is necessary in testing Abel's fuses, for example, as more than one of the most sensitive form has been fired by eight small Daniells cells.

It has been ascertained by experiments carried on in the river Medway, opposite Gillingham, that in sea-water a return-wire is not necessary, and that even earth-plates of any considerable size are not essential when using this fuse in connection with Grove's battery; fuses having been successfully fired with earth connections formed of a few inches only of bare wire, with the addition of a comparatively small number of battery cells over the number necessary with a return-wire or ordinary earth-plates.

Experiments with platinum fuse and Grove's battery.

The following is a short account of the experiments tried: A platinum fuse, represented by $\frac{3}{10}$ inch of platinum wire, in a thermogalvanometer, was placed in circuit with half a mile of a cable, composed of Hooper's core, with a conductor consisting of a strand of 7 No. 22 B. W. G. copper wires, and without a return-wire. One pole of the battery was connected by a short length of No. 12 B. W. G. copper wire, with the copper sheathing of the mooring lighter, the outer extremity of the cable being soldered to a tin case 2 feet 6 inches high, and 2 feet 0 inches in diameter, to form the other earth connection, this tin being about 100 yards from the lighter. With this combination $\frac{3}{10}$ inch of platinum wire, weighing 1.6 grains to the yard, were fused with six cells of Grove's battery of the ordinary military pattern. A second half mile of a similar cable having been added to the conductor, $\frac{3}{10}$ inch of platinum wire were fused with eight cells; on a third half mile of cable, making in all $1\frac{1}{2}$ miles of conductor, being added, the platinum wire fused with 13 cells.

Distance between earth-plates, in sea-water, no objection.

In order to ascertain whether an increase of distance between the earth-plates in any way altered the conditions of the case, the tin can, forming the outer earth-plate, was moved to a distance of rather more than 500 yards from the lighter, and connected with $1\frac{1}{2}$ miles of conductor as before, the electric cable being moved out for this purpose; with this combination $\frac{3}{10}$ inch of platinum wire were fused with 12 cells, and in a second trial with 13 cells of the battery, thus proving that there was no additional resistance interposed by the increased intervening mass of water, or, in other words, that the water resistance was practically *nil*.

Experiments to determine the minimum of earth connection with Grove's battery and platinum fuse.

Further experiments have been tried with Grove's battery, and the platinum fuse, to determine the minimum of earth connection, requisite effectually to fuse the platinum wire, without inordinately increasing the number of battery cells.

With a conductor, consisting of half a mile of cable, (Hooper's core, similar to that used in former experiments,) and $\frac{3}{10}$ inch of platinum wire in a thermogalvanometer to represent the fuse, the following results were obtained:

Number of cells to produce fusion.	Extent of earth in inches of bare wire.
6	24
7	15
8	6
9	$3\frac{1}{2}$
10	3

One pole of the battery was on this, as on the former occasion, attached to the copper of the vessel as an earth-plate.

With on mile of conducting cable in circuit and similar arrangements to the above, the following results were obtained:

Number of cells to produce fusion.	Extent of earth in inches of bare wire.
20	$\frac{3}{4}$
20	$\frac{1}{2}$

The latter failed to fuse, but heated the platinum wire to redness.

The result of these experiments show that earth-plates of the ordinary size will answer every purpose, when used in connection with Grove's battery and the platinum fuse for submarine mining purposes.

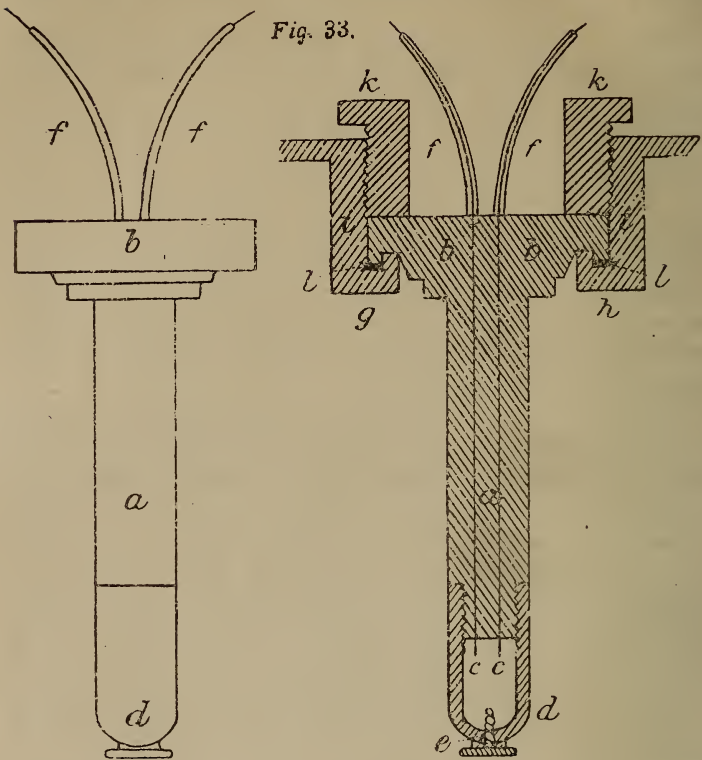
Increase of fusing power produced by the sudden reversal of the poles of a battery.

Mr. Brown, of the chemical department, royal arsenal, gives the following information, as the result of some experminents made by him with Grove's battery and the platinum fuse. He finds that the best results were obtained by suddenly reversing the poles of the battery; that is to say, that a fuse which will not fire with a given number of cells of a battery may be successfully fired by simply reversing the poles of the same battery. The reason of this is that, by keeping one pole of a battery constantly on, copper earth-connections, which are the best for general purposes, become coated either with sub-chloride of copper or with bubbles of hydrogen, both of which partially insulate. A sudden reversal of the poles of the battery dissipates these combinations for a time, that is to say, till they again form by changing places, as it were, on the opposite earth-plates, to those on which each was originally deposited. A similar effect is produced whatever may be the metal of which earth-plates are composed; that is to say, a film of hydrogen bubbles will be deposited on the earth-plate attached to the negative, or zinc, pole of the battery and a film of sub-chloride of the metal on that connected with the positive or platinum pole, both the result of the decomposition of sea-water by the electrical current.

Form of platinum fuse for submarine mining purposes.

A platinum-wire fuse has been designed for submarine mining purposes, which, as far as it has been at present tried, seems to answer satisfactorily. It consists of a couple of copper wires of No. 16 B. W. G., fixed into an ebonite core (*a*), as shown in Fig. 33, and the opening through which they are introduced made thoroughly water-tight by filling it with water-proof composition. It was found impossible to cast the ebonite directly on to the bare wire, which would have been a much more satisfactory arrangement, because the sulphur of the ebonite acted power-

Fig. 33.



fully on the copper conductor and destroyed it. This core is provided with a shoulder (*d*) to enable it to be fitted into the case in such a manner as to prevent leakage of water. The extremities (*c c*) of the copper wires are $\frac{3}{10}$ inch apart, and so arranged that a thin platinum wire may be easily soldered on to connect them and form the bridge of the fuse. A cap (*d*) screws on to hold the priming charge and protect the bridge (*c c*) of the fuse; and in this cap is a loading-hole (*e*) to introduce the priming. The priming may be either ordinary gunpowder, guncotton, or, when the fuse is to be made detonating, in order to produce the effect due to this mode of ignition, fulminate of mercury, which latter must be inclosed in a strong case in order to produce detonation at the moment of ignition. For this purpose the whole cap (*d*) may be made strong.

Priming.

The outer terminals (*f f*) of the copper wires are insulated, and arranged for attachment to the electric cable and to earth; a circular opening, (*g h*,) four inches in diameter, is left in the case (*i i*) of the mine, for the purpose of introducing the charge. The opening is made four inches in diameter to allow gun-cotton, in the form of disks, to be introduced, if it is desired to use this explosive. This opening is provided with shoulders at (*g*) and (*h*), on which the corresponding shoulder (*b*) of the fuse fits, and the latter is forced down, by means of a circular screw, (*k*,) fitting into a corresponding screw in the opening of the case, (*i*.) This forces the shoulder of the fuse down upon a ring of India-rubber packing, (*l*,) shown in black in the section, and makes all water-tight.

Gun-cotton priming forms a very sensitive fuse.

Gun-cotton priming has the effect of rendering the fuse more sensitive than gunpowder, as it ignites at a much lower temperature, as may be seen from the following experiments tried by Lieutenant Bucknill, R. E. With a conductor of one and one-half miles of cable, (Hooper's core, as previously described,) and ordinary platinum fuse, as made in the school for land mining, primed with gunpowder, fired with 12 cells of Grove's battery, and the platinum wire fused with 13 cells. The fuse, Fig. 33, designed by Lieutenant Bucknill, was next tried. With the same cable, (one and one-half miles)—

Gun-cotton priming fired with	6 cells.
Mealed powder fired with	11 cells.
Cotton and powder mixed fired with	7 cells.

With one-half a mile of conductor, the following results were obtained :

Gun-cotton priming fired with	2 cells.
Mealed powder fired with	4 cells.
Cotton and powder mixed fired with	2 cells.

With the same cable (one-half mile) and a leak of one foot of bare wire in the conductor—

Gun-cotton priming fired with	4 cells.
Mealed powder fired with	7 cells.

With the same cable (one-half mile) and a leak of 2 feet of bare wire—

Gun-cotton priming fired with	5 cells.
Mealed powder fired with	8 cells.

With a conductor of one mile of cable and a leak of 2 feet of bare wire—

Gun-cotton priming fired with	9 cells.
Mealed powder fired with	15 cells.

In one case of mixed powder and cotton the powder did not surround the cotton, and the latter ignited without firing the former. It is therefore necessary to imbed the cotton well in the priming-powder, and no failure has ever occurred when this was properly done.

Electric battery for use with platinum fuse.

In order to fire a charge by means of the platinum-wire fuse, a battery producing a current of large quantity must be employed, ignition being produced by heating the piece of fine platinum wire in the circuit to fusion, by the passage of the electric; circuit Grove's, Bunsen's, Walker's, or Smee's batteries are among those suitable for this purpose.

Grove's battery.

The experiments recorded were carried on with Grove's battery, of the form adopted for mining in the British service. A detailed account of this battery may be found in Schino's "Notes on Electricity," and the reasons for its adoption are recorded in an article by Captain (now Colonel) Ward, R. E., in the fourth volume of the new series of corps papers.

Defects of Grove's battery.

Grove's battery possesses the defect of inconstancy; that is to say that, after having been in action, or even mounted and ready for use, for a comparatively short time, the active force of the current is considerably diminished, and in time it would no longer possess the power to fire a platinum fuse. From experiments tried at Chatham it has been ascertained that when used under similar conditions to those for which it would be employed as an agent for submarine mines, 24 hours is about the limit up to which it will perform its work with certainty. If adopted for this purpose, therefore, it would be necessary to take it to pieces, clean, and remount it every 24 hours.

When this battery remains in a passive state—that is to say, not actually in action—it does not deteriorate so rapidly as when in constant use; and, as in working a system of submarine mines, it would only be in action at long intervals, each of comparatively short duration, it would not be so unsuited for the purpose as might, at first sight, appear. In consequence, however, of this defect, it would be desirable to obtain, if possible, a constant battery for the purpose required, and with this view experiments have been instituted with other forms of batteries.

Walker's battery.

Platinum wire may be fused by means of Walker's zinc carbon battery, which has the advantage over Grove's battery of being more constant. It may be allowed to remain mounted for weeks together, without any considerable reduction in the strength of the working current, and in this respect would be preferable for a permanent station.

Mr. Walker states that he has fused $\frac{3}{10}$ inch of platinum wire of 1.95 grains to the yard, with 6 cells of a battery of this form, composed of plates 2 inches wide and 3 inches immersed in dilute sulphuric acid, (1 of acid to 8 of water.) With 7 or 8 cells the wire is fused better, and with 9 it works very well. The plates of the battery used by Mr. Walker are comparatively small, and consequently a large number of cells of this size is required to produce the same result which would be obtained from two cells of the service pattern, portable form of Grove. In order to test the efficiency of this battery, therefore, an experiment was tried in the telegraph-school at this station, (Chatham,) by combining together a number of plates of Walker's battery so as to form two large cells. By arranging in this way so as to obtain an immersed surface of 140 square inches of zinc, we were just able, with two cells, to fuse $\frac{3}{10}$ inch of platinum wire of 1.95 grains to the yard. This surface of 140 square inches might easily be obtained, in a compact form, by giving the plates a cylindrical, or, perhaps better, for the more easy manipulation of the carbon, a polygonal form, under which they might be combined in a diameter of $4\frac{1}{2}$ inches, and height of 8 inches, extreme outside measurement, for each element of the battery. A few large cells of this form of battery have accordingly been procured for experimental purposes, and the results obtained with them have proved so promising that further investigations are about to be made.

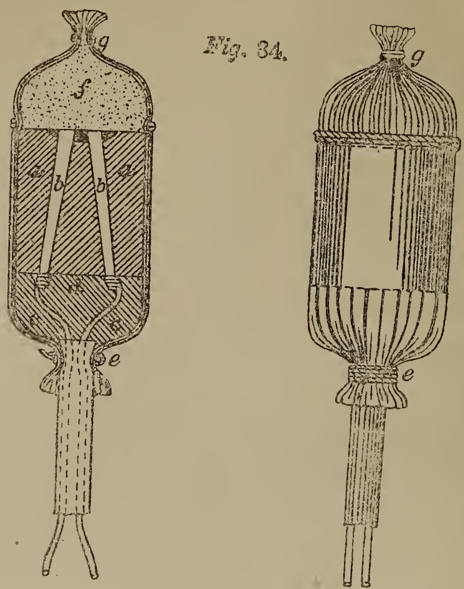
Electric fuse for use with current of high tension.

The platinum-wire fuse is itself very simple and very easily made at any time; but in consequence of the defects as regards the battery for use with it, and the apparent difficulties in overcoming these defects, efforts have been made to produce electrical fuses capable of being fired by a current of high tension, in contradistinction to one of large quantity, which latter, as produced by Grove's and other batteries, is necessary for use with the platinum-wire fuse; also keeping in view the necessity of using a constant battery.

Beardslee's fuse.

One of these, invented by Mr. Beardslee, of New York, consists of a cylindrical piece of soft wood, about three-quarters of an inch in length and about three-quarters of an inch in diameter, shown at (*a*) Fig. 34, through which two copper nails (*b b*) are driven home in a slanting direction, so that while the two heads come as close together as possible without absolutely touching, the pointed ends are at some distance apart from each other, and project below the wooden cylinder. To these ends are soldered the bare terminals of two insulated copper wires, (*c c;*) and a piece of soft wax, (*d*,) of the same size as the wooden cylinder, is pressed around the points of junction. A groove is made with a file across the heads of the copper nails, into which is rubbed a little black-lead from a pencil.* Round the wooden cylinder are now wrapped several folds of paper, forming a cylinder

Fig. 34.

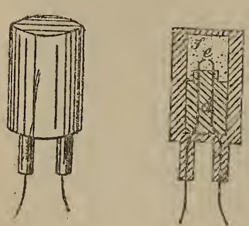


about 2½ inches in length, one end being tightly fastened with a string round the insulated wire at (*e*.) This paper cylinder is then filled with a mixture of very fine grain and mealed powder, (*f*,) and the end (*g*) is choked with twine. The entire fuse is afterward coated with black varnish.

Von Ebner's fuse.

Another form of electrical fuse is the Austrian, invented by Baron Von Ebner, of the Austrian engineers, which is shown in Fig. 35. It consists of an outer cylinder of gutta-percha, covering an inner core (*d*,) composed of a mixture of sulphur and ground glass, cast round the conducting-wire, which is, in the first instance, in one continuous length, the opening (*e*) being subsequently made and carefully gauged, so as to secure a uniform break or interval in the conductor of each fuse.

Fig. 35.



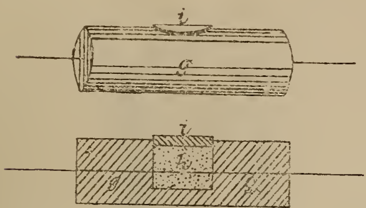
The fuse composition consists of equal parts of sulphuret of antimony and chlorate of potash, to which is added a small quantity of powdered plumbago, the latter to give a

* A minute quantity of some substance which importantly assists the black-lead in its action is applied to the wood in addition to the black-lead in the fuses of Mr. Beardslee's own manufacture. The nature of this substance has not been disclosed.

certain amount of conducting power to the composition for testing purposes. This mixture is put into the hollow (*f*) of the fuse under pressure, the terminals being connected with a very sensitive galvanometer in circuit with a small battery during the operation of filling, and the pressure applied so as to obtain, as far as possible, a uniform electrical resistance in each fuse.

A very similar fuse to this, in fact almost identical, and only differing in form, is used by the Prussians for mining purposes; this is shown in Fig. 36; (*g*) is a small cylinder of hard wood, through which a conducting wire is drawn to the hollow space (*h*) in the center. Similar precautions to those adopted in the Austrian fuse are taken in making and gauging the break in the conducting wire, and in filling in the composition, which is the same as that used by Baron Von Ebner. The opening is stopped with a cork, shown at (*i*) in sketch. Prussian fuse.

Fig. 36.

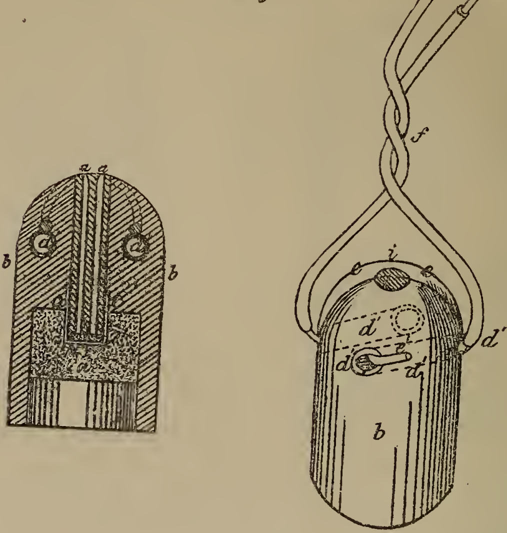


Of these two last forms the Austrian seems to be the best, being less likely to be damaged by a sudden strain or tug, which might easily alter the interval between the points of the conducting wires in contact with the fuse composition in the Prussian fuse.

Another similar form of fuse is that invented by Mr. Abel, chemist to the war department. This fuse was devised and experimented with extensively in 1858; and the above more recently designed fuses (viz, Beardslee's, the Austrian, and Prussian) are based upon the principles first applied in that fuse. It has been modified since its first invention in a few details. Fig. 37 shows its most recent form. The priming of the original fuses consisted of 10 parts of subphosphide of copper, prepared by a special method, 45 parts of subsulphide of copper, and 15 parts of chlorate of potassa; these proportions of the ingredients are, however, now varied, so as to furnish fuses of different degrees of conductivity and sensitiveness to suit different purposes. The ingredients are reduced to a very fine state of division, and are thoroughly incorporated in a mortar, with the addition of a little alcohol; the mixture is then dried at a low temperature, and preserved in tightly-stoppered bottles till required for use. This composition is very sensitive as an electric priming material, and is perfectly stable so long as it is Abel's fuse.

preserved from access of moisture. This condition, essential to the permanent efficiency of the fuse, is secured

Fig. 37.



by the present form of construction, and the precautions adopted in packing such warlike stores as friction-tubes, time-fuses, &c., suffice to insure the preservation of these fuses.

In applying the electric spark to the explosion of fuses, the distance from each other of the metallic points, between which the spark passes, must be adjusted with great nicety; and it is also important, when a number of charges are to be exploded in divided circuit by means of a magneto-electric machine, that no residue should be left between the poles after the explosion of the fuse, which would still serve to conduct the spark across the interval. The composition discovered by Mr. Abel completely fulfills the latter condition, and the former is ingeniously secured by the form of fuse adopted, and hereafter described, which is now an article of store obtainable at the royal arsenal, Woolwich.

Construction of fuse.

Referring to Fig. 37, (*b b*) is a body of beech-wood, hollowed for half its length for the reception of the bursting-charge, and perforated by three holes, one vertical, for the reception of the capsule of sensitive mixture, and two horizontal, to receive the conducting-wires; (*a a*) are two insulated copper wires introduced into the vertical perforation in the body, and resting on the sensitive mixture; (*d*) is a small charge of mealed powder contained in the cavity of the fuse, and fired by the ignition of the sensitive mixture.

The insulated wires are prepared for these fuses in considerable lengths. They consist of copper wires of 24 gauge, (= 0.022 inch diameter,) inclosed in a coating of gutta-percha 0.13 inch in diameter, and separated about 0.06 inch from each other.

A piece of the double-covered wire, about two inches long, is employed in the construction of the fuse. The gutta-purcha is perfectly removed from about 1.25 inches of each wire at one end, and the other extremities of the wires are furnished with clear sectional surfaces by carefully cutting the double-covered wire across with sharp scissors, care being taken that the ends of the wires are not pressed into actual contact by this operation.

A small quantity of the priming composition is put into a small cylindrical paper-cap, (*c*, *c*,) made to fit the double-covered wire. The prepared piece of the latter is then inserted into this cap, and the exposed sectional surfaces of the wires are firmly pressed down upon the composition, so that the latter becomes compressed into close contact with them. The cap is afterward coated with strong shellac varnish. The actual fuse is thus completed, but it has still to be fitted in such a manner as to permit of its ready employment, and to protect it thoroughly from damp.

With this view the capped end of the double-covered wire is inserted into the perforation (*i*) in the head of the wooden cylinder, so as to project about 0.15 inch into the cavity (*d*) of the cylinder. The bare ends of the wires are pressed into small grooves in the head of the cylinder, (*e e*,) and each extremity is bent into one of the small channels or eyes (*d' d'*) with which the cylinder is provided, and which are at right angles to the central perforation. They are then wedged tightly into position in these channels by inserting into the latter two small copper tubes, (shown in outline *d' d'*,) which fit closely into the holes, and are driven in over the wire ends, being afterward filed down flush with the surface of the cylinder.

The cavity of the latter is then filled with meal-powder, which is tightly rammed down, so that the fuse itself becomes firmly imbedded in it. The opening of the cavity is afterward closed by pressing into it a plug of softened gutta-purcha, and, finally, the complete fuse is coated with black varnish.

In order to connect this fuse with the electric exploding apparatus, it is only necessary to insert the bared extremity of each conducting wire into one of the small copper tubes or eyes (*d' d'*) in the head of the fuse, and to fix it there by bending the wire round on to the wood, as shown at e'. Rigidity is imparted to the connection by twisting or turning the wires together over the top of the fuse, as at (f). Perfect contact should be secured by a copper tack used as a wedge.

Before inserting the wires, with the fuse fixed upon them, into a charge of gunpowder or other explosive, it is advisable to cover the connections of the wires and fuse, either by wrapping a piece of gut-skin, oiled canvas, or other waterproof material round the head of the fuse.

The powder for ordinary fuses is contained in the cavity of the wooden body, and the fulminate for detonating fuses in a cylinder of sheet tin, tightly fitting on the fuse-head.

Abel's fuse adopted for currents of high tension.

This fuse is adapted to the electricity obtained by friction, or to the momentary induced currents derived from permanent or electro-magnets, or an induction-coil. It can also be ignited by the direct voltaic current; about 60 cells of Daniells's or 30 cells of Grove's battery being necessary to overcome the resistance with certainty, although very delicate fuses may be fired by 12 cells of Daniells's battery, or even less.

Testing Abel's fuse.

Abel's fuses can be tested by passing a weak current of three or four Daniells's cells through them, with an astatic galvanometer. Each fuse should be thus tested before it is placed in a charge.

Abel's detonating fuses.

The difference between the detonating fuse (required for gun-cotton) and the service electric fuse, consists in the substitution of fulminate of mercury for the priming charge of gunpowder, and in addition of an external tin casing for the bottom of the fuse; the service electric fuse is painted black, while the head of the detonating fuse is painted red.

Effect of test currents on Abel's fuses.

Having heard considerable doubts expressed as to the durability of the composition in this fuse, when subjected to the passage of test currents, some experiments were made at Chatham with a number of them, taken at random from our stock, with the result shown in the following table. (See page 105.) These fuses were of the old form, possessing a very high electrical resistance.

From these experiments it appears that the electrical resistance of the fuses were not materially altered by the passage of a test-current through them, under any of the different circumstances in which it was applied; they all fired at the end of the experiments without any failure, and there seems to be no danger of ignition when using a test-current, provided that current is properly adapted for the purpose. A large number of these fuses are used in the course of in-

Experiments to determine the effect of a voltaic current, from a few cells of a Daniells battery, passing through an Abels fuse, continuously and at intervals. Tested from time to time with a reflecting galvanometer.

Nature of current applied.	Date.	Deflection.	Date.	Deflection.	Date.	Deflection.	Date.	Deflection.	Date.	Deflection.	Date.	Deflection.
	1866.	Division.	1867.	Division.	1867.	Division.	1867.	Division.	1867.	Division.	1867.	Division.
No. 1 fuse } 2 cells, continuous current	Dec. 28	10	Jan. 7	10	Jan. 21	10	Feb. 4	10	Feb. 9	10	Mar. 8	5
No. 2 fuse } 2 cells, continuous current	Dec. 28	45	Jan. 7	30	Jan. 21	30	Feb. 4	70	Feb. 9	30	Mar. 8	20
No. 3 fuse } 2 cells, continuous current	Dec. 28	40	Jan. 7	20	Jan. 21	50	Feb. 4	20	Feb. 9	25	Mar. 8	30
No. 1 fuse } Tested once per day with 2 cells	Dec. 28	80	Jan. 7	25	Jan. 21	35	Feb. 4	10	Feb. 9	8	Mar. 8	10
No. 2 fuse } Tested once per day with 2 cells	Dec. 28	30	Jan. 7	25	Jan. 21	10	Feb. 4	7	Feb. 9	10	Mar. 8	20
No. 3 fuse } Tested once per day with 2 cells	Dec. 28	15	Jan. 7	20	Jan. 21	20	Feb. 4	8	Feb. 9	10	Mar. 8	10
No. 1 fuse } Tested at intervals with 2 cells	Dec. 28	30	Jan. 7	10	Jan. 21	10	Feb. 4	10	Feb. 9	10	Mar. 8	8
No. 2 fuse } Tested at intervals with 2 cells	Dec. 28	10	Jan. 7	10	Jan. 21	10	Feb. 4	10	Feb. 9	10	Mar. 8	8
No. 3 fuse } Tested at intervals with 2 cells	Dec. 28	50	Jan. 7	60	Jan. 21	20	Feb. 4	20	Feb. 9	15	Mar. 8	15

The differences in the deflections, which in Thomson's reflecting galvanometer would be due to minutely small differences of passing current, were probably produced by slight differences of potential in the testing-battery on the several occasions when it was used, and not to an alteration in the conductivity of the fuses.

struction given in the electrical school at Chatham, and the percentage defective is so extremely small that it may be safely asserted that Abel's fuse is remarkably well suited for the purpose for which it was designed. It possesses the essential quality of certainty of ignition, and is further of such construction that its electrical condition can be easily and safely ascertained at any time, both before and after it is placed in the charge, by means of a test-battery and delicate galvanometer.

Precautions necessary in testing Abel's fuses of newest form.

Some of the fuses most recently made by Mr. Abel are extremely sensitive, and have been fired by the passage of a continuous current, of 6 Daniells cells of the ordinary form, in from 4 to 6 hours and upward. These very sensitive fuses are no doubt preferable for simple mining purposes, but it must be borne in mind that they are unsuitable, and even absolutely very dangerous, when placed in a circuit in which they are subjected to the continuous passage of even a very feeble current of electricity, for a comparatively short time. When such a combination is required, the less sensitive form of Abel's fuse, that with which our experiments were made, must be used, and in fact may be used with perfect safety. It must not, however, be supposed that these very delicate fuses, above referred to, cannot be tested; this may be done with perfect safety, provided a suitable battery and galvanometer is used. It would not do, however, to put them in the hands of every one, and they should only be intrusted, when used for submarine mining purposes, to a most careful workman, who must also be an experienced electrician. In using Abel's, or indeed any fuses, each should be carefully tested and marked previous to being placed in the charge, to avoid the smallest chance of ignition in the latter position while testing.

Extemporized fuses.

In certain cases when Abel's or any other manufactured fuses may not be attainable, it may become necessary to make extemporary fuses for use on the spot. This may be done in several ways, which have proved more or less successful.

For example, a fuse, capable of being used with a constant battery of a large number of cells, may be extemporized on the principle of Beardslee's, as described in the report of the committee on active obstructions, as follows:

"A small cylinder, Fig. 38, of hard wood or cork, about $\frac{5}{8}$ inch in diameter and $\frac{3}{8}$ inch thick, is provided with a groove (*a*) round its circumference, and two perforations, (*b b*,) about $\frac{1}{4}$ inch apart, of a suitable size to receive two moderately thin pieces of copper wire, (about 18 B. W.

gauge being a convenient size.) One extremity of both of these wires is sharpened with a file and then converted into a hook, the head of which is afterward flattened, as shown in Fig. 39.

"The straight ends of the wires are then passed through the holes in the cylinder and the flattened heads are fixed in the wood, by driving the pointed extremities into the latter. In this way the broad, thin metal surfaces which form the poles of the fuse are fixed in a parallel position on the surface of the wood or cork, and should be as close together as possible without actually touching. This arrangement is shown in Fig. 40. Before, however, the wires are thus placed in position, the surface of the cylinder, upon which the poles are to be fixed, is brushed over lightly with a feather-tip or hair-pencil, which has been dipped into a solution of ordinary photographic collodion. When the poles have been fixed into the cylinder thus prepared, the small surface of wood which intervenes between them is coated with graphite by drawing a pointed black-lead pencil across it two or three times. A cap of thin paper is then tied round the cylinder (*a*,) Fig. 41, so as to inclose the poles of the fuse; this cylinder is filled compactly with fine-grain gunpowder, and the open end is then choked, as shown at (*b*,) Fig 41.

Fig. 38.

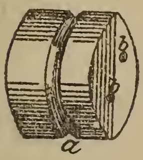
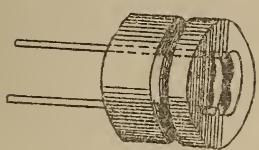


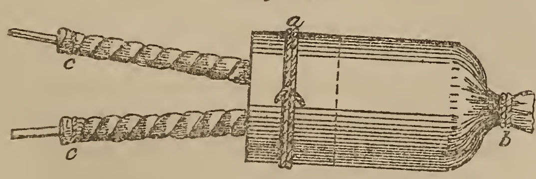
Fig. 39.

Fig. 40.



"The protruding wires of the fuse (*c c*,) Fig. 41, which serve to connect it with the conducting wires, are coated

Fig. 41.



to within a short distance of their extremities by molding ordinary bees-wax round them with the fingers, and then tightly wrapping the wax over with thin strips of tape or rag of any kind, which is secured at the ends with thread.

The entire fuse, except the bare ends of the wires, may then be brushed over with Brunswick black, or any other description of varnish or lacquer which may be at hand.

"The only material not universally obtainable, which is required in the production of these fuses, is collodion, which is, however, now so very extensively used, that it will generally be readily procurable. A small bottle, corked or stoppered, containing one or two ounces of collodion, will suffice for the preparation of a very large number of fuses."

This fuse may be fired by means of a constant battery of sufficient power, or by Wheatstone's magnetic exploder, the former of which generates a continuous current, and the latter a rapid succession of short currents. It would rarely be fired by means of a frictional or other machine capable of producing a single discharge only, because, in order to produce the necessary heating-power, a continuous passage of the current through the plumbago-bridge is essential. In using this fuse it frequently happens that a short interval elapses between the closing of the electrical circuit and ignition, this time being required to produce the necessary amount of heat alluded to.

Lieutenat Fisher's extemporized fuse.

Another form of fuse, designed by Lieutenant Fisher, R. N., is similar in general construction to the above, but differs in the composition of the bridge. For plumbago Lieutenant Fisher substitutes a mixture of powdered charcoal and resin; this, he states, produces a fuse which tests sufficiently well, and is very certain of ignition. The materials of which it is composed are so simple and easily pro cured that it bids fair to make a very useful fuse, easily made where a supply of the more perfect Abel's fuses may not be at hand. As, however, the efficiency of a mine depends very considerably on the quality of the fuse, extemporary fuses should never be used when the more perfect forms are attainable.

Position of fuse in a charge.

Next, as regards the position in which a fuse may be most advantageously placed, and the number required to fire any given charge.

It has been already stated that, in order to develop the full explosive effect of even a small charge of powder, when fired under water, a very strong case is required; in fact, that the maximum effect of a 4-pound charge was not attained until a case of $\frac{1}{8}$th-inch iron, capable of standing a gradual pressure from within of 330 pounds per square inch, was used. For large charges, of 500 pounds and upward, it is therefore evident that it would be quite impossible to make cases proportionately strong to secure a similar development of explosive effect, because they would become enormously heavy.

We may, however, to a certain extent obviate this effect of loss of power, as it were, by igniting the charges when of large size, at several points, providing, in fact, several centers of ignition, and thus burning as much as possible of the charge and converting it into gas, before the envelope is broken and the water admitted.

Maximum charge to be fired with a single fuse.

Let us first consider what would be the maximum charge which it would be desirable to fire with a single fuse, supposing that in other respects it is favorably circumstanced; that is to say, the case being of the best form and of as great strength as circumstances will admit, &c. The radius of ignition due to a single fuse, when fired under the circumstances above described, has not yet been ascertained, but it is supposed to be about 1 foot, and, starting with this basis, our maximum charge, to be fired from a single center of ignition, is at once determined at about 250 pounds. If, therefore, this supposition be correct, and we may assume that it is till reliable *data* have been obtained, we must use a single center of ignition for all charges of less than 250 pounds of powder, adding a fresh fuse, suitably placed, for each additional 250 pounds, or fraction of 250 pounds, in the charge to be fired.

This has reference to gunpowder fired with an ordinary fuse. When gun-cotton and a detonating fuse are used, a much greater bulk may be exploded from a single center of ignition.

Distribution of several fuses in a large charge.

The distribution and holding in proper relative position of a number of fuses in a large charge of powder is a matter of some little nicety, and in addition we have the increased difficulty of testing the fuses after being placed in the charge, and the increased chance of failure and trouble in replacing a defective fuse, or adjusting any accidental derangement of the conducting-wires should a defect occur in the heart of the charge itself, which would render the emptying out of the case necessary. In order to obviate these defects, the following very ingenious arrangement has been suggested by Captain Harding Steward, R. E. The description is extracted from his report:

Captain Steward's tube.

"The charge of powder should be packed in an India-rubber bag, about 12 inches in diameter, (internal,) and of a length sufficient to contain it; (a bag 42 inches long will take a charge of 150 pounds.)

"For the firing arrangement a brass tube and a fuse primed with powder are requisite. The brass tube should be sufficiently long to run the whole length of the bag when filled and tied at the end, and should have an internal diameter of one inch. To fit the tube for its object, it is necessary to cut slits ½ inch wide and 1½ inches long at central intervals of three inches, and following a spiral line round the tube. (See Fig. 42.) These slits should be covered with brass wire-gauze, of a mesh sufficiently small to exclude powder, and one end of the tube should be closed and the other provided with short lugs.

"A fuse primed with 2 drams of powder, placed in the end of the tube and well secured to the lugs, also tightly

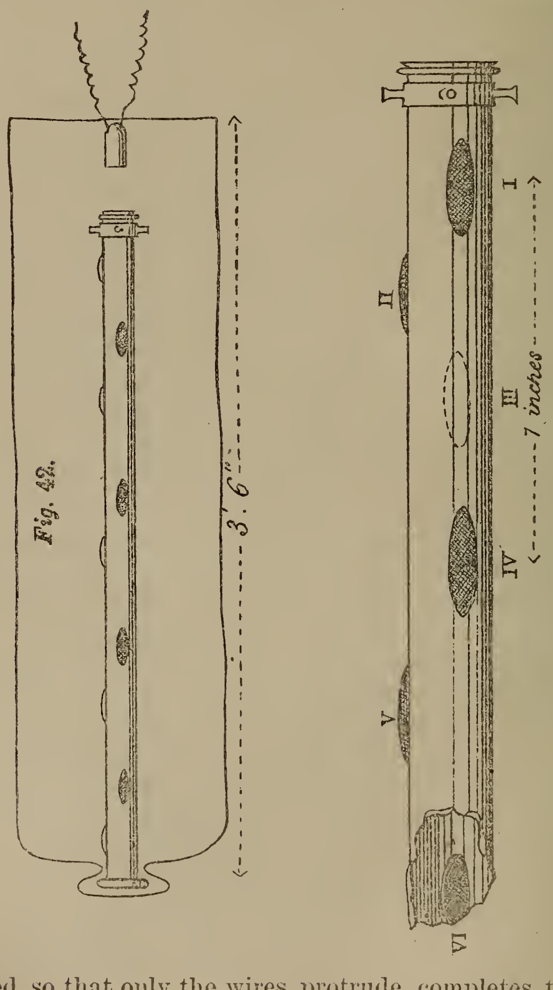


Fig. 42.

covered, so that only the wires protrude, completes the arrangement. It is then put altogether in the central line of the charge and secured, so that it shall not vary its position.

"On applying electricity of a kind suited to the fuse employed, jets of gas are driven from all the openings in the tube. These jets, accompanied by flame or without it, fire the powder within their reach, and the result is the complete ignition of the outlying portions even before the gas evolved by the grains first ignited has time to rupture the case or bag and let in the water.

"The experiments made with this mode of ignition have, owing to circumstances, been confined to lighting several trains and heaps of powder arranged about the tube, at intervals sufficiently large to prevent them communicating on one being fired. The ignition was in all cases attended with perfect success.

"The fuses employed were of my own making, and suited for the electricity of a magnetic exploder. Equally good results can be obtained by priming Abel's mining-fuse, or his experimental fuse, with two drams of powder, provided that the fuse, when packed, fits the tube tolerably well. Two drams of powder only are proposed, as with three and with four drams it was found that the blast not only (in the above experiments) drove away the powder, but prevented the emission of gas from the two or three holes nearest to the fuse. It is, however, possible that with a confined charge an increase of the priming might not be attended with the above results. If it is thought desirable to employ two fuses, so that in the event of one of them proving to be bad ignition may be secured through the other, the same can be done by arranging two tubes three inches apart, connecting their ends in order to keep them in their relative positions. Fuse.

"The mode of ignition proposed will be found so complete that metal cases for torpedoes can be dispensed with, and barrels used instead, for a water-tight covering is all that is required for the charge.

"The proposed plan is also likely to prove useful in all cases in which ignition by means of chemical fuses, or by detonation, is used; for the powder, according to existing plans, is only ignited at a single point, and that one is close to the exterior of the mass of the charge, consequently the combustion of the charge would take place under unfavorable circumstances.

"In the event of the proposed mode of ignition being employed for land-mines, it will certainly economize powder, but its utility will not be so apparent, for the surrounding earth cannot spoil a portion of the charge, as water does; also, that defective ignition can always be compensated for by an increase of the charge. The plan, however, permits of the series of fuses being dispensed with, which is, however, a mode of ignition little used in field-mining operations.

"With very large charges, (say from 300 to 500 pounds,) the following out of the cylindrical form, with a diameter not exceeding 12 inches, as recommended, would involve inconveniently long powder-cases. It is therefore necessary to subdivide the mass of powder, and to employ branches with the tube. This can be best effected by treating a mass of powder as made up of a series of cylinders 12 inches in diameter, and providing a tube for each, one case alone being provided for the whole."

Tube, with branches.

Such a tube, with branches radiating from a single point, has been devised by Captain Steward. In the head of each branch he places a small priming charge, and the gas produced by its ignition would no doubt act in a similar way, down each branch, to that of the fuse with the single tube.

The advantages of a single fuse, or center of ignition, in each charge are very great. It is extremely difficult to test a number of fuses of high electrical resistance in a single circuit without a very delicate galvanometer, or such an increase of power in the testing-battery as to run the chance of firing one of the fuses, and thus causing a premature explosion. Again, one bad fuse, among a number combined for the ignition of a large charge, might destroy the efficiency of the whole arrangement, or cause difficulties in ignition. And finally, should the tests indicate something wrong, it would be a comparatively easy matter to replace a single defective fuse at one center of ignition; whereas the readjustment of a number would involve considerable difficulty, and probably necessitate the emptying out of the entire case.

A few experiments on a very small scale, with charges of 6 pounds of powder, were tried by the floating obstruction committee to ascertain the value of the tube, but no definite results were obtained, nor is it likely that they would be with such small charges, supposing that the theory that a charge of 250 pounds of powder may be fired with a single center of ignition is correct. In order to settle this question it would be necessary to try comparative experiments with charges of not less than 500 pounds of powder, the comparative effects with and without the tube being carefully measured by any suitable means.

Though, for the present, we are not prepared to concur in Captain Steward's ideas, that India-rubber bags, combined with tubes, but without a metal covering of such strength as to develop the explosive force, are sufficient practically to secure complete ignition of a charge; or that a considerably elongated cylinder is the best form of case; still the tube arrangement is extremely ingenious, and would probably render the use of a large number of fuses in a charge of powder of considerable bulk unnecessary.

Several other methods have been suggested for producing this very desirable result of a thorough ignition of the charge; for instance, the Austrians place a pound or two of gun-cotton in actual contact with the fuse, and this substance being much quicker of ignition than gunpowder, the gas and flame produced is supposed to permeate the interstices between the grains of the latter and thus secure a thorough combustion of the charge.

Austrian plan of surrounding fuse with gun-cotton.

Lieutenant Chadwick, R. E., has suggested enveloping the charge of powder in a bag of gun-cotton, under the supposition that by surrounding it, as it were, by an envelope of flame, which would be produced by the more rapid ignition of the gun-cotton, the combustion would be continued inward and that none of the powder could escape unburnt. The effect of such an arrangement would be well worth trying.

Gun-cotton bag suggested by Lieutenant Chadwick, R. E.

In order to prevent any chance of a miss fire, the Austrians recommend the use of two fuses at each center of ignition, so that if one fails there is a chance for the other to produce the required result, and there is no doubt that in all cases, especially where there is any question as to the good quality of the fuses, this is a very necessary precaution, especially when there is only one center of ignition in a charge. It must not, however, be confounded with the use of two fuses, one at each of two distinct centers of ignition, in a charge; it is simply the arrangement of two fuses at a single point where one, if good, would do the work, and is only a matter of precaution.

Use two fuses at each center of ignition.

When no arrangement, such as Steward's tube, is used, and we wish to distribute a number of fuses about in the mass of any given charge, a very good means of keeping them in their proper position is to lash them to pieces of wood which, being rigid, may be arranged so as to remain stationary. This should be done before the charge of powder or other explosive is put in the case.

Fixing fuses in position.

With reference to the above remarks on the subject of the number of fuses required and their distribution in a given charge of large size, it must always be borne in mind that when gunpowder or gun-cotton fired with an ordinary fuse is used, a case of sufficient strength to develop the

A strong case required for gunpowder fired with ordinary fuse.

force of the charge is always necessary, whatever number of points of ignition may be employed. In fact, it cannot be too strongly impressed that the provision of a strong case (except where gun-cotton, fired with a detonating fuse, or some compound similar in the character of its ignition, is used) is a matter of vital importance. When gun-cotton fired with a detonating fuse is used, the strength of the case, as regards the development of the explosive force of the charge, seems to be a matter of no importance; it is to be hoped, therefore, that we may be able to adopt this material and mode of ignition, which would eliminate one considerable source of difficulty.

CHAPTER VII.

ELECTRIC CABLES.

The next point to be considered is the most suitable form of insulated conducting-wire or cable for employment with electrical submarine mines.

The qualifications required in such a conductor are as follows: Qualifications of electric cables.

1. Capacity to bear a certain amount of strain without breaking.

2. Good insulation, composed of such a substance that it may be readily stored and kept for a considerable time without being injured. This is an essential, as the lines will only be submerged while actually in use in time of war, for which purpose they must consequently be kept in store, and always ready in sufficient quantities.

3. For situations where there is a rocky or shingly bottom they must be provided with an external covering capable of protecting the insulation from destruction. Special precautions must, of course, be taken to secure the cables at points where they may be necessarily exposed to a considerable wash of the sea, such as the places where they may be led into a fort, &c.; but as there are others where no such special precautions can be applied, we must provide for the contingency by an external protecting covering over the insulation.

4. Pliability, so that it may be wound on or paid out from a moderately-sized drum without injury.

Several forms of cable have been devised to meet the above conditions. That used by the Austrians was manufactured by Messrs. Siemens Brothers, of Charlton, and consists of a metallic conducting-wire, insulated with gutta-percha, and protected externally by hemp and by several plies of copper tape, wound on in a peculiar manner, so that each strip overlaps the preceding one, as shown in Fig. 43; this is a patent of the above-mentioned firm. Austrian cables for submarine mines.

One defect of gutta-percha insulation is its liability to become hard and brittle when exposed to dry heat, and the consequent necessity of keeping it stored under water. In order to obviate this defect, Messrs. Siemens have recently replaced the gutta-percha by vulcanized India-rubber in some of their cables.

The following list gives the dimensions and composition of some of the forms of cable manufactured by them for military purposes:

Number of cable.	Price per statute mile, free, on board, in London, including package.	Total weight per statute mile.	Description.
	£ s. d.	cwt.	
3006	85 0 0	6	A conductor, consisting of a strand of three soft iron wires, each of 0.05 inch diameter, insulated with two layers of gutta-percha and compound to 0.236 inch, sewed with best Italian hemp strings, and covered with one continuous copper sheathing to a total diameter of 0.39 inch.
3029	81 0 0	4½	A conductor, strand of three soft iron wires, each 0.03 inch, covered with three layers of vulcanized India rubber to 0.264 inch, a layer of hemp, sheathed with copper sheet, and covered with tape painted white.
3030	81 0 0	4½	Same as last, but covered with plaited hemp instead of painted tape.
3031	70 0 0	4½	Same as 3029, but no outer covering of tape or hemp on the copper.
5014	63 0 0	2¾	Same conductor as 3029, sewed with hemp, and covered with tape painted white, with no copper sheathing.
5015	63 0 0	2½	Same as last, but covered with plaited hemp instead of painted tape.

Advantages and defects of cables protected with copper tape.

We have occasionally found the copper-tape covering on these cables to act prejudicially under certain circumstances, as, for example, if by any chance a kink occurs in paying out the line, and a sharp strain is suddenly applied, the copper tape is at that point drawn in such a way as to cut through and destroy the insulation. In handling these cables, therefore, it is necessary to be extremely careful. When once laid down this outer covering of copper tape appears to be a very efficient protection, and it is, of course, less affected by the sea-water than iron. In using it, however, it is necessary to take certain precautions to obviate the electrical action which would ensue were the copper covering to be brought into contact with iron in salt-water. Under such conditions the iron would inevitably corrode very rapidly. The rapidity with which this electrical action destroys iron under the above circumstances is almost inconceivable, and much trouble on this account has been experienced in carrying on some of our experiments.

An elevation and section, showing the general construction of Messrs. Siemens's cables in full size, are given in Fig. 43; (*a*) is the conductor; (*b*) the insulation of gutta-percha or

Indian rubber; (*c*) and (*d*) two coverings of hemp; and (*e*) the outer protecting copper sheathing, laid on in a peculiar way.

Another form of electric cable, suitable for submarine mining purposes, is manufactured by Mr. Hooper, of the Telegraph Works, Mitcham, (now Hooper's Cable Company, limited,) and possesses many qualities which render it especially applicable for this service. It may be described as follows: Hooper's cable.

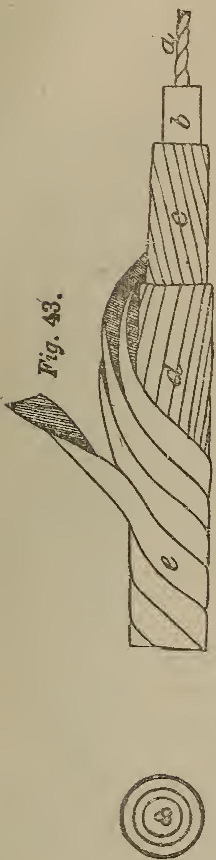


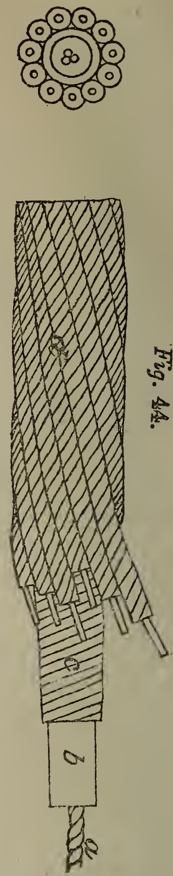
Fig. 43.

A metal conducting-wire, generally of copper, covered with an alloy to protect it from chemical action; over this is a thin coating of raw India rubber, then a thin coating called the separation of India rubber, mixed with oxide of zinc; over this is a thickness of vulcanized India rubber, more or less, according to the amount of insulation and protecting covering required, and the outside protected by tarred hemp and iron wire, or, where the cable is not to be subjected to such usage as to render an outer wire covering necessary, by a simple layer of India-rubber felt. In the process of manufacture, the India-rubber, after being laid on, is subjected to a very high temperature, under a pressure of steam at 300 degrees Fahrenheit, which fuses it into a solid mass; and while thus improving the insulation, renders it indestructible by heat of any degree likely to occur even in a tropical climate.

The object of the separator is to prevent the sulphur of the outer or main insulator penetrating to, and attacking, the metal conductor.

The high degree of insulation attained is due to the use of India rubber, which is an excellent dielectric, and its capabilities in resisting high temperatures have been very severely tested in the existing lines in Ceylon, India, and the Persian Gulf, most favorable reports of which have been received. The advantages claimed for this cable by Mr. Hooper are summed up briefly as follows: high insulation, flexibility, and capability of withstanding dry atmospheric heat, which would destroy gutta-percha.

A full-size elevation and section showing the general construction of Hooper's cables are given in Fig. 44; (*a*) is the conductor; (*b*) the India-rubber insulation; (*c*) the covering of tarred hemp; and (*d*) an outer covering of iron wires; No. 11, B. W. G., each separately covered with tarred hemp, wound on spirally.



Hooper Full size.

Fig. 44.

The table in page 120 gives in a comprehensive form the different cables of Hooper's form, suitable for submarine mining purposes. Those with a stand conductor of three or four small wires only, viz: Nos. 323 A, 321 A, 376 and 323, do not possess a very large amount of tensile strength, which, being necessary for submarine mining purposes, must be supplied by the addition of an outer covering as already described.

Defect of India rubber insulation.

India rubber insulation possesses one defect as compared with gutta-percha, viz, that it does not cling, as it were, to the metallic conductor; and that, consequently, if the India rubber is once cut through, any strain in the cable has a tendency to pull the conductor away and increase the fault. The conductor cannot be thus pulled away from the insulation, when the latter is formed of gutta-perch, which seems to cling to it and prevent such a result. As far as we yet know, however, India rubber is not so easily affected by dry heat as gutta-percha, and is therefore preferable for storage; the latter cracks and perishes unless considerable care is exercised in preserving it, which is best done by keeping it under water. India rubber possesses higher dielectric properties than gutta-percha.

Advantages of India rubber insulation.

Gray's cable.

A cable, very similar in appearance to Hooper's, is manufactured by the India rubber, Gutta-percha, and Telegraph-works Company, of Silvertown, North Woolwich. The chief difference in this cable, as compared with Hooper's, appears to be the absence of the separator, on the use of which, however, Mr. Hooper lays peculiar stress. The form of insulation adopted by the Silvertown Company is called Gray's patent.

A cable of this form was used in the operations against the wreck of the Golden Fleece at Cardiff in December, 1869, and January, 1870.

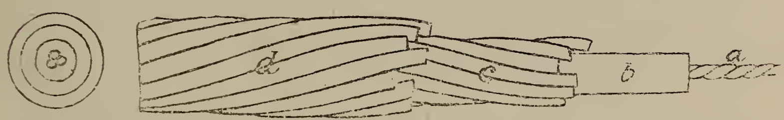
Cable used in demolition of the wreck "Golden Fleece."

It consists of a strand of 3 No. 20, B. W. G. copper wires, insulated with India rubber (Gray's patent) to a diameter of $\frac{2}{10}$ inch, and protected externally with two servings of tarred hemp, wound spirally in opposite directions. This cable possesses considerable tensile strength; when one end of a short length was made fast to a rigid point, it resisted two men pulling at it with their full strength without injury. It remained perfect during the whole of the operations against the wreck of the Golden Fleece, which extended over a period of two months of very rough usage, and turned out to be admirably suited for the purpose to which it was applied. Its cost is about £35 per mile.

For rocky bottoms or situations where the cable is subjected to risk of mechanical injury, a further external protection of iron wires and tarred hemp must be used. This would of course increase the cost.

A full-size elevation and section of this cable, which give a very good general idea of the forms manufactured by the Silvertown Company, are shown in Fig. 45; (*a*) is the

Fig. 45.



metallic conductor; (*b*) the insulating material, (Gray's patent;) (*c*) and (*d*) two servings of tarred hemp, wound spirally in opposite directions.

Multiple cables.

A multiple cable may in many cases be found convenient where it is required to carry a large number of wires in a compact form into a fort. The following description of cable has been designed for this purpose, and seems to meet the necessities of the case:

It is composed of seven distinct cores, each of which consists of a strand of 3 No. 22, B. W. G. copper wires insulated with India rubber (Gray's patent) to a diameter of $\frac{2}{10}$ inch. The interstices between the cables are filled with hemp fibers disposed longitudinally, to afford as much tensile strength as possible, and the whole is protected with a double serving of tarred hemp. The cost of this cable will be about £220 per mile. For a rocky bottom, a situation where the cable

Hooper's patent insulated cables, suitable for submarine mines.

Number of specimen.	Conductor.			Hooper's patent dielectric.		Resistance per knot, temperature 75° Fah.		Gutta-percha required for an equivalent induction (inductive capacity) to Hooper's patent dielectric.	Outside diameter.	Total weight per knot.
	Consisting of—	Weight per knot.	Diameter.	Weight per knot.	Diameter.	Conductor B. A. units.	Dielectric millions B. A. units.	Diameter.		
		Pounds.	*Inches.*	*Pounds.*	*Inches.*				*Inches.*	*Pounds.*
383	7 No. 18's	300	.147	300	.374	4.522	5,000	.472	.400	640
353	7 No. 22's	109	.087	346	.380	12.007	9,200	.549	.400	501
370	7 No. 18's	300	.147	248	.340	4.052	5,062	.419	.360	585
373	7 No. 20's	180	.100	264	.340	7.052	6,000	.450	.360	481
375	7 No. 22's	109	.087	274	.340	12.007	6,949	.478	.360	420
372	7 No. 20's	180	.110	200	.300	7.052	5,000	.385	.320	407
323 A	3 No. 21's	62	.064	160	.260	23.047	8,000	.369	.280	244
321 A	3 No. 20's	78	.070	132	.240	17.061	7,884	.326	.260	228*
376	3 No. 21's	62	.064	136	.240	23.047	7,890	.334	.260	216†
323	4 No. 22's	62	.067	92	.200	23.047	4,000	.263	.220	169‡

* The multiple cable connecting Ireland and Scotland contains this as the center core. † This cable was supplied for the Abyssinian Field Telegraph.
‡ These cores are extensively used in India, on the principal railway-telegraphs, and in the government offices.

is liable to injury, a further external covering of iron wires and tarred hemp, laid on as is usual for the protection of submarine cables, becomes necessary; this addition would increase its cost.

A full-size elevation and section of this cable are shown in Fig. 46; (*a*, *a*, *a*) are the conductors of the several insulated wires of which it is composed; (*b*, *b*, *b*) the insulation of the same; (*c*) hemp fibers disposed longitudinally between the insulated wires to give tensile strength; (*d*) and (*e*) two servings of tarred hemp wound on, the first in one direction and the second in another.

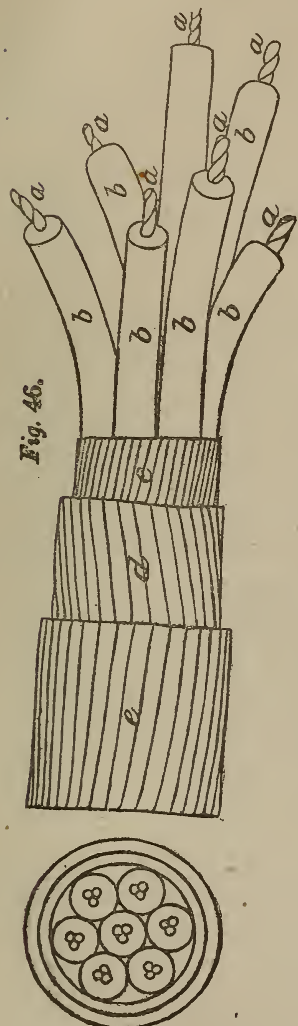


Fig. 46.

Seven conductors are used in this cable, because when all of the same size, the six outer wires fit compactly round a single one in the center. Seven is therefore a convenient number to combine in any multiple cable. When more than seven conductors are required, the diameter of the insulation of the center one must be increased to give room for the others to fit round it.

Defects of mulriple cables.

It must be borne in mind that when a multiple cable is used, any attempt to fire a mine in connection with it by frictional electricity would be nearly certain to result in the explosion, by induction, of every other mine attached to the same cable.

Induction when frictional electricity is used.

Experiments have proved that if several lines of insulated conducting cable are laid in the same trench for a few hundred yards, the inductive effect of the electrical charge, generated by a field-pattern Austrian frictional machine, is so great that its discharge, through one cable so placed, is sufficient, not only to fire the fuse in immediate connection with it, but also, by induction, to ignite every fuse in connection with every other cable in the same trench. This effect occurs equally when the cables are as much as three feet apart, provided they lie parallel to each other for a few hundred yards, and whether the shore-ends of the cables, the fuse in connection with which are not intended to be fired, are insulated or put directly to earth, the connections beyond the fuse being to earth, or even when the latter are insulated, provided a very few yards of conductor exist beyond the fuse. Such a length as must necessarily be used between a charge and circuit-closer would be quite sufficient to insure ignition by induction in this way. The current rushes in, as it were, through the fuse, to charge the small length of wire existing beyond it, and determines its ignition.

Result of experiments on induction.

The following record of some experiments, tried with a view of ascertaining this inductive effect, gives a very good idea of the danger of using frictional electricity under such conditions :

Two cables, each consisting of a strand of 7 No. 22 copper wires, insulated with Hooper's dielectric to a diameter of $\frac{3}{10}$ inch, were laid side by side on dry ground, for a distance of half a mile, the extremities, to which the fuses were to be attached, being separated by a distance of 20 yards. When fuses were fired directly through No. 1 conductor, by a field-pattern Austrian ebonite frictional-machine, fuses were fired by induction on No. 2 line under the following conditions:

1. With both ends of No. 2 cable to earth, viz, that at the firing station, and that beyond the fuse.

2. With the end of No. 2 cable at the firing station insulated, and the connection beyond the fuse to earth.

3. With the end of No. 2 cable at the firing station to earth, and an Abel's fuse to represent a considerable electrical resistance at this point, introduced between the cable and earth-plate, the connection beyond the fuse being, as before, to earth. In this case both the fuses, one at each end of No. 2 cable, were fired.

The same results were obtained under the three several conditions specified, when two fuses, in continuous circuit, were introduced on No. 2 cable, instead of one; and again, when three fuses were substituted, in continuous circuit. These last experiments were tried in order to ascertain whether the introduction of a considerable electrical resistance into the circuit would overcome the effect of the induced current; with two fuses the electrical resistance of the whole circuit would be nearly doubled, and with three nearly trebled, the comparative resistance of the conducting cable being insignificant.

The cables were subsequently arranged three feet apart for half a mile, and the experiments, under the three conditions enumerated, repeated, one fuse only being introduced at the distant end of No. 2 cable, and one between the same cable and earth connection at the firing station; with these arrangements both the fuses on No. 2 cable were fired by induction, as before, on every occasion.

Again, a fuse was introduced on No. 2 cable, with three yards of insulated cable beyond it, the end of this short length being insulated, the cables being, as before, three feet apart. Under these conditions the fuse was fired with the same certainty as in the first experiment.

The object of this last experiment was to ascertain the effect of the induced current on a fuse with a circuit-closer beyond it, the connection with the circuit-closer being represented by the three yards of cable, insulated at its outer extremity.

Experiments for induction with constant battery.

A constant battery of 100 cells, of Daniell's form, was next employed as the firing agent in connection with No. 1 cable; but no fuse was fired by induction on No. 2 cable under any of the conditions enumerated.

We may therefore assume that such a battery might be used with safety to fire any given mine of a system, when the conducting cables lie in close proximity and parallel to each other for a considerable distance, or when a multiple cable is used.

The fuses used were the newest and most sensitive form of Abel's, and the experiments, while establishing, beyond a doubt, the powerful inductive effect of a discharge of frictional electricity, gave substantial proof of the great delicacy of these very sensitive fuses, and of their good qualities as simple agents of electrical ignition, while at the same time rendering it very evident that the utmost care is indispensable in testing and using them.

The inductive effect with a multiple cable would manifestly be very much increased in consequence of the proximity of the adjacent conductors. Frictional electricity must not, therefore, be used to fire charges in connection with a multiple cable, or even when separate cables lie parallel to each other for a short distance, in connection with any system of submarine mines.

Induction does not occur to such an extent as to fire an Abel's fuse, when a constant battery is employed. Such a battery may therefore be used with perfect safety to fire any particular mine of a system attached to a multiple cable without endangering the others. With the platinum fuse there is no danger whatever of ignition by induction.

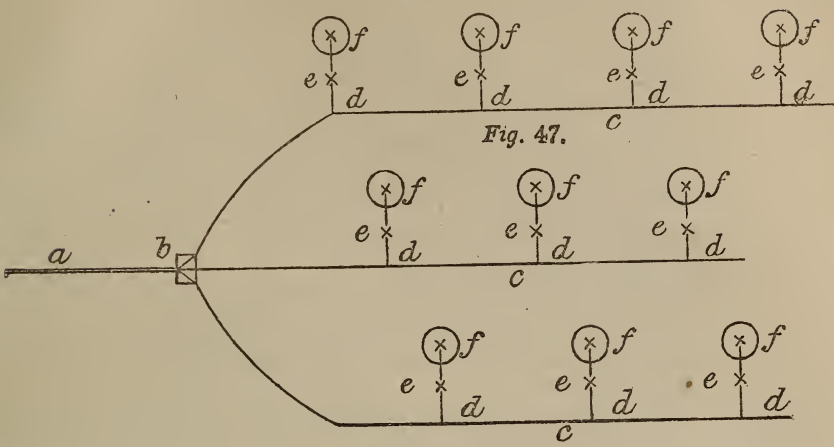
Testing-box for connection of lines to multiple cable.

In order to facilitate the connections of the several separate lines, diverging from the extremity of a multiple cable, a testing-box has been designed. Into one side of this box the multiple cable is introduced through a water-tight joint, while the separate cables make their exit on the other side, through similar joints, and pass thence to the several mines of the system. Within the box is provided an additional separate water-tight joint for each cable, so arranged, on a principle designed by Quartermaster-Sergeant J. Mathieson, R. E., that each cable may be rapidly connected or disconnected to give facilities for examination and testing. In order to bring this box to the surface for the latter purposes it is only necessary to provide a buoy and a line of sufficient strength to enable it to be weighed. The buoy-line must be strong enough, not only to carry the weight of the testing-box, but also that of a short length of the cables connected with it, sufficient to reach to the surface. This testing-box must be placed in such a situation as to be easily attainable, even in presence of an enemy's blockading squadron, and the buoy attached to it must not be conspicuous. It is essential that it should be in a safe and well-guarded position, as any injury to it, or to the multiple cable, would be fatal to every mine connected with it. The necessity for safety would also regulate the length of the multiple cable and the point at which the separate cables should diverge; this must always be dependent on local circumstances. A detailed description of this testing-box shall be given hereafter.

Cables with branches designed by Quartermaster-Sergeant Mathieson.

Another form of cable has been suggested by Quartermaster-Sergeant J. Mathieson, R. E., in connection with a system of electrical self-acting mines, arranged to be fired on the circuit being closed by the contact of a ship, the igniting agents being a quantity battery and platinum fuse. The following is a description of his proposal: From his firing station he carries a multiple cable, (*a*,) Fig. 47, to a test-box, (*b*,) from this test-box, which is arranged in a precisely similar manner to that already described; single conducting cables (*c*, *c*, *c*,) (insulated at their outer extremities,) with branches, (*d*, *d*, *d*,) are carried to the positions in which it is required to place the mines; finally, to the branches are connected the several mines with their respective circuit-closers, and when any one of these latter is struck by a vessel, the circuit of a battery, in connection through the multiple cable (*a*) with the particular line (*c*) to which it is attached, is closed and the mine fired. After any particular mine has thus been fired it becomes necessary to cut it out of the circuit, otherwise the current passing away through the bare extremity of the fractured wire, to which it had been attached, would cause such a loss of battery power as probably to prevent any fuse in connection with the same cable being fired, even if its circuit-closer were struck by a

Fig. 47.



vessel. Furthermore, it is necessary to eliminate this expended line from the system without going near it. In order to do this Quartermaster Sergeant Mathieson proposes to use a quantity battery, (Grove's or Walker's,) and to place a short length of thin platinum wire at a point (*e*) in the branch (*d*) between the main cable (*c*) and the platinum fuse (*f*,) which latter fires the charge. The platinum wire at (*e*) is so arranged, within a Mathieson's connector or other suitable insulated covering, that on its being fused the extremity of the cable at (*e*) is at once insulated, under which circumstances the loss of current, through the fractured extremity of the cable of an exploded mine, would be stopped and the full force of the battery be preserved to fire any mine attached to the same cable, (*c*,) which might be subsequently struck by a passing vessel. It is easily understood how two short lengths of thin platinum wire at (*e*) and (*f*,) in the same continuous circuit, may be fused simultaneously, and thus the charge would be exploded and the ruptured conductor cut off (insulated) at the same moment by the current of the same battery. It may also be easily understood how an arrangement might be made, within the test-box (*b*) by which a whole cable, as (*c*) might thus be cut off, by simply fusing a short length of platinum wire in connection with it, should such be considered necessary.

In order to prevent any chance of failure from the fusion of the platinum at (*e*) before that in the charge at (*f*,) advantage is taken of the fact that if two lengths of platinum wire are placed in simple continuous circuit, one being slightly longer than the other, the longest will be fused first. The battery power to fuse any given length of platinum wire in circuit, as at (*e*) and (*f*,) is easily calculable, and, as a matter of precaution, a considerable excess over the calculated number of cells (say double) should be used in practice, to prevent the smallest chance of failure. It must always be remembered that calculations are made under the supposition that the batteries are perfect, insulation absolutely faultless, and fuses, &c., of uniform resistance; conditions which never really exist in practice, however good the arrangements may be, and which a very small defect may seriously disorganize.

Experiments have proved that the combinations described are not only quite practicable, but capable of being arranged to act effectively without any considerable amount of complication.

Plan proposed as a substitute for mechanical mines.

This plan has been proposed as a substitute for the mechanical self-acting system. It must still undergo a further trial, and, if successful, will enable us to get rid of that element of equal danger to friend and foe which is inseparable from any purely mechanical method. It is easily seen that by it perfect safety is secured to a friendly vessel by simply detaching the firing battery.

Cable suitable for this purpose.

The cable proposed consists of a strand of 7 No. 20, B. W. G. copper wires, insulated with India rubber, (Gray's patent,) to a diameter of $\frac{324}{1000}$ inch, and protected with a double serving of tarred hemp. The branches formed of the same core are one yard long each, and inserted at any suitable intervals on the main cable, and are similarly protected with tarred hemp.

A further external protection of iron wires and tarred hemp must be added to this cable for situations where such may be required. The cost of such a cable is about £120 per mile, or, with the additional external covering, somewhat more.

Experiments are about to be undertaken with it in order to test its efficiency.

A full-size elevation and section of the form of cable, suitable for this arrangement, are shown in Fig. 48; (*a*) is the main metallic conductor; (a^1) a branch conductor; (*b*) the insulation, (Gray's patent;) (*c*) and (*d*) servings of tarred hemp, wound on, the first, (*c*,) in one direction, the second, (*d*,) in the other.

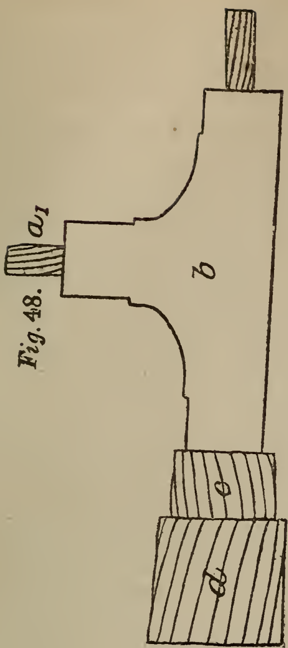


Fig. 48.

Best form of cable for general service.

Some further experience is required in order to determine definitely the peculiar advantages and defects of these several cables, but with our present knowledge, and taking all the conditions to be fulfilled into consideration, Hooper's core, or something similar to it, would seem to be the best form at present manufactured, which would be capable of being used for submarine mines, combining, as it does, high insulating power with a capability to resist injury to the insulating substance, (vulcanized India rubber being one of its principal components,) and a considerable amount of flexibility. For rocky or shingly bottoms, where there is much rubbing on the surface of the cable, Mr. Hooper proposes to protect it by an outer covering of iron wires, each covered with hemp, laid on in the manner shown in Fig. 44. It would not be difficult to lay on such a covering anywhere, at a foreign station, for example, or to repair it when required. Without some external covering Hooper's core does not possess very high tensile strength and must be used carefully.

Hooper's or Gray's.

Gray's patent insulation is very similar to Hooper's in many of its characteristics, and his external covering of tarred hemp, laid on first in one direction and then in the other with rather a long twist, adds considerably to the tensile strength.

Outer protection of ordinary rope for electrical cables.

One mode of protecting an insulated cable, suggested by the floating obstruction committee, and almost simultaneously by Captain David, R. M. L. I., while the latter was under instruction in the electrical school at Chatham, is to cover it with rope, to place it in the core, as it were, of a hempen cable. Two short lengths of Hooper's core have been covered in this manner, in the rope manufactory at Chatham dock-yard, for trial. The insulated wire was held steady in the center, and the rope was made upon it in the usual way, so that in outward appearance it differed in no respect from an ordinary hempen cable. It has been suggested by the floating obstruction committee as a cheap and ready means of covering an electrical cable, and so protecting it from external injury, and from experiments tried with the lengths in our possession, it promises to be very useful in certain positions, and might no doubt be used with advantage when the more approved form of cable is not obtainable, and when the bottom on which it is laid is not too shingly or rocky and likely to cut through the external hempen coverings. In forming the rope upon it, considerable care is necessary to prevent any great amount of tension or torsion coming on the insulated wire, as either one or the other is likely to injure it.

It was suggested by Captain David, in connection with an idea he had for exploding charges in combination with a floating boom, or to indicate that a boom was broken.

Captain David's plan of combining an electric cable with a boom.

His idea was to lay one or more of such rope-protected electric cables along the whole length of the boom, carefully attaching them thereto. With such an arrangement any attempt to break the boom must be accompanied by a fracture of one of these cables; and the bare extremity of the conducting wire, falling into the water as soon as the cable was cut through, would be sufficient to complete the circuit of a battery, one pole of which was attached to the cable with the other to earth. It is easily seen how a charge previously placed in such a circuit would thus be fired, and would destroy any vessel or boat in its vicinity. It would only be necessary to insulate the extremity of the cable beyond the charge, as regards the firing battery, to render the system inactive till the cable was cut. It is, no doubt, probable that this cable, resembling in outward appearance an ordinary rope, would not excite suspicion and would be likely to be cut, but any mine in connection with it, near enough to injure a vessel or boat, would also generally be near enough to damage the boom itself, a result which would not be at all desirable. Some experiments were tried by Captain David which demonstrated the practicability of the idea, as far as the firing of a charge is concerned.

Such a combination useful as an indicator.

As an indicator of the continuity or otherwise of a boom at night or in a fog, it would probably be useful. The arrangement of an insulated cable for such a purpose would be the same as that for firing a mine, but instead of a charge of powder or gun-cotton, a galvanometer would be introduced into the circuit, and a fracture of the conductor indicating the breakage of the boom by storm or an enemy's operations, would at once be indicated by a deflection of that galvanometer, consequent upon the current from the battery, the circuit of which would be completed through the severed cable as before. In this manner a most effective watch from the interior of a fort could be kept over obstructions in a channel, even though such obstructions were perfectly invisible from any cause whatever.

Improvised electric cables.

The electrical conducting cable is perhaps the most important item in any system of electrical submarine mines; an accident to it would nearly always render a mine ineffective; it is therefore a difficult matter to treat of, in reference to any improvised arrangements that may be practicable. As a general rule, in the event of the more approved forms of cable not being obtainable, the test conducting-wire and insulator at hand should be used; and, bearing in mind the conditions to be fulfilled, already enumerated, it should be most carefully tested under a considerable pressure of water before being employed. Any of the ordinary forms of conducting-wire insulated with gutta-percha, might, with the addition of some external protecting covering, be made available, or even a wire insulated with a thick covering of well-tarred canvass might answer for a short distance. In forming an impromptu cable, a large conducting-wire of small electrical resistance should be selected. The reason of such a selection is manifest, with reference to the well-known law of division of electrical currents.

CHAPTER VIII.

WATER-TIGHT AND INSULATED JOINTS AND CONNECTIONS.

The next point to be considered is the mode of carrying the conducting-wires and attached fuse into the charge, so as to insure a water-tight joint, and keep the arrangement in proper condition for ignition at any moment required.

The great object is to exclude the water; this was effected in the Austrian apparatus by means of a stuffing-box.

Mathieson's method of introducing fuse into charge.

The following suggestion of Quartermaster-Sergeant J. Mathieson, R. E., is perhaps the best that has yet been devised for attaining the above very desirable object, and it not only possesses the advantage of being extremely water-tight, but is also capable of being opened at any time, with the greatest facility, for the examination of the fuse. The mode in which this may be done may be easily understood from the following descriptions:

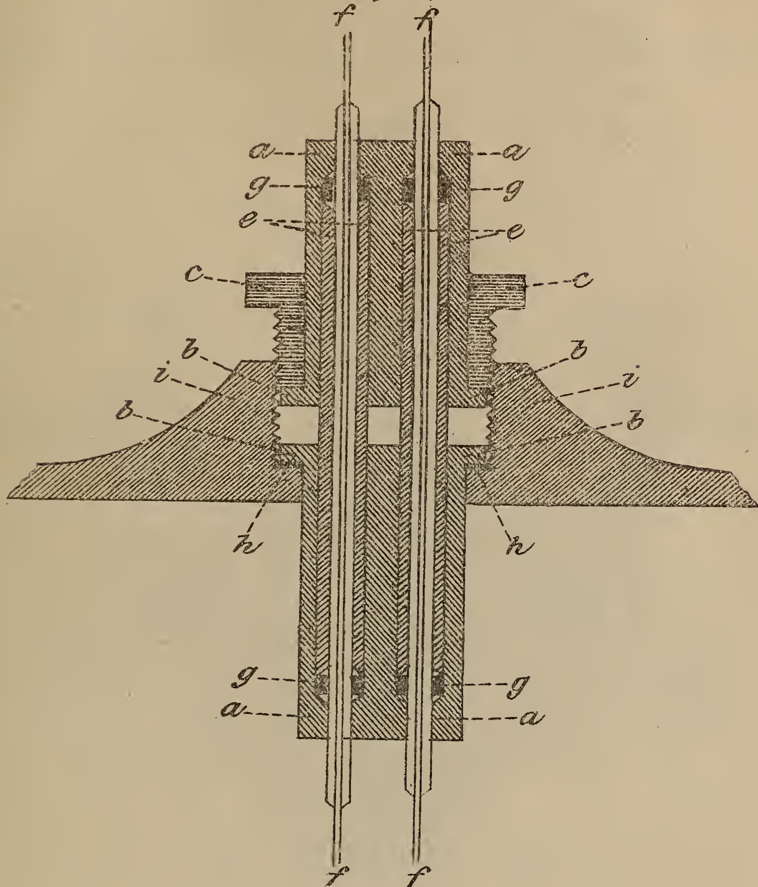
Objects to be attained.

He has designed several arrangements to meet the objects to be attained, which may be enumerated as follows, viz, that the opening, through which the conducting-wires of the fuse are introduced, may be water-tight, and that the apparatus may be easily unscrewed and the fuse taken out for examination, or for the introduction of a new one, in the event of a defect being discovered.

Apparatus for a metal case.

One of these is shown in section in Fig. 49; (*a a*) are two cylinders of ebonite, through which a pair of holes are bored for the reception of the wires attached to the terminals of an Abel's fuse, and with shoulders (*b b*) on each, the lower one arranged to fit on a flange, attached to the metal case, to contain the charge, and the upper to receive a metal screw (*c c*) which, when screwed home, would exercise a pressure tending to force the two ebonite cylinders into close contact, as well as to fix them firmly into the case for the charge. Within the holes for the reception of the insulated conducting-wires (*f f*) are a pair of ebonite tubes fitting over the latter, and their extremities beveled into a wedge form. Four cylinders of vulcanized India rubber, (*g g*, *g g*,) each perforated to enable them to pass over the insulated wires, (*f f*,) are placed just over the wedge-formed extremities of two ebonite tubes (*e e*.) A ring or washer (*h*) of vulcanized India rubber is placed between the shoulders of the lower ebonite cylinder and the flange of the metal case on which it rests. A metal shoulder, (*i*,) formed with a female screw to correspond with the screw (c c,) receives the latter, and it is easily seen how, when (c c) it is screwed

Fig. 49.

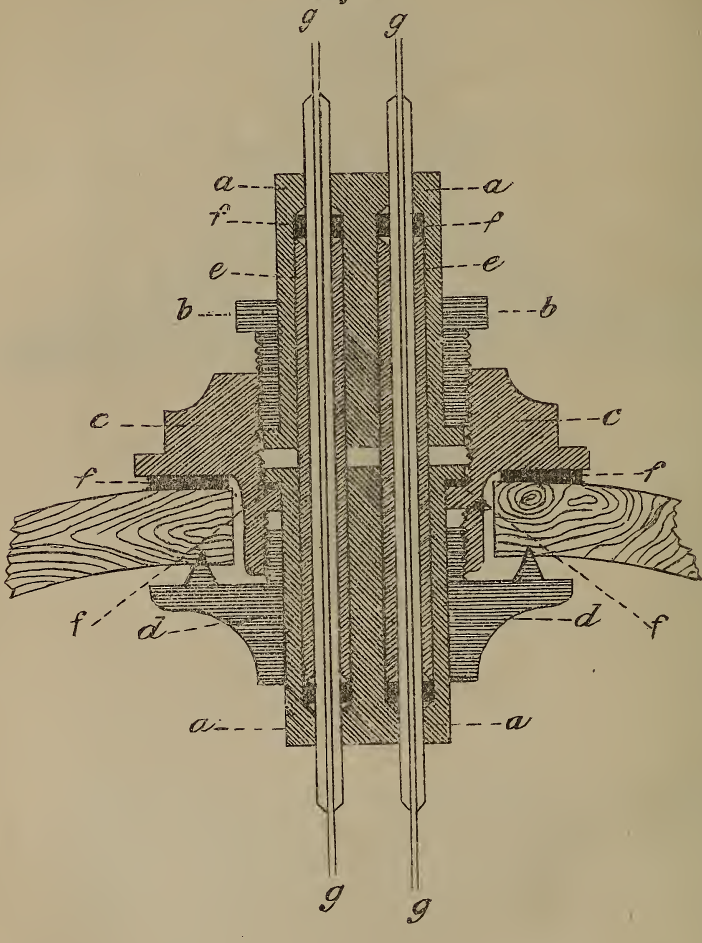


home, the several parts of the apparatus are forced closely together, and pressure is brought to bear upon the India-rubber cylinders (g g, g g) and the India rubber ring or washer (h.) These are thereby forced into all the interstices in their vicinity, and everything becomes perfectly water-tight. The shoulder (i i) should be cast or welded on to the case to contain the charge, so as to form one solid piece with it. When the metal, of which the case for the charge is composed, is iron, the screw (c c) must also be of iron; if any other metal, brass for example, were used in contact with iron in sea-water, an electrical action would be immediately set up, and the iron would be very rapidly decomposed. This is an important point to remember in the construction of apparatus of this nature.

Apparatus for use with a barrel.

Another similar form of apparatus has been designed by Quartermaster-Sergeant Mathieson, R. E., for carrying the conducting-wires into a charge placed in an ordinary wooden barrel; this is shown in section in Fig. 50, and is precisely

Fig. 50.



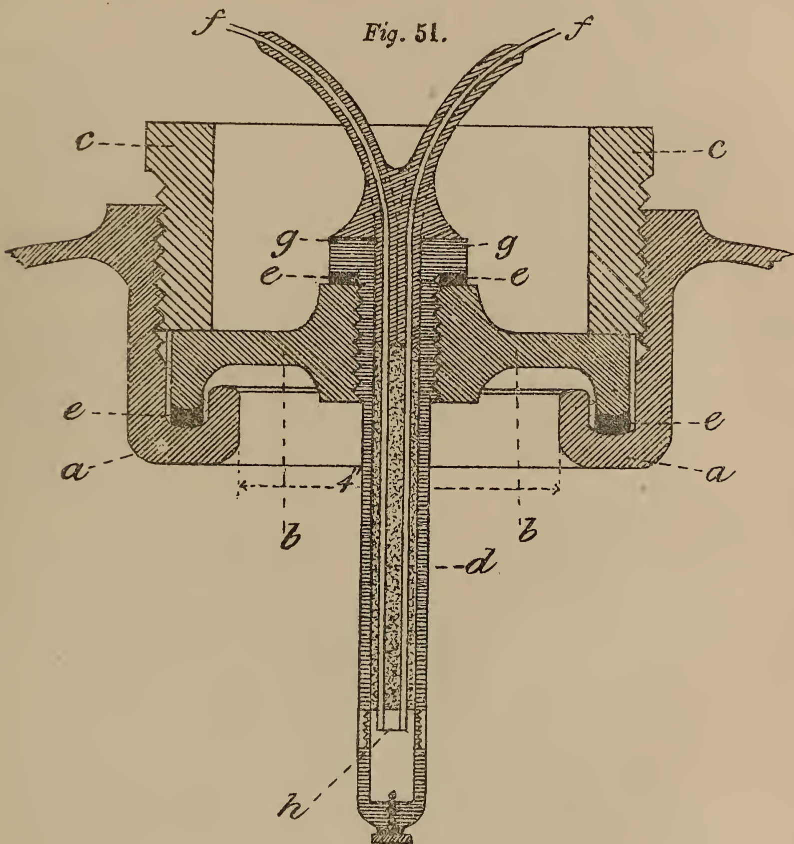
similar in principle to that for the metal case, Fig. 49. There being no iron here to decompose, the metal screws, &c., may be formed of brass, which is an advantage, as this latter metal is more easily worked in the form required; (*a a*) are the two ebonite cylinders; (*b*) the brass coupling-screw; (*c*) a brass socket, in connection with another brass screw (*d*) within the barrel; (*e e*) are the ebonite tubes as before; (*f f*)

India-rubber washers, and (*g g*) the insulated conducting-wires to connect the fuse. The screw (*d*) is furnished with spikes, which grip the inside of the barrel and secure rigidity.

Apparatus for use with platinum-wire fuse.

Another form of apparatus, somewhat similar to that described in page 96, but an improvement thereon, has been designed for use with a platinum-wire fuse and a metal case for the charge; this is shown in section, Fig. 51; (*a a*)

Fig. 51.

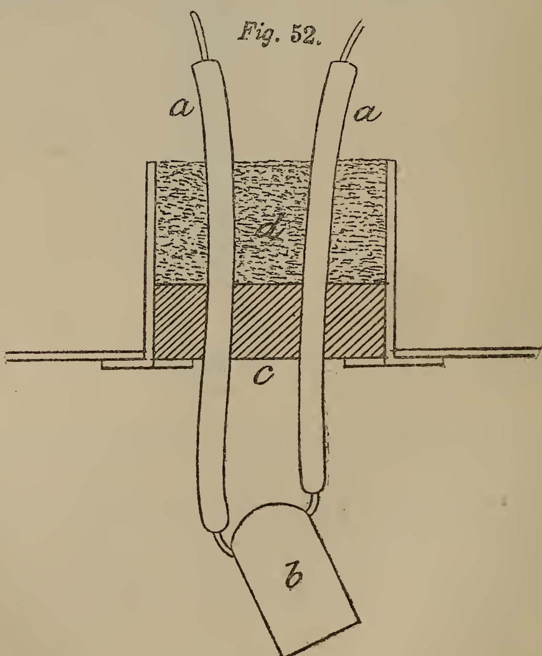


is a shoulder of peculiar form, cast or welded on, and forming one solid piece with the metal of the case, in which a circular opening, 4 inches in diameter, is left for the introduction of the charge of gun-cotton disks; (*b b*) is a socket with shoulder, made to fit over (*a a*;) (*c c*) is a metal coupling-screw; (*d*) is the platinum-wire fuse, formed on precisely similar principles to that described in page 96, but in this case made to screw into the socket (*b b*) so that it may be taken out for examination without disturbing the main arrangements by which the loading-hole is secured; (*e e*) are vulcanized India-rubber rings or washers, by which the whole is made water-tight, in precisely a similar manner to that already described; (*f f*) are the fuse terminals; these are insulated with vulcanite, which has been made to adhere to the ebonite frame (*g*) of the fuse, the cavity (*d*) being filled in with a composition consisting of 16 of pitch, 2 of bees-wax, 2 of tallow, and 6 of gutta-percha, pressed into it in a melted state. When cool this composition becomes quite hard, and completely insulates the fuse terminals within the ebonite frame. This composition has also been found very effective in preventing water passing down along the conducting-wires, between them and the insulation, (when the apparatus is submerged to such a depth as to entail a considerable pressure,) and thus entering the charge. The addition of gutta-percha to the water-proof composition has the effect of hardening it materially. The thin platinum wire, (*h*,) forming the fuse, is soldered to the terminals in the usual way.

Temporary water-proof connection.

In ordinary submarine practice, or when a good form of connector is not to be had, the following composition, viz, 1 tallow, 8 pitch, and 1 bees-wax, will be found very good. The vessel or can in which the charge is to be placed, having been formed with a shoulder or neck (see Fig. 52) of

Fig. 52.



sufficient size to receive a moderately large bung, the insulated conducting-wires (*a a*) having first been attached to the fuse (*b*) are passed through two holes in a bung, (*c*,) which latter is passed into the neck, which it should fit tightly, and the above composition is then pressed into the space (*d*) above it. This composition soon becomes hard, and renders the whole water-tight. It is amply sufficient for all charges to be fired soon after submersion. It becomes plastic at about 150° Fahrenheit.

Much care necessary in sealing charges with heated composition.

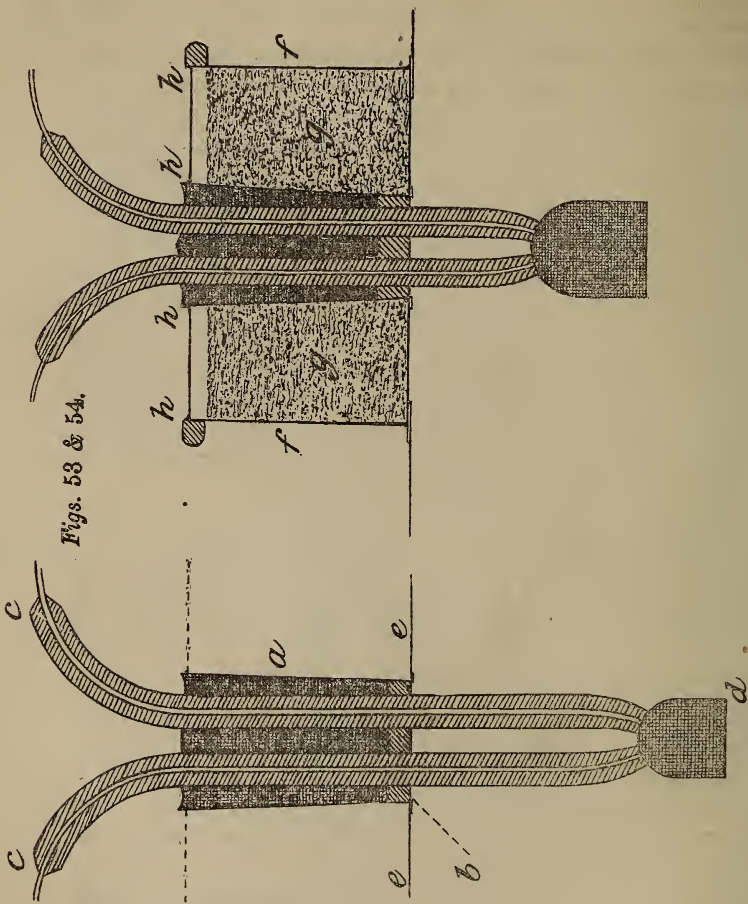
The addition of a little gutta-percha, as already stated, hardens this composition and renders it less likely to be affected by atmospheric heat. More care is, however, necessary in using it, after the gutta-percha has been added, because the higher the temperature the nearer it approaches to the igniting point of an explosive, and it may be superheated without indicating the fact by any outward appearance. Gutta-percha becomes plastic at a temperature of about 160° Fahrenheit, and should never be used by itself to seal up the bungs or connections of loaded cases. Serious accidents have, on more than one occasion, occurred when it has been used for this purpose. When using any of the new forms of explosive, which ignite at comparatively low degrees of heat, or even with gun-cotton, the temperature at which the composition used to seal up a charge becomes sufficiently plastic is a matter which must be most carefully considered.

Arrangement with clay joint.

An improvement upon this plan is shown in section, Figs. 53 and 54; (*a*,) Fig. 53, is a tin socket, in the form of a very long truncated cone, with shoulders to support the cork (*b*) through which the insulated terminals (*c c*) pass to the fuse (*d*,) and with an outside rim or shoulder (*e e*) to fit into the nozzle, (*f f*,) Fig. 54, of the case to contain the charge. The fuse, wires, and cork, having been inserted into the socket (*a*,) Fig. 53, as already described, the top is filled in with water-proof composition (16 of pitch, 2 bees-wax, 2 of tallow, and 6 of gutta-percha,) shown black in the sections, this is done before the fuse is brought near the charge, and there is consequently no danger incurred from heat. The socket, complete with fuse, &c., is next inserted in the nozzle, (*f f*,) Fig. 54, and moist clay (*g*) is carefully pressed in over it, to fill up and keep it steady in its place. A disk of tin, perforated in the center, so as just to pass over the top of the socket, is then placed over the top of the nozzle (*f f*,) of the case which it is made to fit, and its outer and inner rims, at (*h h*, *h h*,) are made water-tight by soldering. During this operation of soldering the heat is thus kept well away from the charge, and separated from it by the moist clay, &c., so as to be perfectly safe. This arrangement was always used, during the summer of 1869, in carrying on gun-cotton experiments in the Medway, and scarcely an instance, out of a large number of charges fired, occúrred in which water found its way through it.

Arrangement of fuse in a separate compartment.

One mode in which the charge may be kept dry is to introduce the fuse into a small compartment, let in, as it were, but totally separate from the charge, as, for example, in Fig.



Figs. 53 & 54.

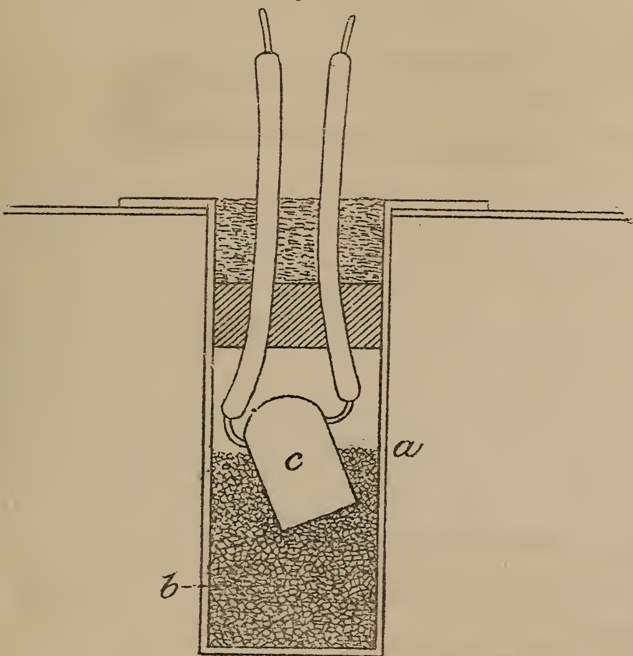
55, a tube (*a*) of tin, made quite water-tight, may be introduced into the charge, which, however, it should completely separate from the priming-powder (*b*,) in contact with the fuse (*c*,) the remainder of the tube being filled in as before with a bung and water-proof composition. The effect of firing the fuse in this case is to burst the tin tube (*a*) by means of the priming-powder (*b*) and thus ignite the mine. This may do well enough for small charges, say up to fifty or sixty pounds, but for larger masses it is always preferable to have the fuse in actual contact with the charge itself.

The object of this arrangement is to save the main body of the charge, in the event of any leakage of water through the opening left for the fuse; it was formerly much used in submarine explosions, but we are now able to make such good water-tight connections that it seems to be almost an unnecessary precaution under ordinary circumstances.

Fuse must always be tested before and after being placed in charge.

In all cases the fuse or fuses should be carefully tested electrically, before they are placed in a charge, and this

Fig. 55.



testing should be done both singly and in a group, arranged in the same combination in which it is proposed to use them in the mine itself, and they should be subsequently tested after being placed in the charge.

Joints.

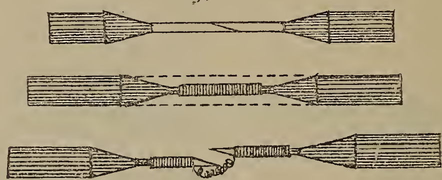
Next, as regards the best mode of making an insulated joint in a cable. Several systems have been recommended and have proved perfectly effective.

Permanent joints in cables.

For a permanent joint we have the ordinary gutta-percha and India-rubber joints, which, under certain circumstances, would be very useful for submarine purposes. These are somewhat troublesome to make, and would require a considerable time to render them sufficiently good for the purpose required. They must be made deliberately and are similar to those used for ordinary submarine-telegraph cables. The mode of making such insulated joints as recommended by the India-rubber, Gutta-percha, and Telegraph-works Company, Silvertown, North Woolwich, is as follows: For a gutta-percha cable remove about 1½ inches of the insulation at the ends. After warming gently it is easily pulled off with the fingers, (this is much safer than cutting;) clean the two ends with emery-cloth, and file a ½-inch scarf on them, (see Fig. 56.) The wires are then caught with the scarfs together in two

Permanent gutta-percha joint.

Fig. 56.



small vises, fixed on a bench, one working on a slide, so that they can be set at any required distance apart, and soldered. After soldering, clean the scarf off with a small file. Then bind it round with four strands of fine copper wire, laid side by side; loop one end on the left-hand vise, and wind from left to right, taking care that the wires are evenly laid on and do not ride over each other; the length of the binding should be about 1¼ inches; the ends of the binding wires are now snapped off by a sharp tug with the pincers. This binding is then soldered at the center and at the ends, leaving two parts of the binding unsoldered, so that if the scarf be drawn asunder the four-strand wire shall still connect the two ends and form a metallic circuit.

The joint is then well washed to remove all acid from the copper.

To scarf a strand conductor.

In scarfing a strand conductor, the two ends are first soldered, making them solid. If the diameter of the conductor exceed No. 14 gauge, two courses of binding are used, the first soldered all over, the second in the center and ends only. This is the mode adopted for submarine-telegraph cables, but for the comparatively short lengths used for submarine mining purposes, an efficient metallic connection may be made, in the case of a strand conductor, by simply twisting the wires of the two portions to be joined tightly together; after cleaning them and soldering, care must be taken to prevent any projecting ends of wire remaining at the junction.

To complete the insulation, clean the joint all over with a little spirit of naphtha on a rag, and give it a thin layer of Chatterton's compound; warm the joint in the flame of a spirit-lamp, and taper the gutta-percha by drawing it gently with the fingers until it nearly reaches the center; then with a hot tool, designed for the purpose, work the two portions together to form a solid mass; then apply a thin layer of coumpound, followed by a strip of sheet gutta-percha $\frac{1}{8}$ inch thick and large enough to cover the whole, warmed together with the joint, and lapped round it, taking care that the under part and ends shall adhere first; warm the whole gently again, and close it from the bottom upward taking care to expel the air in front. When the two edges meet, cut them off as close as possible with a pair of scissors and work them into one another with the tool, doing the same at the ends; then gently warm the whole, and burnish it off with the wet hand. In this way the insulation is completed to the same diameter as the original. To complete insulation.

In joining gutta-percha the great point to guard against is not to give it too much heat; if it is a litte too hot it becomes oily and will not adhere.

The insulation having been thus completed, any outer protecting covering of wire, hemp, &c., should be laid on and secured which completes the operation.

In the case of an India-rubber cable the following method is recommended:

Before the portions of the conductor are soldered together, warm the two ends of the India-rubber insulation and taper them off with a pair of scissors. After the joint is soldered and cleaned off in the manner already described a little India-rubber solution is rubbed on the small ends of the taper of the insulation, and a layer of rubber compound tape is wound round spirally and tighly, on the copper core; this compound tape is $\frac{2}{8}$ inch wide; next a layer of India-rubber (not compound) $\frac{3}{8}$ inch wide is applied, then a thin layer of India-rubber solution followed by another layer of Indian rubber. Continue the alternate layers of rubber and solution until the joint approaches nearly to the diameter of the original core, and finish off with one layer $\frac{1}{2}$ inch wide, commencing and finishing $1\frac{1}{2}$ inches on each side of the joint. These layers must be each laid on very tightly and regularly. Permanent India-rubber joint.

When required, any outer protecting covering must be put on as before.

In some cases it may become necessary to insulate a gutta-percha cable with India rubber, and for this purpose the following method is recommended: Permanent India-rubber joint on gutta-percha cable.

First apply a coating of India-rubber compound, (strip,) then warm the gutta-percha and taper it over the compound layer, then spread a thin layer of India-rubber solution on the gutta-percha; next apply a layer of India rubber $\frac{3}{8}$ inch wide followed by a thin layer of India-rubber solution. Continue the layers until the insulation becomes nearly of the same diameter as the original core. Finish off with one layer $\frac{1}{2}$ inch wide, commencing and ending $1\frac{1}{2}$ inches on each side of the joint.

In making insulated joints, moisture, grease, and dirt hould be scrupulously avoided. So much stress is laid upon these points, that the manufacturers of submarine cables only employ men with very clean and naturally dry hands at such work.

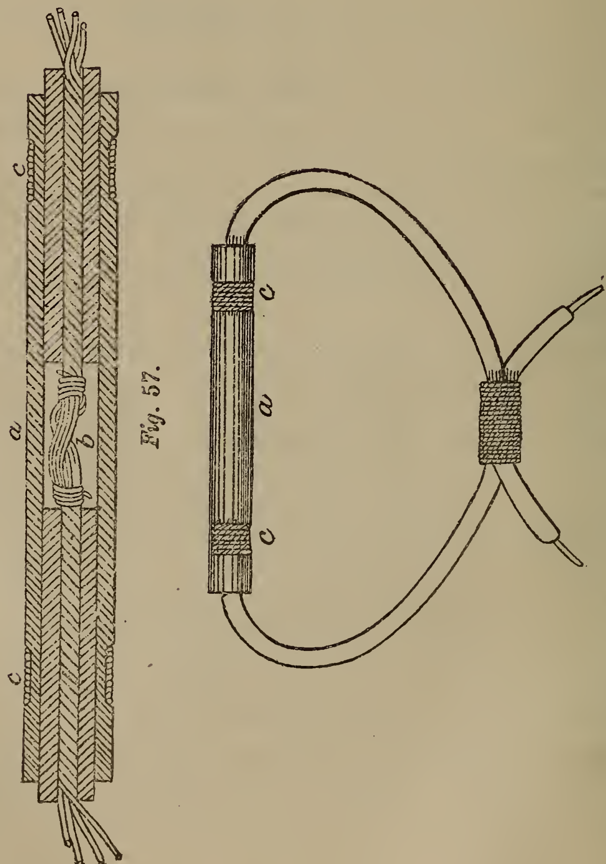


Fig. 57.

Temporary insulated joints.

For temporary purposes, that is to say, when a charge is to be fired immediately after immersion, it is unnecessary to make a permanent joint such as that described. For this purpose an ordinary piece of vulcanized India-rubber tubing passed over the naked ends of the conducting-wires from extremities of the two cables to be connected, which have been previously joined together and, if necessary, soldered, answers the purpose very well.

India-rubber tube joint.

To prepare this joint, about 1.5 inches of the copper conductor of each of the insulated wires, which are to be connected together, are laid bare and thoroughly cleaned. A piece of vulcanized India-rubber tubing, (*a*,) Fig. 57, about 4 inches in length, is then slipped over one of the insulated wires. The two clean and bright ends of the wires are then spliced or twisted together as shown at (*b*) Fig. 57, care being taken to bend the extremities quite flat, so that they may not be liable to puncture the India rubber used for rendering the joint water-tight. When the wires have been joined the tubing is brought forward so as to overlap the junction by about 2 inches, and is secured at each end upon the insulated wire by several laps of string, tightly bound round, (*c c*,) Fig. 57. In order to relieve the junction from any direct strain it is formed into a loop by tying together the insulated wires at a distance of a few inches from the point where the junction is made, as shown in Fig. 57.

The insulation covered by the India rubber tube should be well greased before the latter is pulled over it and tied. In doing this care must be taken to prevent the grease penetrating to the metallic joint and thus impeding the electrical circuit. The grease is intended simply as an additional precaution against leakage of water.

A very important matter to be attended to in making a joint, whether of a permanent or a temporary nature, is that the metallic ends should be perfectly clean—that there should be no oxide or impurity which would tend to increase the resistance to the passage of the current. To insure this they should be well rubbed with emery-paper just before the joint is made.

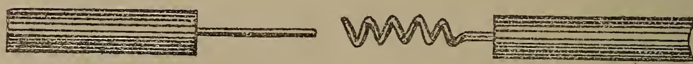
Moisture to be carefully excluded.

In making this, or indeed any joint for submarine use, the great object is to exclude the very smallest ingress of water or even moisture, which would at once afford a path for the current and cause a loss or, as it is termed, a leak in the cable; if, therefore, there is any external hemp or other covering, though which moisture might percolate in ever so small a degree, it must be carefully removed so that the India-rubber tubing may come in direct contact with the insulation at the point where it is tied. Care must also be taken to make the whole very dry at the moment when the joint is made.

Nicoll's metallic joint.

A very ingenious mode of making the wire portion of the joint has been invented by Donald Nicoll, esq., of Kilburn. His idea suggested itself in connection with his own system of underground telegraph-wires, but is equally applicable to the formation of joints of the nature required for submarine work and is very simple. He first prepares the extremity of one of the conducting-wires by forming it by means of a very neat and ingenious little instrument into a spiral twist, (see Fig. 58,) and the corresponding extremity

Fig. 58.



of the cable to be connected being left straight, it is slipped in, the whole placed on a small anvil, and, by a single blow of a hammer, pressed so closely together that soldering is almost unnecessary, while the joint is rendered capable of standing a considerable tensile strain.

Advantages and disadvantages of India-rubber tube joint.

The great advantage of a joint insulated with this India-rubber tubing is the facility with which it can be made at any time and under any circumstances; it is also very economical. The chief danger to it is the chance of a projecting end of a wire perforating the India rubber and causing a leak, through which a loss of current would take place; care must therefore be taken to prevent such an accident. One mode in which the chance of such a contingency may be reduced, is by lashing pieces of wood on over the joint, outside the India-rubber tubing, to prevent any bending at that particular point. Under Mr. Nicoll's system, no projecting ends are left in making the joint, and the chance of a perforation is thus reduced to a minimum.

Dent's bottle joint.

Another very good joint, in many respects superior to the India-rubber tube, is that invented by Mr. Dent, of the chemical department, royal arsenal, Woolwich. It consists of two parts, viz, a cylinder or plug of vulcanized India rubber, about 1 inch in length, and the same in diameter, through which three holes of sufficient size to admit the two insulated wires, (*b b*,) Fig. 59, and a tapering cylinder of wood, have been bored by means of a red-hot wire; and a stout glass tube (*cc*) about 1 inch in diameter and $1\frac{3}{4}$ inches in length, sealed at one end.

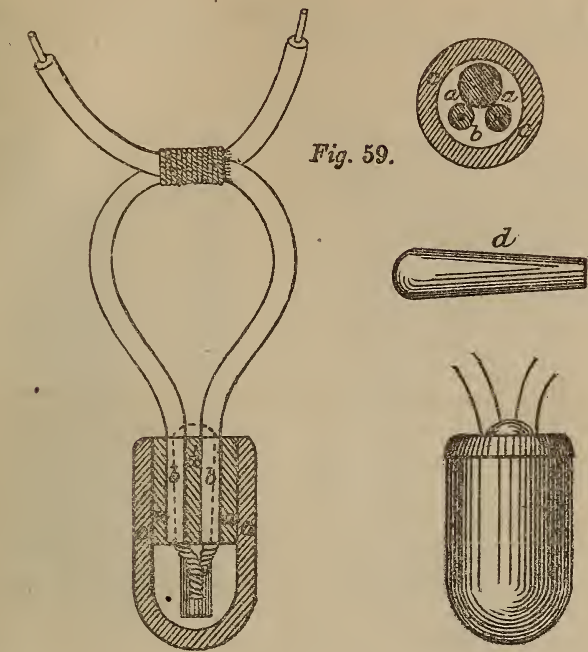


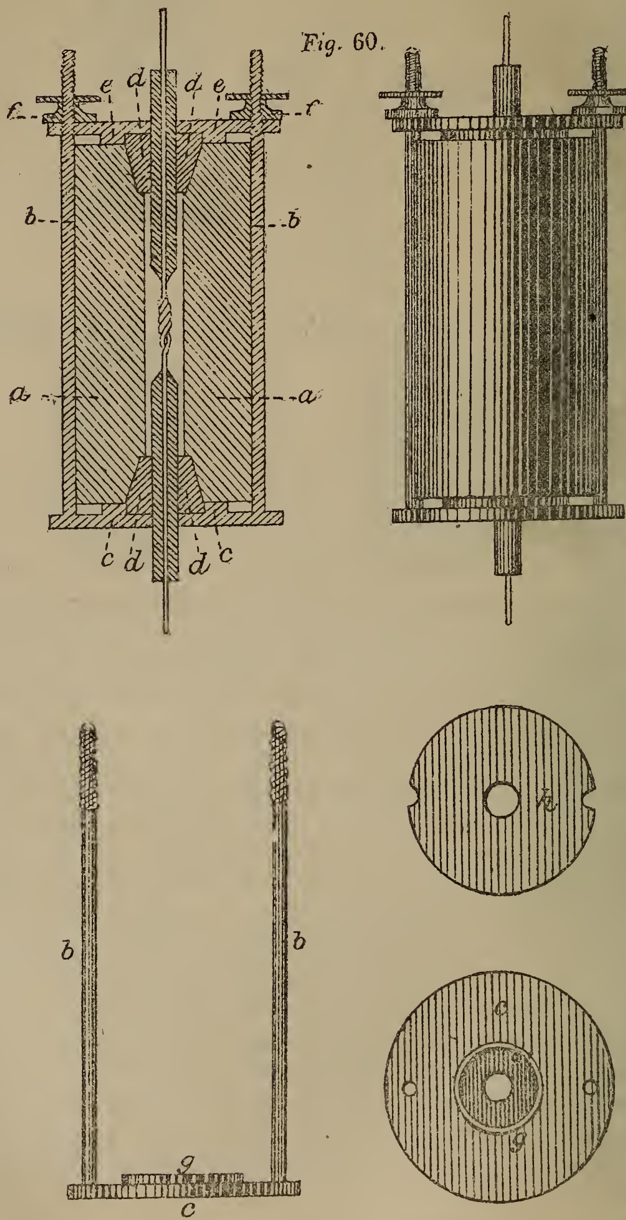
Fig. 59.

This joint is employed as follows: Each insulaled wire is passed through one of the holes in the vulcanized rubber cylinder, and the clean bare ends of the metal wire are then twisted together and cut off short. If tape-covered wire is used the tape must be previously removed from about three inches of each wire. Into the third hole of the cylinder is loosely inserted a tapering plug of hard wood, (*d*) about $\frac{3}{8}$ inch in diameter at the larger end, and 2 inches in length. The cylinder, with the wires and plug, is then firmly pressed into the glass tube, and the wooden plug is afterward forced into the hole as tightly as possible, as shown in Fig. 59, which has the effect of forcing the India rubber against the sides of the glass cylinder and around the insulated wires. It is important that the India-rubber cylinder should fit tightly into the glass tube, and that the perforations made to receive the wire be not larger than absolutely necessary. A very small quantity of grease applied to the surfaces of the insulation of the wires, the plug, and the cylinder will greatly facilitate the fitting up of the joint and improve its efficiency.

This joint is extremely simple and economical, and is easily made. A joint made on this principle was severely tried

Advantages and disadvantages of Dent's bottle joint by being kept under a pressure of 18 feet of water, and tested at intervals with a reflecting galvanometer, under which treatment no appreciable loss of insulation was indicated during a period of ten days. At the end of this time

Fig. 60.



the glass cup was found broken, as if forced outward by pressure from the swelling of the plug or wedge, while it remained submerged. It proved itself, however, an excellent joint as regards insulation. One of its defects is its inability to stand a tensile strain, in order to decrease the chance of which, as much as possible, the insulated-wire connections are tied together, as shown in Fig. 59. Another is the chance of the breakage of the glass by a blow, to obviate which the glass cup is covered with an India-rubber cap; it is, however, easy to arrange it in such a manner that it may not be subjected to either of these contingencies. Another defect, above referred to, is the danger of breaking the glass, by pressure exerted from the inside, in consequence of the swelling of the wooden plug after immersion in water. In order to obviate it, the plug should be made of box or some other very close-grained wood.

Another, and much more elaborate, joint is that invented by Corporal Glover, R. E. It consists of an ebonite cylinder (*a*,) Fig. 60, fitted with two grooves to receive the uprights (*b b*) of a brass disk (*c*) which forms one end of the apparatus. This ebonite cylinder is bored through the center to admit the wires to be joined with their insulation, and the diameter of the bore is expanded, at each extremity, into a conical hollow to receive two similarly shaped plugs (*d d*) of vulcanite, which latter pass over the insulation of the wires and fit accurately into the cavities left for them; (*h*) shows a horizontal and (*a*) a vertical section through the ebonite cylinder. A brass disk (*e*,) similar to (*c*) but with holes to receive the brass uprights of the latter, is placed over the top of the ebonite cylinder, and is held firmly on by screws (*f f*) passing on to the uprights. A small projecting ring (*g*) on the lower disk (*c*) and a similar arrangement on the upper one (*e*) keep the vulcanite plugs from being forced out laterally when pressure is applied. A metallic connection having been established by twisting the conducting-wires together, the outer protecting covering having, as before, been carefully removed, the base wire is drawn into the center of the ebonite cylinder, the screws (*f f*) are tightened, and the vulcanic plugs are driven forcibly into their respective cavities, making the whole water-tight. A little grease carefully applied to the insulating material at the points of pressure will in this, as in other similar cases, improve the insulation of the joint. Glover's joint.

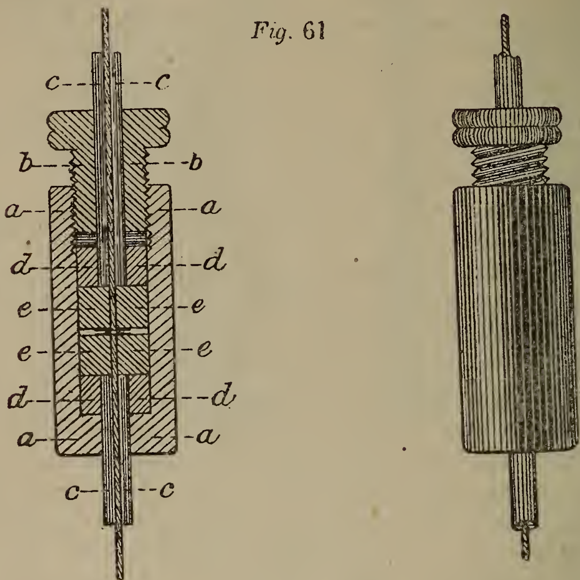
The defects of this joint are its high cost and the uneven bearing given by the two screws used in tightening up; this latter might, however, be obviated by the employment of three screws, in a triangle, instead of two, by which all side Defect of Glover's joint.

motion, after the process of tightening up, would be obviated.

Beardslee's joint.

Another joint is that said to have been invented by Mr. Beardslee, of New York, but bearing the name of Goodyear's patent on a specimen left at Chatham by him. It consists of an ebonite cylinder, (*a*,) Fig. 61, with closed ends, one a fixture and the other fitting the cylinder with a screw (*b*.)

Fig. 61



Each end has a perforation of sufficient size to admit the insulated wires (*c c*) which are to be connected. The bare extremities of the wire having been cleaned to the extent of about ⅜ inch, each one is passed through one of the perforations in the joint, as well as through a disk of vulcanized rubber (*d d*) of ⅜ inch thick, and one of metal (*e e*) ¼ inch thick. The bare extremities of each conductor are secured by spreading them out upon the metal disks, and these are then brought into close contact in the interior of the ebonite cylinder by screwing up the movable end thereof as tightly as possible.

Specially applicable to a strand conductor.

This joint is specially applicable to a strand conductor, composed of a number of fine wires, which may be separated and spread over the metal disks so as to insure good contact.

The usual precautions, as to the removal of any outer protecting covering and greasing the insulation, must be borne in mind in forming this joint.

It is particularly necessary, in employing this joint, to guard against direct strain being thrown upon the wire extremities which are inclosed, as they would be even more liable to be drawn out of the cylinder, in which they are rigidly fixed, than in the case of other joints; the electrical connection, in this case, being formed by the simple contact of the two metal disks and not by twisting the wires together. The wires should therefore be firmly braced together at a short distance from the point of juncture, as shown in Figs. 57 and 59.

Defects of Beardslee's joint.

The defects of this joint are its inability to stand a tensile strain, which would tend to draw out the wires, or so far separate the metal disks on which the wires are spread out as to break the metallic contact, and thus interrupt the current, and that the wires to be connected cannot be soldered.

Mathieson's joint.

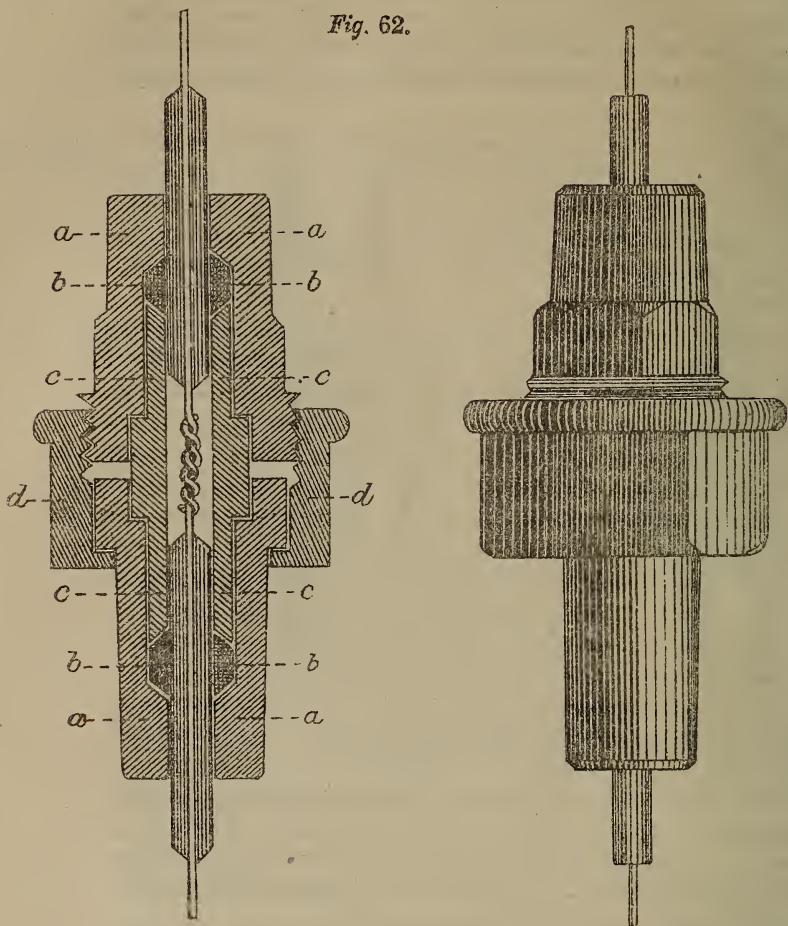
Another joint is that invented by Quartermaster-Sergeant Mathieson, R. E. It consists of two ebonite cylinders, (*a a*,) Fig. 62, perforated to receive the cables to be connected, the opening at the outer extremities being just large enough to admit the insulation of the wire to pass freely, while the inside is larger, thus forming shoulders against which thick perforated vulcanite rings (*b b*,) encircling the insulation, are placed. Within these cylinders is an ebonite tube with wedge-formed ends in contact with the vulcanite rings, within which the wire connection should be placed. The center of tube (*c*) is of square section, and fits into a hollow of similar form in the cylinder (*a a* ;) the ends of the tube are of circular section; the object of the square center is to prevent the wires to be connected being twisted round and round during the process of tightening up, as any torsion of this nature would be liable to disarrange the metallic connection within or to injure the insulation. A coupling-screw, (*d*,) with a shoulder to catch a corresponding shoulder on one of the ebonite cylinders, and a corresponding screw on the other, completes the arrangement.

Portions of the coupling-screw, and one of the ebonite cylinders, are made of hexagonal form, to fit a couple of spanners to be used in tightening up the apparatus when greater force than that which can be applied with the hands is necessary. It is easily seen how, by tightening up the coupling-screw, the two ebonite cylinders may be drawn together and the internal tube forced upon the vulcanite disks, making the whole water-tight.

To make a joint.

To make an insulated joint with this apparatus, the coupling (*d*) is unscrewed as far as possible without separating the two parts, (*a a*,) and a little grease is applied to the threads of the screw; the whole apparatus is then slipped bodily on to one of the insulated cables to be connected; the insulation of each cable, having been previously rubbed with a little grease, is then carefully tapered off to a blunt point

Fig. 62.



and rubbed with a little grease, taking care that this grease does not extend to the metallic conductor. The extremities of the metallic conductors, having been carefully cleaned, are next twisted together so as to leave as short a length of naked wire as possible, care being taken that the diameter of the two wires, when twisted together, does not exceed that of the insulation. The exposed metallic joint is next drawn back into the center of the connector, which is then screwed tightly up with a spanner and the India-rubber packing so firmly wedged round the insulation as to exclude damp most effectually from the bare conducting-wire in its center.

If the connector be unscrewed and the ends of the wire carefully drawn out, the same apparatus may be used any number of times, provided it has not been injured by the explosion of a mine. If the inside be wetted it must not be used again till thoroughly dried; especial care is necessary if it has been accidentally wetted with sea-water, the latter being a better conductor of electricity than fresh water.

The same apparatus may be used more than once.

When the cable is covered with an outer protection of tape, hemp, or any similar substance, it is necessary to remove this carefully from the vicinity of the joint, as the damp would penetrate through the fibers were it allowed to remain.

In order to test the efficiency of this apparatus, a piece of cable, which had previously been tested for insulation and found good, was cut into *nine* pieces and joints made at the cuts with Mathieson's joint, thus forming *eight* points through which the current might leak. This was sunk to the bottom of the river Medway, a depth of 36 feet, and tested from day to day for a period of more than two months, with 48 Daniell's cells, and an astatic galvanometer, without showing any indication of leakage of current.

Experiment to test insulation.

This joint possesses considerable tensile strength, but were it likely to be submitted to any considerable strain, it is nevertheless a good precaution to form a loop in the cable, as recommended for those previously described and shown in Figs. 57 and 59.

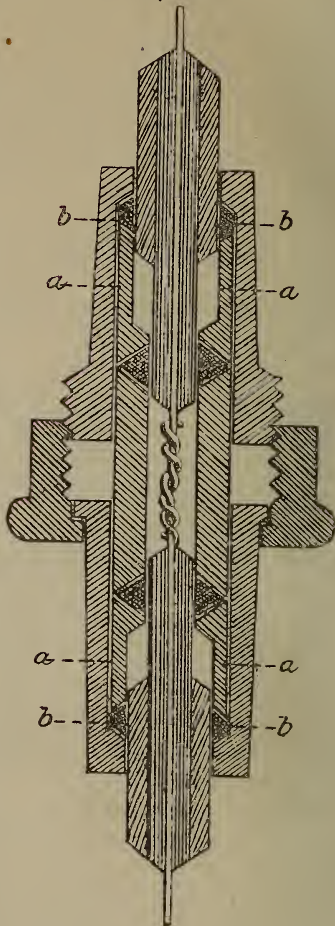
When an insulated cable has an outer protecting covering of wire, a modification of Mathieson's joint must be used. This is shown in section, Fig. 63; a simple addition in the shape of two ebonite tubes (*a a*) made to pass easily over the outer protecting covering, with India-rubber cylinders (*b b*) also fitting over the same, in addition to those in contact with the ebonite tube covering the metallic joint of the conducting-wires, is all that is necessary. It is easily seen how, by simply drawing the parts of the apparatus together by means of the coupling-screw, everything may be made water-tight and consequently insulated as before. In making a joint on a cable with an outer protecting covering of wire, this latter must necessarily be removed, and a weak place, at which the cable would bend easily, would be formed. The joint described, by gripping the outer covering beyond the actual point of connection, prevents any such bending

Mathieson's joint for cable, with wire protecting covering.

with the danger inseparable from it of piercing the insulation by a projecting wire.

These joints must be made to fit the insulation of the cables they are intended to connect with a certain amount of accuracy. They must be sufficiently loose to slip easily over it, before being screwed up, and the limit, within which a joint made for one size of cable may be used for a smaller one, is dependant upon the extent to which the India-rubber cylinders may be compressed, so as to fill up the vacant space and make the joint water-tight.

Fig. 63.



When there is no iron in contact to be damaged by the electrical action set up by the sea-water, the coupling-screw and outer portions of this joint may be made of gun-metal, which gives greater strength than ebonite.

Advantages of Mathieson's joint.

Mathieson s is decidedly the best of all the temporary joints described, possessing, as it does, excellent insulating qualities, great facilities for making or detaching a connection between two cables in a short space of time, and being capable of standing a considerable tensile strain. In many situations it may conveniently be used to supply the place of a permanent insulated joint, to which, as far as insulating qualities are concerned, it is quite equal, and to which, where facilities for examination are required, it is superior.

Experiments to test temporary joints.

All the temporary joints, above described, were tested for insulation, similarly to Dent's, (see page 144,) and all stood the test, which was a very severe one, remarkably well. Mathieson's was again more severely tested, as already described, with very satisfactory results.

CHAPTER IX.

SUBMERGING MINES, ETC.

We now come to the mode of laying down the mines in such a position that they shall be most effective, and at the same time so disposed that the explosion of one shall not injure the cables, circuit-closers, &c., in its vicinity.

Marking position of mines.

The position of the mines having been first determined, should be marked off by means of buoys, arranged to correspond with the charges to be subsequently placed in position, and points on shore to guide the vessels employed in laying them. The moorings may either be first placed in position, and the mines and circuit-closers hauled down to them, or the whole (moorings, mines, and circuit-closers) may be launched overboard, attached together in proper relative position, at the same time. In deep water it would probably be found preferable to adopt a system of hauling down to moorings previously placed, while in shallow water it would, under certain circumstances, be found quicker and more convenient to adopt the latter mode of proceeding. The cases ready charged, and with the electrical cables, &c., attached, having been lowered into position at such intervals as may be required, according to the size of charge to be used, and each carefully buoyed with a numbered buoy, the paying out of the cables may be proceeded with. The electrical cable attached to each, having been previously arranged on a drum, should be placed on board a pinnace or launch, which should proceed directly to pay it out in a line as nearly as possible perpendicular to the line of mines. Each boat should be provided with a small testing-battery and astatic galvanometer, by which the insulation and electrical resistance of the system should be tested at intervals, from the moment of submerging the mine till the other extemity of the cable is safely lodged in the testing-room. Any defect likely to cause a failure in firing at the proper moment would, in this way, be immediately discovered during the operation of submergence. As the boat, in paying out the cable, passes the position marked out for the second or covering line of mines, care should be taken to have it, as nearly as possible, midway between two adjacent mines in this line, to prevent the cable being damaged by the explo-

Paying out electrical cables.

sión of the mines in this line; the mines of this second line would, as stated in page 23, be so placed as to cover the intervals of the first. In passing this line the position of the electric cables should be marked off by buoys as a guide to those laying down the second line of mines, which, as soon as the work of the first has proceeded so far, may at once be commenced. In order to distinguish between the buoys marking the positions of the mines from those indicating the directions of the cables, different colors might be used; as, for example, those attached to the mines might be painted red, and those in connection with the cables black. As the third line of mines would be placed to cover the intervals of the second, it would be necessary, after proceeding in a direct line for about 100 yards in rear of the second line of mines, to change the direction in which the cable is to be laid by carrying it perpendicular to the direction hitherto followed, till a point directly in rear of one of the mines of the second line is reached, when it should again be turned inward, and would be in a position to pass safely through the center of an interval between two mines of the third line, as it had previously passed through those of the second, so as not to be injured in the event of their explosion. In passing this third line of mines it should be again buoyed for guidance in laying the mines belonging thereto, and so on till the extremity of the cable was connected to its corresponding wire, if a multiple cable were used for any portion of the distance, or if each were to be taken in singly, till safely landed in the fort in which the operating-room is placed, when it should be attached to its proper binding-screw, and its insulation and resistance carefully tested and registered.

Lines of cables to be as far as possible from charges.

The same process would be gone through with every charge, the utmost care being taken so to lay the cables that they shall be as far as possible away from the mines in the vicinity of which they may be required to pass, so as to give the least chance of injury from the explosion of the latter. By the arrangement above described they would also be in a favorable position for underrunning and picking up, should such an operation become necessary.

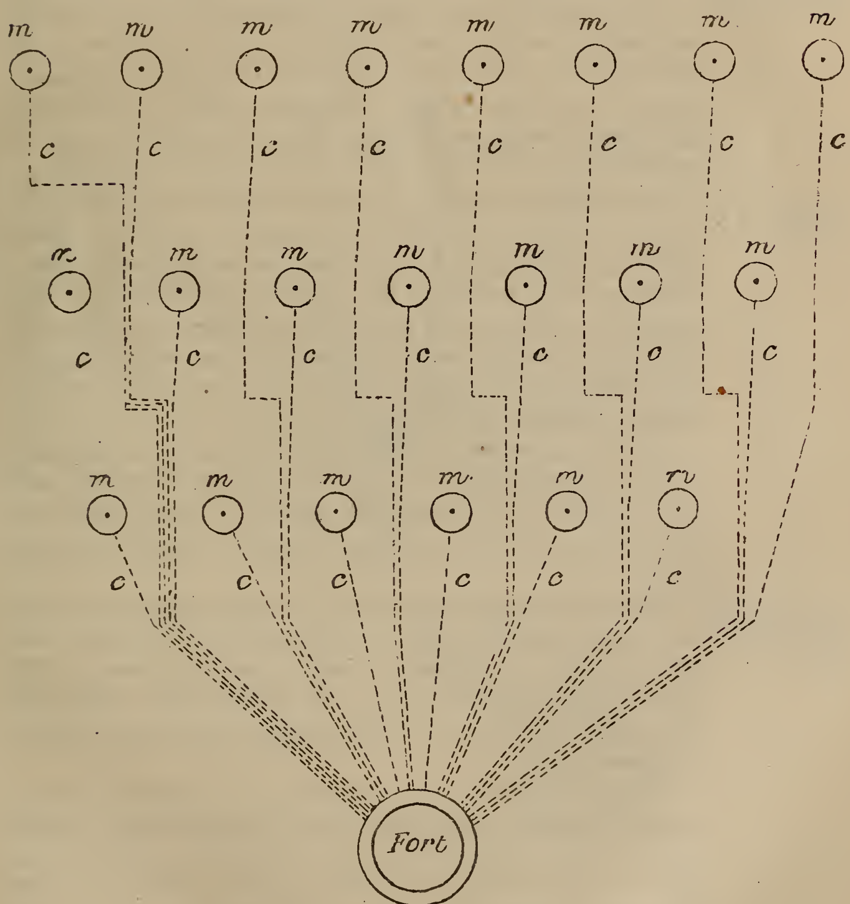
Slack to be allowed.

A certain amount of slack should be allowed in laying the cables to facilitate picking them up for examination and repair. This amount of slack will depend on the depth at which a cable is submerged.

Positions of charges to be identified by bearings and marked on a plan.

The position of each charge should be identified by means of bearings taken by two theodolites, from points well situated for the purpose, and marked in position on a plan, with the number of each mine, as a guide to facilitate its discovery at any future time. This done, and the whole system having been proved to be electrically correct, all the surface-buoys should be removed, to prevent any indication of their position being given to an enemy. Dummies to deceive an enemy may be judiciously arranged in a manner not too ostentatious, but they should never be placed in such a position as might, in ever so remote a manner, lead to the discovery of a real mine. Fig. 64 gives a general idea of the position of the cables if laid down on the principle described; the cables are indicated by the dotted lines (*c c c*, &c.,) the mines of the system are shown at (*m m m*, &c.)

Fig. 64.



They should be laid, as far as possible, parallel, and never be allowed to cross directly over each other, otherwise the operation of underrunning will be much complicated.

Electric cables carried round flank of mines.

The arrangement of the cables above described is that in which the shortest possible length would be consumed, and would, perhaps, be the safest from discovery by an enemy's boats. In certain cases, however, it might be convenient to carry them by a detour to the fort, as for example round the flank of the second and third line of mines, and there would be no difficulty in this, always bearing in mind that they should, in the first instance, be carried directly back for about 100 yards, so as to be safe from injury due to the explosion of their own line of mines, and that their subsequent course should be so arranged as to keep them safe from damage from the explosion of any other mine in the system.

Cables to be protected from wash of sea.

In selecting any line to be taken, places where the cables would be subjected to a wash of the sea should be, as much as possible, avoided, and when it becomes necessary to place them in positions where they are necessarily subjected to the friction and rubbing consequent upon the motion of the water, special precautions must be employed for their protection.

Position of electric cables to be concealed.

The confederates used all sorts of devices to conceal their electrical cables, such as laying dummies, making considerable detours inland, &c., and such precautions must always be taken when required by peculiar circumstances. It is impossible, however, to lay down any rule for such cases, which must be left to the ingenuity of those in charge of the mines, who will be best able to judge of the capabilities of any particular position.

The only general rule which can be laid down for guidance in such circumstances is to place the cables where they can be subjected to the greatest amount of supervision, and where they can be most easily defended from injury by an enemy.

Mode of placing mines in position, proposed by Lieutenant Anderson, R. E.

The following proposed mode of placing submarine mines in any given position, and of dealing with the cables in connection with the different charges, has been drawn up by Lieutenant Anderson, R. E., and is applicable where the land or river banks are conveniently situated for erecting the poles.

The direction of a line of mines, to be placed across a channel, may be determined by two poles previously erected on the shore, as shown at (*a* and *b*,) Fig. 65. The arrangement to give the intersections on the above-mentioned alignment, where each mine is to be placed, is shown by the poles marked (*c*, and 1, 2, 3, 4, 5, 6) to correspond with the numbers of the mines.

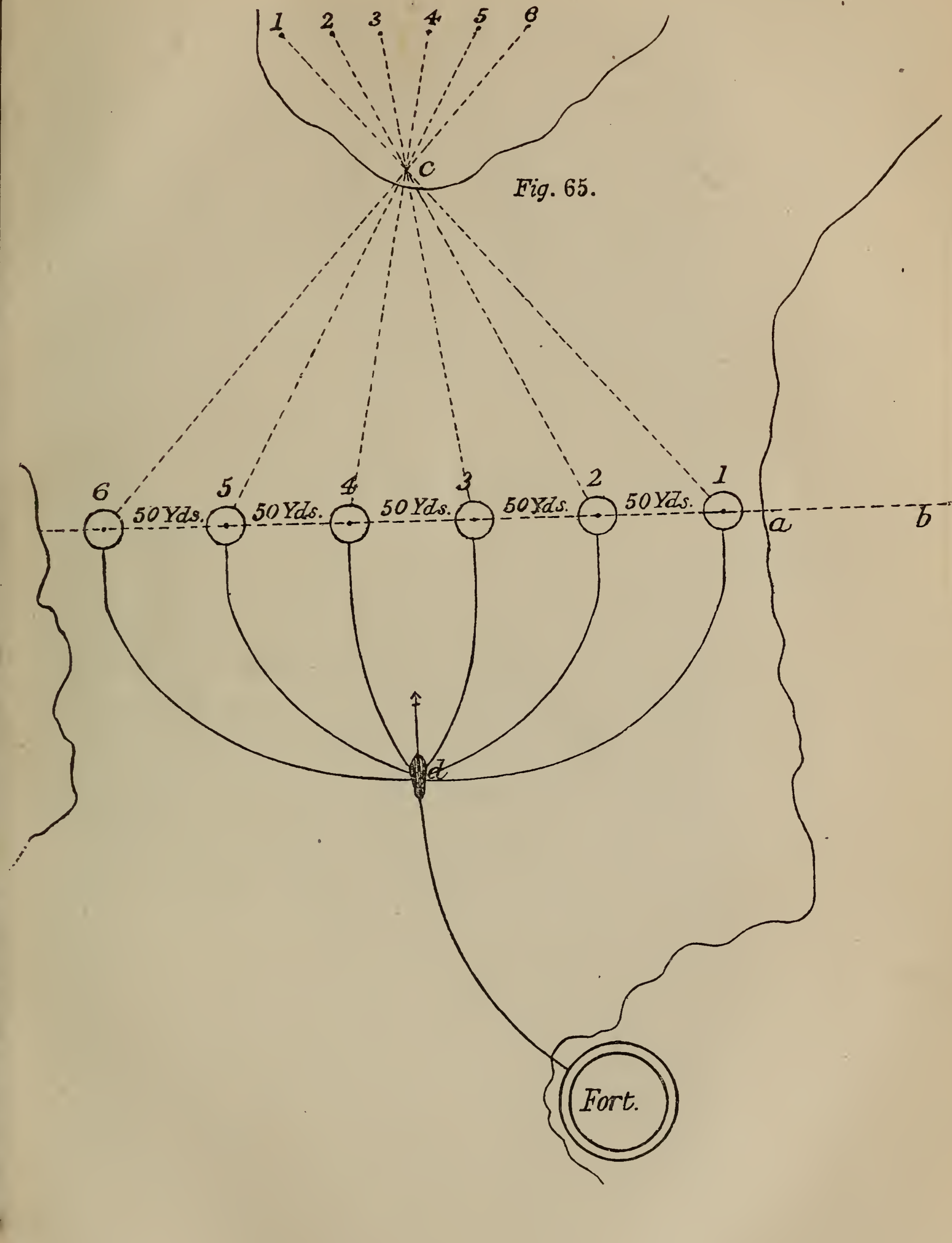


Fig. 65.

The proposed mode of placing the charges in position is as follows:

Soundings are first taken at the required points, and the length of mooring-line for each charge determined accordingly. The anchor is to be suspended from the davit of the working pinnace, and everything made ready to let it go with a run. The electric cable to be stoppered to the mooring-line between the charge and the anchor, and a strong mooring-chain or wire rope to be provided to connect the charge to the circuit-closer, so that, by this chain, both the charge and anchor may be raised if required. The electric cable, between the circuit-closer and charge, should be stoppered to the chain or wire rope in the same manner as from the charge to the anchor. The length of the electric cables, from the anchors of the different charges to the point (*d*) on which they converge, would vary according to the position of the charges with regard to the center line of the channel. Each electrical cable to be coiled on a small portable drum, so that it may be easily moved in and out of the working pinnace.

To place the first mine.

To place the first charge the pinnace (with the anchor connected with the charge and circuit-closer by moorings of proper length, as above described, and suspended by the davits at the stern) would be turned out into the exact alignment given by the line (*a b*,) proceeding only fast enough to obtain steerage-way; as soon as the stern of the pinnace arrived at the intersection given by the alignment (*c* 6,) the order would be given "let go," and immediately anchor, charge, and circuit-closer would be drawn down into position. The electric cable would then be payed out, at first directly away from the charge, and finally taken to the boat (*d*,) which had been previously anchored in a position 100 yards or more in rear of the center of the part of the channel to be defended. When many charges are to be placed in the same line, it is recommended, in order to avoid the use of long cables and consequently unwieldy drums, that the cable from the charge 6 should only be long enough to reach to the boat (*d*,) in which the end of this cable is for the time being secured. The next charge, with all its attachments complete, having been arranged as before, the pinnace would again slowly cross the channel along the alignment (*a b*,) till her stern arrived at the intersection 5 with the pole (*c*,) when the anchor would be let go, and the cable of this charge carried in the same manner to the boat (*d*.) Thus all the charges up to No. 1 would be similarly deposited into position, and their cables carried as far as the boat (*d*.)

Tests to be made during submergence.

Tests for continuity and insulation should be made as soon as each electric cable arrives at the boat (*d*.) When a multiple cable is to be employed for the main conductor, (and if battery power were always used for firing there would be no objection to the use of such a cable,) it would now be a simple matter, by means of insulating ebonite joints, to connect each cable to its corresponding main conductor; or, if circumstances permitted, it would be advantageous to establish at this point of the electrical circuit a test-box, into which all the cables from the charges might be carried, and in which the connections with the main conductor might be made.

This test-box, which should be of iron, and supplied with a lid screwed firmly down to the body of the box by means of nuts and screws and a substantial washer, should be sufficiently heavy to insure its not being disturbed at the bottom of the channel by the force of the tide or current. A test-box would facilitate examination for the discovery of any leak or fault that might occur in the circuit. This could be done without disconnecting the other wires in the test-box; and in the event of any one charge being exploded or carried away, it would only be necessary to renew the cable from the test-box to that particular charge. Where the use of a multiple cable is impracticable, each must be carried separately into the fort from which the system is to be controlled. It would, probably, be most convenient to have the drum of the multiple cable or the separate drums of the single cables in the fort, and lay the cable or cables therefrom to the anchored boat (*d*.) This operation might thus be carried on simultaneously with that of mooring the charges. The objection to it in the case of cables carried in singly would be the joint to be made in the boat, (*d*,) for which reason it would, with single cables, be preferable to preserve them in one continuous length and lay them from the boat (*d*) to the fort, after the previous portion of the work had been completed. If single cables are used, they should be payed out in parallel lines so as not to cross each other, in order that each might be conveniently underrun and examined, if required, without fouling any of the others; or the single cables might all be tied together with spun yarn and laid out as one. It is certain that if some systematic manner of placing a series of cables along the bottom of a channel is not adopted they will become entangled with each other. There is, however, an objection to their being laid out close to each other—that an enemy grappling in that direction would be certain to catch all the cables together.

When everything has been completed the boat (*d*) should be removed, its position having been previously carefully determined by bearings, to facilitate any future search for the cables at that point. The poles or marks (*a*, *b*, *c*, 1, 2, 3, 4, 5, and 6) should also be removed, their positions having been carefully marked, so that no indication of the locality of the mines may be given to an enemy.

All marks indicating position of mines to be removed.

As there would nearly always be more than one line of mines, it would be necessary to repeat this process for each, for which purpose we should have to establish a separate set of poles to mark the intersections.

In working from a chain or hawser, on which the distances have been marked, as described at page 75, the weight of the working-pinnace holding on to the chain at the required position produces a certain amount of sag, greater in proportion to the length of the directing hawser, and this sag must be taken into consideration, and as a check a couple of poles, as at (*a b*,) Fig. 65, or two buoys, where poles could not be used, would be found convenient. For short distances, across the Medway, for example, the arrangement with a directing hawser works with sufficient accuracy.

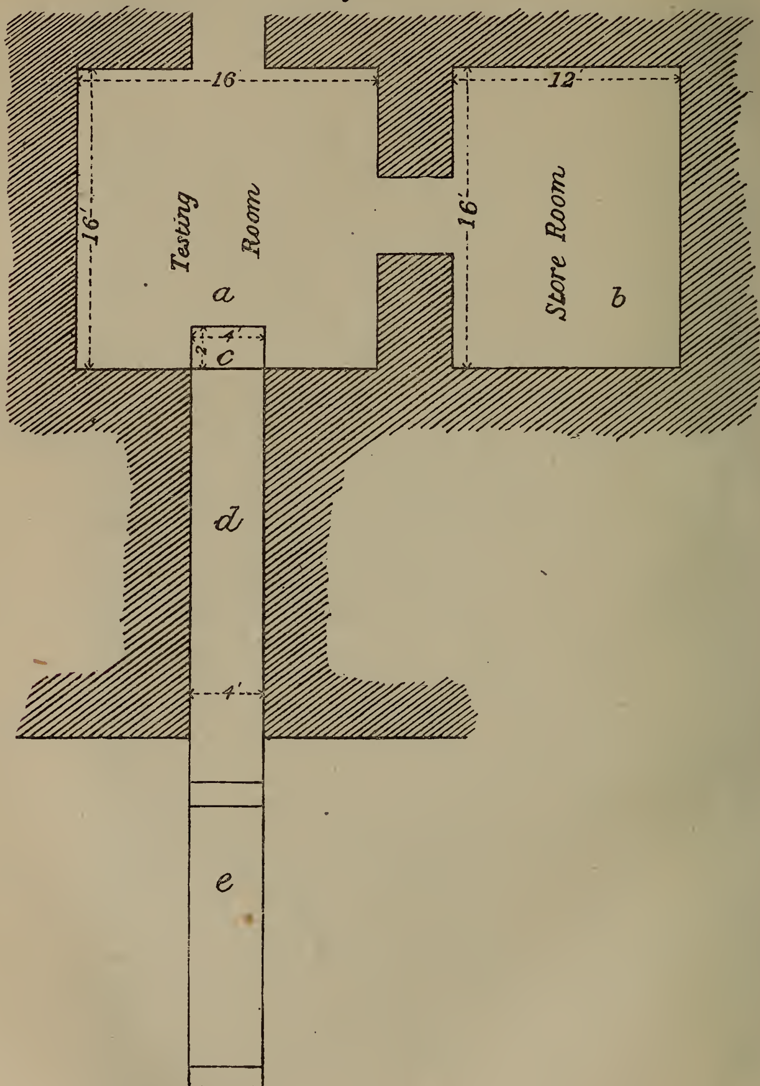
Introduction of electric cables into a fort.

The next point to be considered is the best mode of introducing the cables into a fort or sea-battery. In doing so they should be protected to the utmost, not only from injury by an enemy, but from the friction and rubbing necessarily caused by the wash of the sea. Bearing these objects in view, advantage must be taken of local circumstances which will present an endless variety of conditions, which must be met by expedients suited to the nature of each particular case. A great deal must therefore be left to the discretion of the officer in immediate charge, and very few general rules can be laid down. As already stated, it is, however, necessary to carry them into such forts and defensive positions as are likely to hold out longest in any system of defense, and not, as a matter of course, into those nearest to them. They must be covered to the utmost from an enemy's fire, and, as far as possible, be protected from his interference in any way, as his great object would be to break and destroy the electrical circuit; when exposed to rubbing and motion from the wash of the sea, they should be provided with an outer protecting covering of iron wires, copper tape, or something similar, as already described in treating of the description of electrical cables best suited for the purpose, and should be further, as far as possible, covered and placed in sheltered situations. It is a great matter in such situations to weight a cable well, and a good expedient would be to attach it to a heavy chain. This would be a good plan to adopt in carrying it over shallows not only near its entrance into a fort, but wherever they may occur along its line.

Modification of design by Lieutenant W. G. Nicholson, R. E.

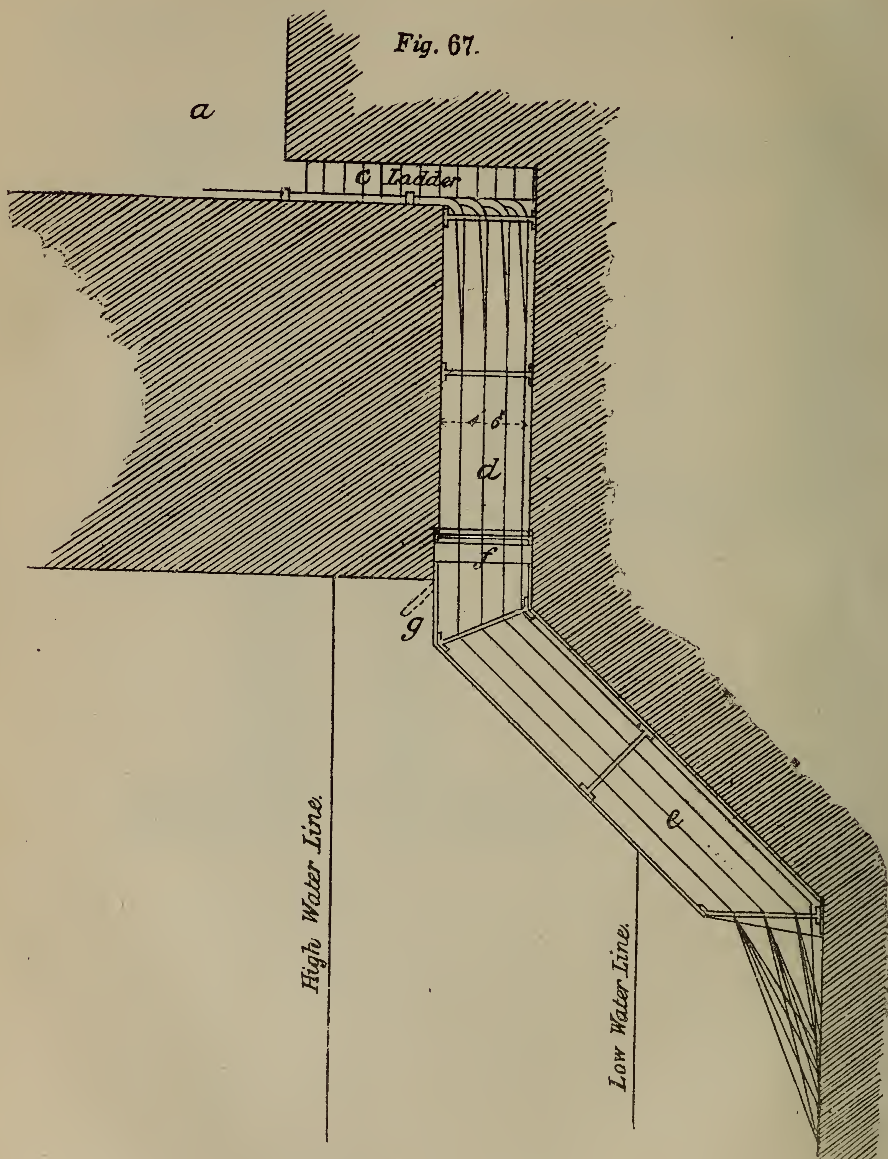
The following design for introducing the cables into a fort, is a modification of one proposed by Lieutenant W. G.

Fig. 66.



Nicholson, R. E.; it is applicable to the particular section shown, and serves to give some idea of the essential points to be kept in view, while the details of each particular case

Fig. 67.



must, as already stated, be modified according to local circumstances.

A plan of the proposed mode of introducing the wires is shown in Fig. 66, and a section in Fig. 67; (*a*) is a testing-room, into which all the cables must be brought, and where the apparatus, by which the whole system is controlled, is arranged; (*b*) is a store adjoining; (*c*) is a shaft 2 by 4 feet, by which access is gained to the gallery (*d*) cut through the outer masonry of the fort; the shaft (*c*) is provided with a ladder; (*e*) is an iron-plated hood carried down to the level of the bottom of the sea; the iron plating is carried sufficiently far below low-water mark to secure the hood from the enemy's shot; (*f*) is a gun-metal diaphragm, through which each cable passes by means of an apparatus precisely similar to Mathieson's joint; this diaphragm need not be water-tight, and is only intended to prevent the wash of the sea rushing violently into the passage (*d*) and thence in the testing-room, as would be the case without it in stormy weather. A man-hole (*g*) gives access to the hood and permits the sea, rushing in through the hood and checked by the diaphragm, (*f*,) to escape without bursting in the latter.

Testing-room, store, shaft, passage, and hood.

The cables, on arrival at the foot of the hood, are carried in on a system of frames, as shown in section, Fig. 68. These are placed at intervals along the hood and gallery, and are provided with four shelves or compartments, each carrying 20 cables, laid in a separate groove and numbered, making a total of 80 for the whole. These frames should be of gun-metal; iron is too apt to oxidize, and wood, which would be alternately in water and air with every rise and fall of the tide, would be liable to rot and render constant repairs necessary. The frame-work occupies half the breadth of the gallery, leaving the other half for access and examination of the cables. On arrival at the shaft (*c*,) each twenty cables are collected together and carried up along the sides of the shaft to the testing-room. Should it be necessary to carry more than 80 cables into the fort, it would only be necessary to arrange a series of hooks, on the far sides of the frames, on which several additional lines could be supported.

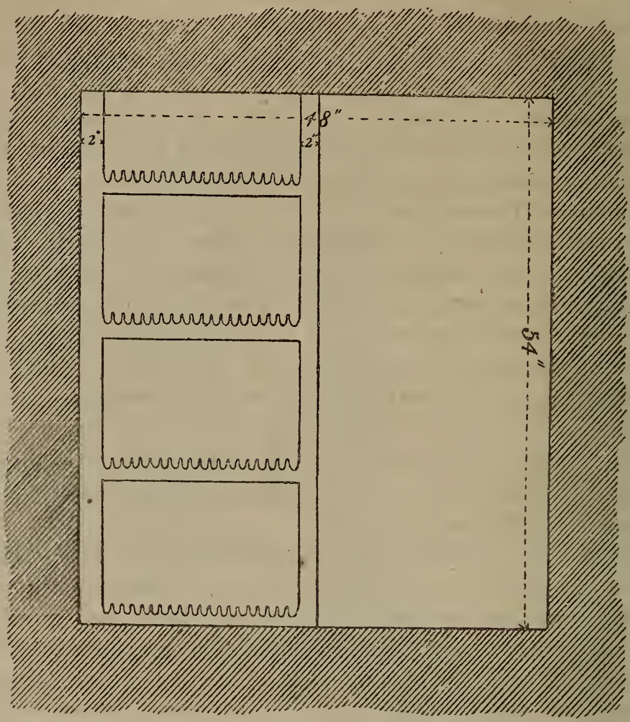
Frames to carry cables.

The floor of the testing-room should, if possible, not be less than three feet above high-water spring tides, otherwise, it would be very liable to be flooded by the wash of the sea in rough weather, for even with the diaphragm, (*f*,) there would still be a certain amount of motion in the water. Where possible, the outside of the hood should not be less than 10 feet below low-water spring tides, because at such

Level of floor of testing-room and foot of hood.

a depth, except on extraordinary occasions, there would be comparatively little motion from the wash of the sea.

Fig. 68.



(Section of gallery showing 1 frame. Number of cables, 80.)

To make connection with exterior.

The man-hole (*g*) gives access to the hood; for the manipulation of the cables, it would only be necessary to go in at low water and establish a communication with the exterior by pushing a buoy beyond the outside of the hood by means of a pole of sufficient length; the buoy, on floating to the surface, would carry a line with it, which would be all that is necessary, and by it a cable might be hauled in or out as required. This would, in a great many cases, do away with the necessity of employing a diver, though it would, nevertheless, be necessary that a diver be at hand where any very extensive system of submarine mines may be used for defensive purposes.

Identity of each cable to be carefully preserved.

In passing from the outside to the testing-room, the identity of each cable must be carefully preserved throughout by means of a number, and each would be finally attached to a binding screw or connection similarly numbered, so that any particular one might be easily picked out if required.

Much care would be necessary to prevent confusion in carrying in the electric cables, in the first instance.

The arrangement of a system of submarine mines in lines possesses one serious disadvantage, viz, that an enemy, having once ascertained the position of one mine of a line, either by its explosion, or by any other accidental circumstance, would know within limits where the others were to be looked for. In order to obviate this disadvantage, it would always be necessary to scatter a few mines at irregular intervals in front of the advanced line—to put them, so to speak, in the position of skirmishers, retaining the line-formation for the main defense. These advanced mines might either be simply electro-self-acting, or arranged for ignition on the same principle as those of the main system, as circumstances required.

Disadvantage of an arrangement of mines in line.

Mode of obviating this disadvantage by advanced mines at irregular intervals.

The first object of an enemy would be to clear a passage of sufficient width through the system to enable him to pass freely in, and for this purpose he would probably employ drifters, with or without dragging-grapnels, for the purpose of either firing some of the charges by striking the circuit-closers, or grappling and destroying the electrical cables and other gear. These drifters might be boats allowed to float in with the tide or wind, and need not necessarily contain any men, so that the loss of human life would not be a certain consequence of their destruction by the explosion of a mine. In order to stop such a system of attack, light booms or strong fishing-nets would no doubt be extremely useful, and should be employed wherever circumstances admitted. To stop drifters with dragging grapnels, it would seem to be a good plan to lay three or four heavy chain-cables at intervals across the channel in advance of any system of mines. The grapnels would catch in these, and the weight of the chains would be sufficient to bring up the drifters before arriving at the system of mines.

Defense of mines from drifters.

Defense by booms and fishing-nets.

Defense by heavy mooring-chains.

The night would unquestionably be the safest time for an enemy to carry on operations of this nature, and it would be necessary to employ boats to row guard in order to watch his proceedings. The mode of communication with these boats is a matter of considerable importance, and some means of rapidly transmitting intelligence is absolutely necessary. This can, of course, be done by the army and navy system of flashing signals, but the lights, in such cases, would be a disadvantage, as they would indicate the position of the guard-boat. In order to obviate this, a system has been devised by which a boat rowing guard can be put in electric telegraphic communication with a fort or

Mines must be watched at night.

Electrical system of communication between a fort and guard-boat.

guard-ship, by simply paying out an insulated wire attached to a telegraph instrument in the fort or ship, and carrying a second telegraph instrument on board the boat. The system is so arranged that no electrical batteries need be carried in the boat, the whole of them being retained at the headquarter telegraph station. The instrument in the boat would be a simple Morse sounder, so that no light of any sort would be required to read the message. The telegraph instrument at the headquarter station might either be a Morse sounder or a Morse recording instrument, and, when the latter is used, the system has been so arranged that all messages, both those emanating from the headquarter station and those received from the boat, may be recorded for future reference. By this means messages can be transmitted either by the Morse telegraph alphabet or by any signal code, and, when the latter is employed, any man who has been taught the army and navy system of signaling can learn to use these instruments with very little practice. The apparatus has been used for some time in the river Medway, in carrying on our submarine mining operations, and answers perfectly. Should the guard-boat be chased, it would be only necessary to detach the electric cable from the telegraph instrument and throw it overboard, with a buoy and line attached to it, and pull away. It could be recovered at leisure.

Illumination of channels defended by submarine mines.

Several systems have been devised for illuminating channels at night by means of the electric light, the Drummond light, magnesium light, &c., and there is no doubt that, where practicable, such devices should always be used. The action of the several lights named is too well known to render it necessary to describe them here, but there is one device which might be easily made use of in connection with a guard-boat. A substance, producing by its ignition a very bright light, (magnesium, for example, would be one of the best,) might be arranged on a float, and a guard-boat carrying a few of these might, if chased, ignite and throw one out. The apparatus should be provided with a short fuse, to enable the guard-boat to get a little distance off before the actual light burst out. In this way an enemy's vessel might be seen and fired on by the guns of a battery. Boxer's parachute shells, or any similar device, would also be useful for illuminating purposes.

CHAPTER X.

ELECTRICAL IGNITING AGENTS.

Having carried our electrical cables into the fort, the next point to be considered is the agent by which the mines shall be ignited.

Ignition at will or by curcuit-closer.

Ignition may be effected either at will or by a self-acting arrangement, the vessel, in the latter case, herself completing the circuit by means of a circuit-closer. The means employed in firing at will may be a magneto-current, frictional electricity or battery-power; when a circuit-closer is used, battery-power only is available.

Firing at will.

First, with reference to the employment of a magneto-current. Several instruments for the production of a current of this nature have been devised, and perhaps the most beautiful and ingenious of them is that of the well-known electrician, Professor Sir Charles Wheatstone; a description of it, which is given in the printed *Course of Instruction in Military Engineering*, published by authority, page 152, will serve as a key to the construction of all instruments of this nature.

Wheatstone's magnetic exploder.

The mode in which the uneven succession of currents, produced by a magneto-induction apparatus, and which is not given in the *Course of Instruction in Military Engineering*, is overcome is very ingenious. Sir Charles Wheatstone has placed two bobbins on each pole of the magnets instead of one, by which arrangement he obtains the result shown in

Fig. 69.

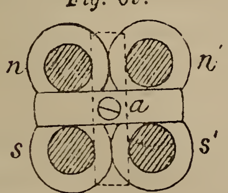


Fig. 69, where, if (n n', s s') be the bobbins, and (a) the armature revolving in front of them, the latter is so arranged that, at the moment when it is breaking contact with (n') and (s,) it shall be making contact with (n) and s',) and thus the difficulty occasioned by the uneven succession of currents, which would occur if only one pair of bobbins were used, is got over; for the coils are so arranged that, for example, in the position of the armature shown, the larger or breaking-contact current, induced in the coils (n) and (s',) is transmitted in the same direction as the smaller or making-contact current, induced in the coils (n') and (s,) and thus we obtain an even succession of currents, first in one direction and then in the opposite; for, as the armature continues to revolve, it first makes, and then breaks, contact with the opposite pairs of bobbins simultaneously and with great rapidity.

The defect of this instrument is the small quantity of the electrical current induced, which renders it necessary to have very perfect insulation throughout the whole of the connections.

Arrangement of fuses for Wheatstone's exploder.

Fuses to be fired with this apparatus must be arranged in simple divided circuit, and the number of charges, which may be fired in any given group, depends on the extent of the leakage or loss of current through the ends of the conducting-wires laid bare, after any given number of mines in such group have been fired. Though practically simultaneous, the charges are really fired in extremely rapid succession, and as each explodes a greater surface of bare wire is exposed, and brought in contact with the surrounding earth or water in which the mines are placed. When this bare wire amounts in the aggregate to a conducting surface, sufficient to carry away a large proportion of the current generated, no further fuses will be exploded. The conducting-power of water, especially salt water, is much greater than that of earth, and consequently, though as many as ten fuses may be fired with this apparatus in dry earth, we cannot reckon on igniting more than four with certainty in salt water.

Beardslee's magneto-electrical exploding machine.

Mr. Beardslee, of New York, has designed an instrument of somewhat similar construction to Wheatstone's, capable of producing a greater quantity of electricity with less electromotive force. The general principles of this instrument are similar to those of Wheatstone's.

It consists of a compound magnet, (said to be made of cast iron,) provided with ten arms arranged like the spokes of a wheel, each arm being composed of four separate magnets about $\frac{1}{4}$ inch in thickness. It is mounted on a central axis, upon which it may be made to revolve with very great rapidity, by means of wheel-gearing and a handle.

The armatures with their coils of insulated wire (about 24 gauge) are fixtures; they are arranged in two circles, and are placed in as close proximity to the arms of the magnet as is possible without touching them, one coil being above and the other below each arm. The coils are connected together in four series of five each, by means of two insulated wires; each of these terminates in a separate metal plate, whereby each is brought into distinct connection with the external poles of the machine, (communicating with the conducting-wires.) By this arrangement each set of poles of all the coils is connected with one pole of the machine. The machine is inclosed in a box, in which it is very firmly fixed by means of a stout iron frame-work. On an inner lid of the box is the handle, by the movement of which the magneto-electric current is developed; the binding screws, which are immediately over the inclosed pole-plates, and which receive the conducting and earth wires; and lastly a key arrangement, by the movement of which, at the required moment, when the magnet is revolving at its maximum velocity, the electric current is passed to the binding screws, and thus to the charge which is to be exploded. An outer lid incloses the entire mechanism, so that all parts are protected from injury during transport.

It was especially adapted for use with Beardslee's fuse.

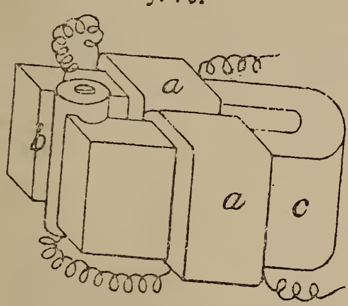
Dynamo-electrical machines.

Kindred instruments to the above, called dynamo-electrical machines, are manufactured by Messrs. Siemens Brothers, of Charlton, and Mr. Ladd, of Beak street, London. An important difference exists in these instruments as compared with the ordinary magneto-induction apparatus, namely, that they are independent of permanent magnetism for the current induced.

Siemens' dynamo-electrical machines.

The instrument made by Messrs. Siemens is very similar in its arrangements to any magneto-electrical apparatus of ordinary construction, but in it the permanent magnet is replaced by a piece of soft iron, (*c*,) Fig. 70, round which a coil of fine insulated wire is wound as at (*a a*;) (*b*) is a Siemens armature of soft iro, on which a coil, in metallic connection, through a commutator, with the coil (*a*) is wound. When this armature is made to revolve rapidly, the residual magnetism in the horseshoe-formed piece of soft iron (*c*) induces a series of currents of electricity in the coils of the armature; or if there is absolutely no residual magnetism in (*c*,) it is only necessary to touch it with a permanent magnet for a moment, when beginning to move the armature (*b*.) The currents thus induced in the coils of (*b*) circulate through the coils (*aa*,) and increase the magnetism, which in its turn re-acts on the coils (*b*,) and induces a stronger series of currents. In this way the one may be made to re-act on the other, till (*c*) becomes a powerful electro-magnet,

Fig. 70.



and a very considerable current is induced in the coils. This occurs after a very few turns, and it may be utilized in any way of a similar nature to that for which the ordinary current produced by a magneto-electrical machine is available, by simply discharging it through any circuit required.

This property of soft iron was discovered by Dr. Werner Siemens, of Berlin. He states that there is always sufficient residual magnetism in the soft iron to induce a small current in the coils, and in these instruments the re-action of magnetism on currents, and *vice versa*, increases this residual magnetism very rapidly.

Experiments with Siemens's dynamo-electrical machine.

One of Siemens's small instruments, weighing 28 pounds, has been tried at the School of Military Engineering, at Chatham, with the following result:

Twelve Abel's fuses, out of twenty, placed in continuous circuit in dry air, were exploded at the second discharge. Twelve Abel's fuses placed in divided circuit in dry air were fired, one at the first discharge and eleven at the second. The instrument is so arranged that several turns of the handle are made in the first instance on short circuit, in order to accumulate a sufficient charge in the coils, and on arrival at a certain point this accumulation is discharged through the main circuit in which the fuses to be fired are placed. In order to produce this latter result, the short circuit is broken by means of a cam in connection with, and turned by, the handle by which the armature is put in motion, which allows a spring to descend and simultaneously to break the short and complete the firing circuit. The reason of the partial failure in the two experiments mentioned was, that the handle had been turned very nearly up to the point where the action of the cam, throwing in the firing circuit, took place, and consequently, instead of the accumulated charge produced by several turns being stored up, only that due to one or two turns was discharged through the firing-circuit.

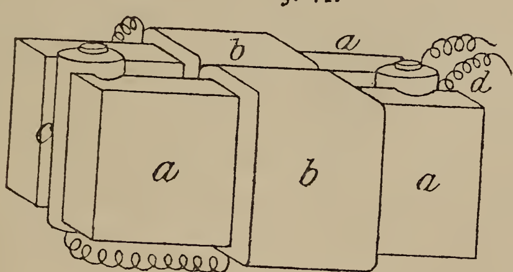
It is necessary, therefore, in using this instrument, to commence turning the handle from that point where the maximum number of turns, before the discharge, is obtained. In subsequent experiments, where this precaution was taken, no failure of the nature described took place. It may be assumed, therefore, that the instrument in question possesses the power to fire twelve Abel's fuses, either in continuous or divided circuit, in dry air. As the fuses are all fired by a single discharge, and not by a succession of short currents as in Wheatstone's magnetic exploder, the number which may be relied on to be fired in earth, dry or damp, or in sea-water, depends upon the quality of the insulation of the electric cable. To test this, a single Abel's fuse was fired with this instrument through a quarter of a mile of cable, (a strand of 7 No. 22 copper wires, insulated with Hooper's dielectric to a diameter of $\frac{3}{10}$ inch;) it failed to fire with a leak of $\frac{1}{16}$ inch. With the same cable the ebonite frictional machine failed with a leak of $\frac{1}{2}$ inch. With a conductor consisting of $1\frac{1}{4}$ miles of similar cable, the dynamo-electrical machine failed to fire the fuse with a leak of $\frac{1}{32}$ inch. With the same cable the frictional machine failed with a leak of $\frac{1}{4}$ inch. As regards power to overcome a leak, therefore, a dynamo-electrical machine of this weight ($28\frac{1}{2}$ pounds) is about on a par with Wheatstone's exploder, weighing 31 pounds, which has been tried against it for the sake of comparison.

Machines of this nature may be made of considerable size, and, where portability is not essential, may be arranged to develop a very considerable electrical current.

Mr. Ladd, of Beak street, London, has invented another instrument adapted to the explosion of mines, the principle of which is precisely similar to that of Siemens's dynamo-electrical machine, but the arrangements differ, inasmuch as Ladd employs two armatures, one to create the electro-magnet, and the other to produce a current therefrom, with which to perform any work required. Fig. 71 gives the general arrangements of the instrument; (*a a*) are two soft-iron bars, around which coils of fine insulated wire (*b b*)

Ladd's dynamo-electrical machine.

Fig. 71.



are wound, in metallic connection, through a commutator, with the coil of an armature, (*c*,) revolving between their extremities. When the armature (*c*) is made to revolve, exactly the same effect is produced as in Siemens's instrument, and the result is that the two bars (*a a*) become very powerful electro-magnets, the poles of which are so arranged as to be exposed to each other at their extremities. Now, instead of discharging the current thus induced through his working-circuit, to fire fuses or perform any other work which necessitates the beginning again, as it were, to create a new current, Mr. Ladd introduces a second armature, (*d*,) revolving between the soft iron bars, from which he obtains his working-current; the magnetism of the bars is thus always kept up. The residual magnetism of the system is always sufficient to commence the action described, except, possibly, when an instrument had just been made, and had never been used, when it might be necessary to touch the bars with a permanent magnet, or pass a voltaic current through the coils for an instant, to obtain the magnetism required. An instrument of this nature was exhibited at the Paris Exhibition of 1867; it was only 24 inches long, 12 inches broad, and 7 inches thick, but the effects produced by it when worked by a steam-engine of one horse-power were very great, and would seem to augur well for the future of this system, which Mr. Ladd proposes to apply to the production of an electric light for light-house purposes, the principle is, of course, equally applicable to the ignition of charges of gunpowder or other explosives.

The following description of another instrument of a similar nature is extracted from the report of the committee on active obstructions, page 86:

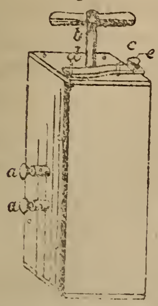
Magneto-exploder, by Markus of Vienna.

"A small magneto-electric exploding machine, which was first devised by Herr Markus, an Austrian philosophical-instrument maker, at the suggestion of Baron Von Ebner, (after the latter had witnessed the performances of Wheatstone's instruments and Abel's fuses in England in 1862,) and which is stated to be employed in the Prussian service, was obtained by government for the purposes of the committee from Messrs. Gessler & Co., of Berlin. This instrument is not more than half the size of Wheatstone's exploders, from which it differs materially as regards the mode by which the generation of magneto-electric currents is effected. It was only disposed of to the English government upon the understanding that it was not to be examined, and no detailed description of its construction can, therefore, be attempted, but the mode of using it affords a sufficient indication of the manner in which the magneto-electric current is generated. The magneto-electric apparatus is completely inclosed in a square oblong metal case, to one side of which are fixed two binding-screws, (*a a*,) Fig. 72, for connecting the instrument with the conducting-wires, while one of the ends forming the top of the case carries the arrangement for 'setting' the instrument and firing the mine.

Mode of using the instrument.

"Before this magnetic exploder is connected with the conducting-wires, a key, with powerful leverage, (*b*,) fixed upon the top of the instrument, to which it always serves as a handle, is turned to the right as far as possible. By this operation the armature of the inclosed magneto-elec-

Fig. 72.



tric machine is separated from the magnet and placed under the influence of a powerful spring. This spring is in connection with a pin (*c*) which projects from the top of the instrument, and moves as the key is turned in a slot of a long spring, (*d*,) one end of which is fixed upon the instrument, while the other carries a knob made of ebonite, (*e*.) When the key has been turned to the full extent, the pin which controls the armature spring has become firmly fixed by its head in the slot of the external spring, (*d*,) and the instrument is now ready for action at any moment. It is then connected with both conducting-wires, and the explosion of the charge is accomplished by pressing down the ebonite knob, (*e*,) whereupon the armature spring is released by the liberation of the pin (*c*) from the outer spring (*d*,) and the armature returns to the magnet with great velocity, an electric current being thereby established.

"This instrument is even more portable than Wheatstone's ordinary exploder, and is fully as powerful—*i. e.* it is capable of exploding as many, if not more, charges in simple circuit; but it is much more limited in its power of firing charges through a divided circuit, because it is incapable of furnishing a succession of currents, such as obtained by means of Wheatstone's and Beardslee's instruments.

"Several of these instruments of different size and power, constructed by Markus, were exhibited among the collection of military implements sent to the recent Paris Exhibition by the Austrian government. The smallest of the machines was stated to be capable of exploding five or six of Von Ebner's fuses, and the largest fifteeen in simple circuit. That officer states that the magneto-electric instruments of Markus have been introduced into the Austrian service for land operations in place of the frictional electrical machine.

"Some very efficient rotary magnetic exploders, similar in their powers to Wheatstone's ordinary exploders, and differing only from them in details of construction, were also shown in the exhibition of the Austrian war department at Paris."

Fuses adapted to electricity of high tension, may also be fired by means of the induction-coil, for which they must be connected in simple divided circuit, for the same reason that it is necessary so to arrange them for Wheatstone's mag- Induction-coil.

netic exploder, viz, that the action produced is a very rapid succession of currents of very short duration.

The defects of all these instruments for submarine mining purposes are the same as those of Wheatstone's magnetic exploder, viz, the small quantity of the current, which renders it necessary to employ a cable with very perfect insulation.

Frictional electrical machines.

Next, as regards the use of frictional electricity as an exploding agent for submarine mines. The well-known frictional machine, designed by Baron Von Ebner, colonel of the Austrian corps of engineers, is a very good type of instruments of this class. Several instruments of this kind, but slightly differing in size and construction, were exhibited at Paris in 1867 by the Austrian war department. Some of them were made with glass disks and inclosed in a wooden box, but the best for military purposes are those in which the glass disks are replaced by ebonite, as described in the *Course of Instruction in Military Engineering*, page 156, par. 334.

These instruments produce a charge of electricity much larger in quantity and higher in tension than either the magneto-induction or dynamo-electrical machines. One of their defects is the time required to charge the condenser, which takes from 20 to 30 seconds, and the condenser must be recharged after each explosion. There is also a certain liability for the charge to leak out of the condenser when the air is highly charged with moisture, but when the instrument is in good working order and Abel's fuse may be fired with it through a considerable resistance, say 13 B. A. units, on a mile of No. 16 copper wire, from 15 to 20 minutes after the condenser has been charged, and under favorable circumstances we have fired one after an interval of 6 hours.

The chief defect of this instrument is the danger, when using it, of accidental ignition to mines, the conducting-cables of which may be in the vicinity of that in connection with the mine to be fired, as shown by the experiments detailed in page 121. Some further experiments have since been made at the School of Military Engineering, Chatham, to ascertain the limits within which the inductive action is so energetic as to render it dangerous to lay electric cables, when mines are to be fired by means of frictional and induced electricity. From these it is evident that the utmost care is necessary in using the frictional machine.

On the 18th of May, 1870, two half-miles of electric cable, each consisting of a strand of 7 No. 20 copper wires, insulated to a diameter of $\frac{3}{10}$-inch with Hooper's patent dielectric, were laid out and connected with fuses. The fuses were placed 20 yards apart, and the line was, in each case, put to earth beyond them. One of the cables was connected with the instrument used for firing the fuse, the end of the other, at the point from whence the fuses were fired, being carefully insulated. The two cables were laid parallel to each other as far as they would go, till it becomes necessary to diverge to the positions where the fuses were to be placed; they therefore lay under conditions favourable for inductive action for nearly half a mile. The annexed table, page 160, gives the results obtained:

Table of experiments to ascertain the limits within which the inductive action of frictional electricity is sufficient to fire an Abel's fuse under the conditions specified.

Distance of cables apart.	Instrument used.	Number of turns given to frictional machine.	Results.
6 feet ...	Frictional.........	20	Both fuses fired; one directly, one by induction.
3 feet ...	......do	4	Do.
3 feet ...	......do	4	One fuse fired on direct circuit, second fuse not fired by induction.
9 feet ...	......do	20	Both fuses fired; one directly, one by induction.
12 feet ...	......do	20	Do.
15 feet ...	......do	10	One fuse fired on direct circuit, second fuse not fired by induction.
15 feet ...	......do	20	Do.
15 feet ...	......do	30	Both fuses fired; one directly, one by induction.
20 feet ...	......do	20	One fuse fired on direct circuit, second fuse not fired by induction.
20 feet ...	......do	30	Both fuses fired; one directly, one by induction.
30 feet ...	......do	30	Do.
40 feet ...	......do	30	One fuse fired on direct circuit, second fuse not fired by induction.
40 feet ...	......do	40	Do.
40 feet ...	......do	50	Do.
40 feet ...	......do	50	* Do.
35 feet ...	......do	50	Do.
30 feet ...	......do	50	Both fuses fired; one on direct circuit, one by induction.
Touching	Dynamo-electric machine.	....	One fuse fired on direct circuit, second fuse not fired by induction.
Touching	......do	....	Do.
Touching	Wheatstone's magnetic exploder.	....	Do.
Touching	......do	....	Do.

* The second fuse was changed in this case, in order to ascertain that the failure to fire did not arise from a defective fuse, or one comparatively less sensitive.

From this it is evident that the use of frictional electricity, in connection with a system of submarine mines, is limited to very exceptional cases. For certain purposes, as, for

Frictional electricity only applicable to exceptional cases.

example, with isolated mines, this instrument is no doubt a valuable agent, but in consequence of the great danger, inseparable from the inductive effect of the discharge, to which it is subject, it should only be intrusted to careful men who are thoroughly acquainted with its use.

The dynamo-electrical machine seems to be the best for general use.

Taking intoconsideration the advantages and defects of each of the instruments described, it would seem that the dynamo-electrical machine is the best adapted for use in connection with a system of submarine mines. When made of moderate size it is sufficiently portable for all practical purposes, while at the same time its power to generate a charge of electricity renders it available, under nearly all conditions, for the ignition of a mine with certainty. The absence of permanent magnets gives it an advantage over Wheatstone's magnetic exploder and Markus's machine, and there is, with the smaller form of instrument, no danger of explosion by induction, as in the case of the frictional machine. This latter should never be used where any other electrical igniting agent is obtainable.

Ignition by battery-power.

We now come to the ignition of submarine mines by battery-power. For use in connection with forts, or in stationary positions, there is no doubt that the battery is by far the most important agent.

Battery for use with platinum fuse.

Where a platinum-wire fuse is used, a current of large quantity is necessary to insure ignition. For this purpose Grove's, or Walker's, or some battery producing electricity of the requisite nature, must be used. This question has already been discussed. See page 93 and those following.

Grove's battery.

A description of Grove's battery, with the general principles to be borne in mind in using it, is given at page 138, par. 295 of *The Course of Instruction in Military Engineering*, and the paragraphs following.

Walker's zinc-carbon battery.

A platinum-wire fuse may be used in connection with Walker's constant battery. Some experiments have been tried at the School of Military Engineering, at Chatham, with this form of battery.

Experiments.

The battery was composed of two cylinders of zinc, each $\frac{3}{16}$ inch thick, 7 inches long, and 3 inches in diameter, connected together so as to form a single metallic plate, and two cylinders of graphite, each $\frac{3}{8}$ inch thick, 7 inches long, and 3 inches in diameter, similarly connected. The cells were formed of gutta-percha pots, $7\frac{1}{2}$ inches in diameter and 7 inches deep, capable of containing about half a gallon of liquid. If the battery-plates had been made in one single piece, instead of in two portions, the whole would have been very much more compact, but at the time it was made the manufacturers had no large plates in stock, and those described above were used to save time.

The battery was made upon the 10th of December, 1869. The number of cells employed was four, and $\frac{3}{10}$ inch of platinum wire, weighing 1.6 grains to the yard, was employed as the standard of measure to ascertain the fusing-power of the current. The electrical resistance of one turn of the rheostat employed was .0249 B. A. unit. The proportion of acid to water used in the cells was one of acid to ten of water.

December 10, 1869.—Platinum wire fused through 21 turns on rheostat.

December 13, 1869.—Platinum wire fused through 19 turns on rheostat.

December 17, 1869.—Platinum wire fused through 28 turns on rheostat.

December 20, 1869.—Platinum wire fused through 31 turns on rheostat.

December 23, 1869.—Platinum wire fused through 25 turns on rheostat.

December 30, 1869.—Platinum wire fused through 26 turns on rheostat.

December 31, 1869.—Platinum wire fused through 28 turns on rheostat.

January 3, 1870.—Platinum wire fused through 30 turns on rheostat.

January 4, 1870.—Platinum wire fused through 30 turns on rheostat.

January 5, 1870.—Platinum wire fused through 30 turns on rheostat.

January 6, 1870.—Platinum wire fused through 32 turns on rheostat.

January 7, 1870.—Platinum wire fused through 32 turns on rheostat.

January 10, 1870.—Platinum wire fused through 30 turns on rheostat.

January 12, 1870.—Platinum wire fused through 30 turns on rheostat.

January 14, 1870.—Platinum wire fused through 29 turns on rheostat.

January 15, 1870.—Platinum wire fused through 28 turns on rheostat.

January 17, 1870.—Platinum wire fused through 30 turns on rheostat.

January 19, 1870.—Platinum wire fused through 30 turns on rheostat.

January 24, 1870.—Platinum wire fused through 26 turns on rheostat.

January 25, 1870.—Platinum wire fused through 26 turns on rheostat.

January 26, 1870.—Platinum wire fused through 24 turns on rheostat.

January 28, 1870.—Platinum wire fused through 23 turns on rheostat.

January 29, 1870.—Platinum wire fused through 23 turns on rheostat.

January 31, 1870.—Platinum wire fused through 25 turns on rheostat.

February 1, 1870.—Platinum wire fused through 25 turns on rheostat.

February 2, 1870.—Platinum wire fused through 23 turns on rheostat.

February 3, 1870.—Platinum wire fused through 24 turns on rheostat.

February 4, 1870.—Platinum wire fused through 24 turns on rheostat.

February 6, 1870.—Platinum wire fused through 24 turns on rheostat.

February 8, 1870.—Platinum wire fused through 24 turns on rheostat.

February 9, 1870.—Platinum wire fused through 24 turns on rheostat.

February 10, 1870.—Platinum wire fused through 23 turns on rheostat.

February 11, 1870.—Platinum wire fused through 22 turns on rheostat.

February 12,* 1870.—Platinum wire fused through 18 turns on rheostat.

February 14, 1870.—Platinum wire fused through 19 turns on rheostat.

February 15, 1870.—Platinum wire fused through 20 turns on rheostat.

February 17, 1870.—Platinum wire fused through 20 turns on rheostat.

February 18, 1870.—Platinum wire fused through 20 turns on rheostat.

February 21, 1870.—Platinum wire fused through 20 turns on rheostat.

February 22, 1870.—Platinum wire fused through 19 turns on rheostat.

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* On this day the battery was removed from one table to another.

February 23, 1870.—Platinum wire fused through 19 turns on rheostat.

February 24, 1870.—Platinum wire fused through 18 turns on rheostat.

February 25, 1870.—Platinum wire fused through 18 turns on rheostat.

The battery was made up afresh on the 25th February, with fresh acid and water, (1 acid to 10 of water,) and zinc plates re-amalgamated. At the first test, made five minutes after filling the cells, $\frac{3}{10}$-inch platinum wire was fused through 32 turns of the rheostat. The experiments were continued as follows:

February 26, 1870.—Platinum wire fused through 32 turns on rheostot.

February 28, 1870.—Platinum wire fused through 33 turns on rheostat.

March 1, 1870.—Platinum wire fused through 33 turns on rheostat.

March 2, 1870.—Platinum wire fused through 34 turns on rheostat.

March 3, 1870.—Platinum wire fused through 34 turns on rheostat.

March 4, 1870.—Platinum wire fused through 34 turns on rheostat.

March 5, 1870.—Platinum wire fused through 35 turns on rheostat.

March 7, 1870.—Platinum wire fused through 35 turns on rheostat.

March 8, 1870.—Platinum wire fused through 34 turns on rheostat.

March 9, 1870.—Platinum wire fused through 34 turns on rheostat.

March 11, 1870.—Platinum wire fused through 32 turns on rheostat.

March 14, 1870.—Platinum wire fused through 32 turns on rheostat.

March 16, 1870.—Platinum wire fused through 32 turns on rheostat.

March 20, 1870.—Platinum wire fused through 30 turns on rheostat.

March 22, 1870.—Platinum wire fused through 30 turns on rheostat.

March 25, 1870.—Platinum wire fused through 28 turns on rheostat.

March 28, 1870.—Platinum wire fused through 28 turns on rheostat.

March 29, 1870.—Platinum wire fused through 27 turns on rheostat.

March 31, 1870.—Platinum wire fused through 25 turns on rheostat.

April 3, 1870.—Platinum wire fused through 23 turns on rheostat.

April 5, 1870.—Platinum wire fused through 23 turns on rheostat.

April 8, 1870.—Platinum wire fused through 21 turns on rheostat.

April 10, 1870.—Platinum wire fused through 20 turns on rheostat.

April 11, 1870.—Platinum wire fused through 20 turns on rheostat.

April 13, 1870.—Platinum wire fused through 19 turns on rheostat.

Battery proved very constant.

The results obtained have proved this battery to be very constant, so that there need be no further doubt on that account as to the use of the platinum-wire fuse. The want of constancy in Grove's battery is certainly a serious consideration. It will be observed that on the 12th of February, when the battery was moved from one table to another in the same room, there was a slight depreciation in the fusing-power of the current, but that it subsequently, to a certain extent, recovered itself. It should therefore be moved as little as possible, but as it is only applicable to permanent stations, this is not of much consequence. It was noticed, too, that if the circuit was kept closed, that is to say, a constant flow of current kept up, its working power was materially diminished, as shown by the smaller number of turns through which the plantinum wire was fused. As, however, in any system of submarine mines, the circuit would only be closed for an instant, as each mine was fired, and as no continuous work would be required, this latter, though a fact to be noticed, need not interfere with its use for such a purpose. The cost of a cell of a battery of this form would be comparatively large, but, on the other hand, a much smaller number of cells would do the work. Its size and weight are ill-adapted to portability, but for a permanent station this is of comparatively little consequence.

Experiments with a much larger number of cells must be made before any definite conclusion, as to the advantage of this form of battery, can be arrived at. As far as we have yet gone, however, it promises remarkably well.

To fire a fuse adapted to electricity of tension, such as Abel's for example, any of the ordinary forms of battery used for working a line of electric telegraph may be employed; the object in such a case being to obtain electro-motive force rather than quantity. It is of importance that the battery should be constant—that is to say, that it should be capable of being allowed to remain mounted and ready for use for a considerable time, say a month, and not, like Grove's, required to be taken to pieces and refitted every twelve hours; that it should generate a sufficient quantity of electricity to allow of a certain amount of leak or fault in a cable and yet fire a fuse beyond that leak; and, at the same time, that the electro-motive force to be obtained from the battery may be such as, with a sufficient number of cells, to fire an Abel's fuse with certainty.

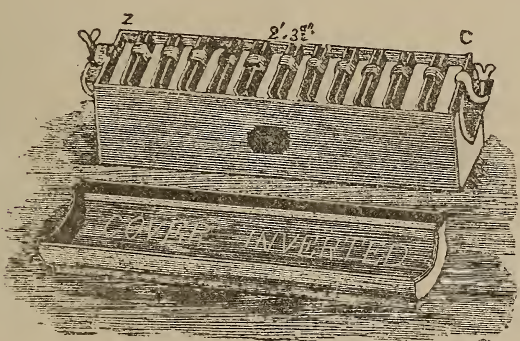
Battery for use with tension-fuse.

The best forms of battery for this purpose seem to be Wollaston's sand-battery, the Marié-Davy battery, and Daniell's battery.

The ordinary form of sand-battery is shown in Fig. 73, twelve

Wollaston's sand-battery.

Fig. 73.



cells being united in a trough made of gutta-percha. The usual dimensions of the plates are $3\frac{1}{2}$ by $4\frac{1}{2}$ inches. They are alternately copper and zinc, connected together in pairs by copper strips riveted and soldered to them. The zinc plates are amalgamated with mercury, and the cells are filled with fine siliceous sand, moistened with sulphuric acid diluted with water in the proportion of $\frac{1}{15}$. This battery develops a powerful current of electricity when first made up, but, when the circuit is kept constantly closed, it is very inconstant, and after being in use for a certain time, varying according to circumstances, it loses its power from various causes; the sand must then be washed out, and the battery made up again with fresh solution and the zincs re-amalgamated.

Defects.

The great defect of the simple combination of zinc and copper in dilute acid is, that the bubbles of hydrogen-gas resulting from the decomposition of the water by the electric force adhere to the copper plate, and, being in a state of electrical polarization, act in opposition to the direct current and reduce its strength very materially; moreover, the hydrogen being in what is termed the nascent state, combines very readily with the oxygen of the sulphate of zinc, produced by the action of the battery, and metallic zinc is thus deposited upon the copper plates, and so, similar metals being opposed to each other, the action of the battery ceases. Many methods have been adopted to get rid of the hydrogen. In Grove's and Daniell's batteries it combines with the oxygen of the solution in which the electro-negative metal is immersed. In Smee's, and its kindred forms of battery, the hydrogen is assisted in escaping from the negative plate by giving it a rough surface, presenting a multitude of small points from which the bubbles separate easily.

The sand is chiefly useful to prevent the acid from spilling when the battery is moved about; it tends also to make the action of the battery more regular; but it should not contain carbonates, such as carbonate of lime, or a chemical action takes place with the sulphuric acid, which is detrimental to the battery.

mprovements.

In the best form of this battery a small gutta-percha pipe is inserted in each cell, extending down to the bottom; through this fresh diluted acid is poured in from time to time to make up for waste by evaporation. By thus introducing the fresh acid at the bottom of the cell, where the heavy sulphate of zinc gravitates, a more regular action is obtained. If the sulphate of zinc be allowed to accumulate in the lower part of the cell, a cross voltaic current is established between the upper and lower portions of the plates which are in solutions of different strengths. The effective current in circulation is thus diminished, and the upper portion of the zinc plates are rapidly dissolved away.

	lbs.	oz.
The weight of the 12-cell battery is, without sand or liquid	14	14
With sand	22	00
Sand and liquid	23	12½

It requires about 1 pound of mercury and two pints of acid per annum for each 12 cells.

For submarine mining purposes the conditions are different from those which occur in the simple working of a line of electric telegraph, in which the circuit would be closed much more frequently and for longer periods; under these latter circumstances its defects become much more apparent, as the mischief is done almost entirely when the circuit is closed. This fact, however, renders it less objectionable as a firing agent for submarine mines than as a battery for telegraphic purposes.

A solution of sulphate of zinc is sometimes used, as an exciting fluid, instead of diluted sulphuric acid; the effect under such circumstances is, to a certain extent, to reduce the consumption of zinc, with a reduction, however, of the active force of the current generated. A battery of this form, charged with diluted sulphuric acid, is more energetic when first made up, while one charged with sulphate of zinc is, after coming fairly into a working state, more constant and requires less attention to keep it in good order. One advantage of sulphate of zinc is that, being in the form of crystals, it can be more easily stored and carried about than sulphuric acid; this is a very decided advantage or board ship.

This battery possesses another advantage for use on board ship, inasmuch as the liquid being kept absorbed in the sand is not liable to be split.

There are several forms of the Marié-Davy battery which might be used for firing Abel's fuses; it may be described as consisting generally of plates of zinc, and carbon in a saturated solution of proto-sulphate of mercury. Marié-Davy battery.

One form of this battery, called "Silver's Marine Battery," has been manufactured by the India-rubber, Gutta-percha, and Telegraph-works Company, of North Woolwich, expressly for use with Gisborne's system for signaling on board ship; it consists of a combination of zinc and platinized graphite plates in a saturated solution of proto-sulphate of mercury. This is perhaps the best and most constant form of battery of this nature, but it is rather bulky. It could be used on board ship, having been expressly manufactured for sea service, to stand rolling about. The smaller forms of the Marié-Davy battery, which have been tried in the electrical school at Chatham, though excellent when first made up, both as regards quantity and electro-motive force, deteriorate very rapidly, and are not so good for submarine mining purposes as Daniell's form.

Daniell's constant battery is well known to all persons engaged in working the electric telegraph, and consists of zinc and copper elements in a saturated solution of sulphate of copper. The copper plate is placed in a porous cell with a quantity of sulphate of copper in the form of crystals, and water is poured in, which dissolves the latter and sets up an Daniell's constant battery.

electrical action. An excess of sulphate of copper must be placed in the porous cell to keep the solution, as it is termed, saturated, or, in other words, carrying a maximum of the sulphate of copper in solution.

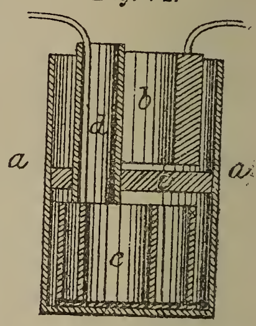
Muirhead's form of Daniell's battery.

Muirhead's form of Daniell's battery would be a very good one for stationary submarine service. It consists of the usual Daniell's elements, zinc and copper plates, the copper is a porous cell, the exciting liquid being a saturated solution of sulphate of copper. The plates in this form of battery are comparatively large, which is advantageous when a defect exists in an electrical cable. The greater the immersed surface of the plates, the greater the quantity of the current generated.

Varley's form of Daniell's battery.

Another form of Daniell's battery, suitable for use with Abel's or any similarly constituted fuse, is Varley's. The arrangement proposed is shown in section, Fig. 74; (*a*) is the outer cell, of cylindrical form, and made of common glazed earthenware; (*b*) is the zinc element, a semi-cylinder, of thick cast zinc, occupying the upper half of the outer cell, and with a metal strip to connect it with the copper plate of the adjoining cell; (*c*) is the copper element, occupying the lower half of the cell, and consisting of a thin plate of copper wound round and round, so as to expose a sufficient metallic surface; the connection with the zinc plate of the adjoining cell consists of a copper strip passing up through a glazed earthenware cylinder, (*d*;) (*e*) is a porous diaphragm consisting of several thicknesses of flannel, fitting tightly round the glazed cylinder (*d*) and completely filling up the space between it and the outer cell (*a*.) This flannel diaphragm is the chief peculiarity of this form of battery; it supplies the place of the porous cell in the other combinations of Daniell, and is so placed that, taking advantage of the greater specific gravity of a solution of sulphate of copper over a solution of sulphate of zinc, each metal may be, to a great extent, in a solution of its own sulphate; that is to say, the copper in a solution of sulphate of copper, the zinc in a solution of sulphate of zinc. To set the battery in action, crystals of sulphate of copper are dropped through the glazed cylinder (*d*) into the lower portion of the cell, and water is then poured in. When first put together this battery does not at once produce a maximum of working current; it gradually improves for the first

Fig. 74.



forty-eight hours, after which it remains very constant for a long period. The flannel diaphragm produces a high internal resistance in the cell, but, taking it on the whole, it seems to be one of the most efficient batteries for submarine-mining purposes, for which service its constancy, when once fairly in action, is a very desirable quality.

A battery in connection with the torpedoes exhibited by the Austrian government at Paris in 1867 is also worthy of notice. It was designed by Baron Von Ebner, colonel of the Austrian imperial corps of engineers, and is described as follows, in the notices of objects exhibited by the Austrian war department: Austrian battery for submarine mines.

"These batteries may be considered a modification of that known as Smee's.

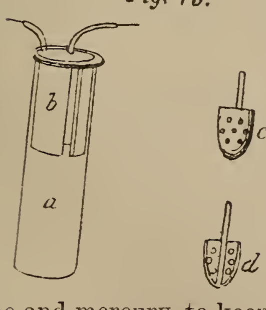
"The large quantity of liquid contained in the cell retards considerably the tendency to alter its internal resistance; platinized lead is used instead of platinized silver for the positive pole of the battery; and zinc, cut up into pieces and held in a bath of mercury—the whole in a porcelain cup, pierced so as to admit the diluted acid freely—forms the negative pole of the battery.

"The consumption of zinc and mercury, which is very considerable in the ordinary battery, is thus materially diminished.

"These batteries have been employed for some time in working a system of telegraph instruments of dial form. In this case the force of the electric current required is very small, but so little zinc was consumed that the batteries worked for eighteen months without being touched."

The general form of one of these cells is shown in Fig. 75.

Fig. 75.



It consists of a vessel of glass (*a*) 18 inches deep and 5 inches in diameter, to contain the diluted sulphuric acid, within which is suspended a plate (*b*) of platinized lead, which is bent round into a cylindrical form to fit close around the inner surface of the glass. In the center of this latter is hung the porcelain perforated cup [containing the cut-up zinc and mercury, to keep it (the zinc) amalgamated. This is shown in elevation at (*c*) and in section at (*d*.)

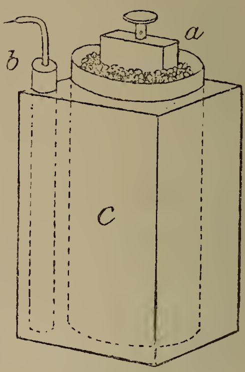
The top of each cell is furnished with a porcelain cover, through which the wires attached to the positive and negative plates pass for convenience of connection. The cells are arranged in a wooden frame in batteries of twelve each.

This battery is said to be very constant, but its great bulk is much against it.

Leclanché battery.

In the French section of the Paris Exhibition of 1867, a form of battery, invented by M. Leclanché, and manufactured by Messrs. Bonner, Jamin, Bailly & Co., Paris, was shown. Fig. 76 represents a cell of this battery. The positive pole (*a*) consists of a plate of graphite in a porous jar surrounded by a mixture of peroxide of manganese and graphite broken up into small pieces. The negative pole (*b*) is a plate or pencil of amalgamated zinc. The whole is in an outer glass cell (*c*) containing a solution of sal-ammoniac. The peroxide of manganese is a good conductor of electricity. This system may be described as a battery with one acid, and of which the positive pole has great affinity for hydrogen.

Fig. 76.



The endosmosis, inevitable in a battery of two acids, is avoided in this combination. Zinc may be preserved for a long period in a solution of sal-ammoniac, and peroxide of manganese being quite insoluble in that liquid, local chemical action is avoided. When the circuit of the battery is closed, the hydrochlorate of ammonia is decomposed, and chloride of zinc is formed. The electro-motive force of this battery is said to be considerable, 28 elements of the Leclanché battery being said to be equal to 40 of Daniell's. Its internal (or liquid) resistance is also said to be very small.

It has been adopted by the chemins de fer de l'Est, de l'Ouest, du Nord, de Paris, and Lyons à la Méditerranée, and in the former is said to have been tried for ten months with very excellent results.

The advantages claimed for it are, absence of chemical action when the battery circuit is not complete, and consequently no waste of material; it requires little or no looking after; the cost of maintenance is small; it cannot be injured by mixing or upsetting the liquids; the battery, ready for action, may be placed in store without deterioration or loss in its component parts; and it possesses great facility for transport, without injury to the working powers.

This battery seems to possess qualities which may render it useful as an agent for submarine mining purposes, and experiments should be made with it in order to ascertain its advantages for this purpose.

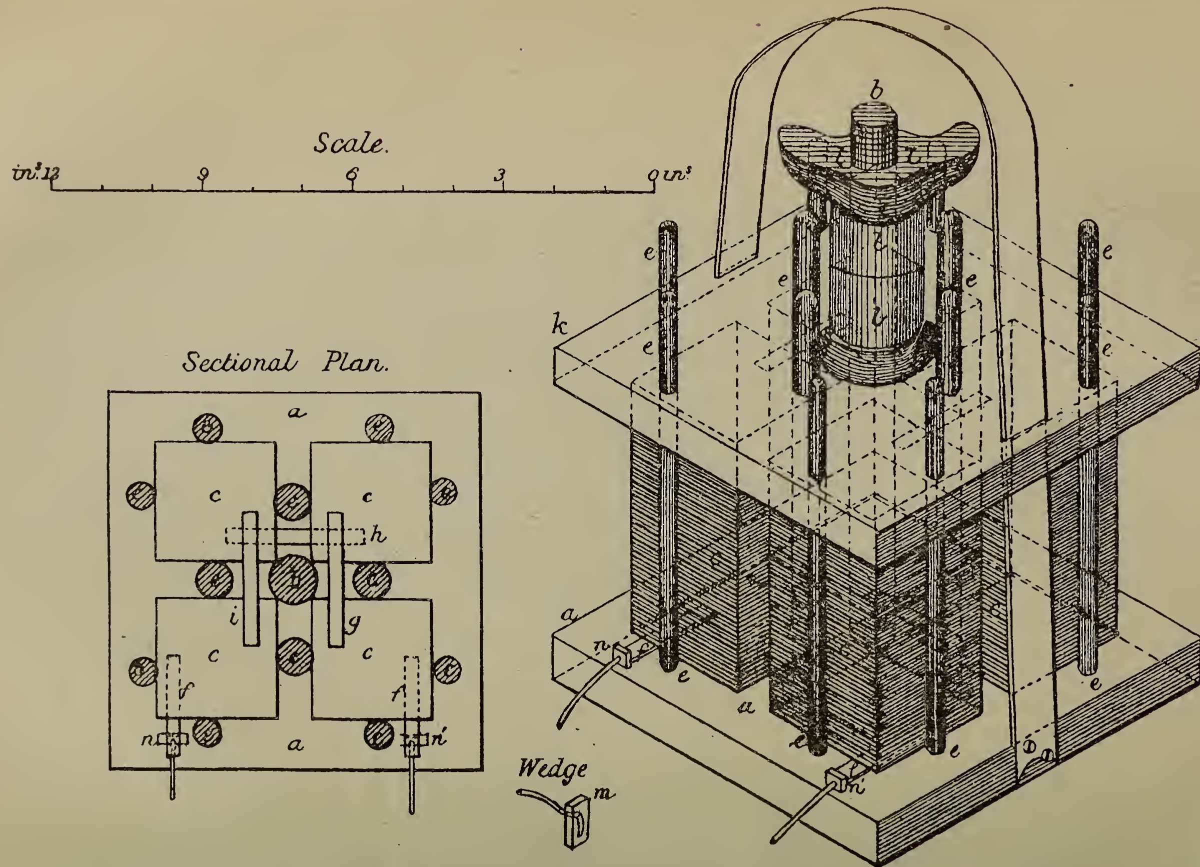


Fig. 77.

For boat service, a voltaic pile has been devised by F. Abel, esq., F. R. S. It is described as follows in the report of the committee on active obstructions: Voltaic pile.

"This battery consists of a series of pairs of zinc and copper disks, or square plates, each pair being separated by a piece of flannel of corresponding size, steeped in a saturated solution of salt acidified with a little vinegar, the pairs being arranged in four piles, connected by strips of metal with each other, and confined between two boards in such a manner that they afford the means of pressing the disks compactly together. The most efficient form of this battery is constructed as follows: Extemporized voltaic pile.

"A piece of hard, dry wood, (*a*,) Fig. 77, about $7\frac{1}{2}$ inches square and 1 inch thick, is well lacquered or varnished on its upper surface, or coated with a mixture of gutta-percha and pitch, or of bees-wax, rosin, and pitch. A wooden rod, $\frac{3}{4}$ of an inch in diameter and 11 inches in height, with a screw cut upon about 6 inches of its upper end, is fixed vertically into the center of the wooden slab. Construction.

"Around this rod are arranged four piles of zinc and copper plates, (*c c*,) either square or circular, of $2\frac{1}{2}$ to $2\frac{3}{4}$ inches diameter, and which may be cut out of smooth copper and zinc sheets. Eight slight wooden rods or sticks, (*e e*,) 9 inches in height and about $\frac{1}{4}$ of an inch in thickness, are loosely fixed into perforations in the board so as to be capable of removal at pleasure, being merely required to support the metal plates during the process of piling them.

"The two poles of the battery (*f f*) are formed of two strips of copper about $\frac{1}{4}$ of an inch in width, and of sufficient length to reach from the exterior of the board to the center of one of the piles of plates. One end of each strip of copper is bent downward and fixed into a separate small slot cut into the board near one edge.

"A number of disks of flannel are prepared $\frac{1}{8}$ of an inch less in diameter than the metal plates. They may consist of old blanket or of a double thickness of service cartridge serge roughly stitched together."

The mode of arranging the battery is as follows: Arrangement for action.

"The flannel disks are soaked in a liquid prepared by saturating water with common salt, and adding some vinegar in the proportion of one ounce to a quart of water; they are afterward squeezed out as dry as possible by the hand before being used. A zinc plate is then placed upon one of the strips of copper which lies flat on the board and leads into one of the slots, and a disk of flannel moistened as described is placed upon the zinc. A pair of copper and zinc plates is then placed upon the flannel, the copper being undermost; a second flannel disk follows, then a pair of plates as before, and so on till a pile of 30 zinc, 30 flannel, and 30 copper disks has been completed. A precisely similar pile is then constructed by its side, the first plate being, however, copper in this instance, and the position of the copper and zinc disks in each pair being the opposite of that in the first pile, the zinc being, therefore, the lower plate. The top disk of pile No. 1, (copper,) and the top disk of pile No. 2, (zinc,) are then connected by laying a thin strip of copper (*g*) across them. The third pile is now commenced, a thin strip of copper (*h*) having been laid upon the board to connect it with the second pile. A zinc plate is taken first, this time as in the case of pile No. 1. Lastly, a fourth pile is commenced by placing a copper plate upon the strips of copper, which constitutes the second pole of the battery, and this pile is built up like No. 2 pile. The top disks of piles Nos. 3 and 4 are then connected by a strip of copper, (*i*.)

"A piece of hard wood, (*k*,) similar to the bottom board, is well coated with pitch composition or varnish on one side, and is provided with a central perforation through which the screw is to pass, and with holes of sufficient size to allow all the thin rods which support the piles of plates to pass freely through. This board is placed with its coated side downward upon the piles, and is then pressed upon them by means of wooden nuts, (*l l*,) which are screwed on to the central rod. The plates are thus firmly held in their places, but the pressure applied by means of the screw must not be sufficiently great to squeeze any water out of the flannel disks.

"If there is no workman or lathe at hand to provide the screw and nuts, the pile may be firmly braced together by passing two or three turns of stout cord round the boards and tightening these cord bands by means of wooden wedges.

Employment.

"To connect the battery with the firing-wires, the cleaned end of the conducting-wire is inserted into one of the slots containing a pole of the battery, and it is maintained in close contact with the copper strip in that slot by passing a wire round a small wooden wedge, which is then forced into the slot at (*n*.) The circuit is completed when required by bringing the return firing-wire (or earth-wire) into contact with the strip of copper forming the other pole of the battery, (n^1.)

Directions for cleaning it.

"When the battery is taken to pieces the flannels should be placed in water acidulated with vinegar or oil of vitriol, and, after having soaked for about one hour, they should be washed in pure water and wrung out. The plates of zinc and copper should be thoroughly cleaned by scrubbing them with wet sand."

Working-current of battery improved by insulation.

The working-force of the current of any voltaic battery or pile is much improved when it (the battery) stands on a good insulating substance. When practicable, therefore, it is recommended that the whole battery or pile may be arranged to stand upon a sheet of thick crown-glass. The reason of the improvement is, that the insulating substance prevents minutely small losses of current, which occur more or less in practice, even when batteries have been put together with the utmost care, and which pass to earth without completing the working circuit when the battery stands upon any less perfectly insulating material.

The following table gives the internal resistance and comparative electro-motive force of several forms of voltaic battery:

Name of battery.	Size of plates.		Interval resistance of one cell, B. A. units.	Electro motive force, comparative.
	Copper or graphite.	Zinc.		
Varley's Daniell	22″ × 2″ spiral	5″ × 1¾″	10	911
Muirhead's Daniell	3½″ × 4″	3½″ × 4″	7	880
Schaw's Daniell	4″ × ¾″	3½″ × ¾″	10	858
Wallaston's sand	3½″ × 4½″	3½″ × 4½″	15	835
Marié-Davy	6″ × 1¾	6″ long, ½″ diameter	3	1220
Leclanché	7½″ × 1¾″	6″ long, 5-16″ diameter	2	1065

NOTE.—These results have been obtained from cells freshly made up; the experiments were tried at 6 hours, 30 hours and 54 hours after the batteries were put together.

CHAPTER XI.

CLOSING ELECTRICAL CIRCUIT.

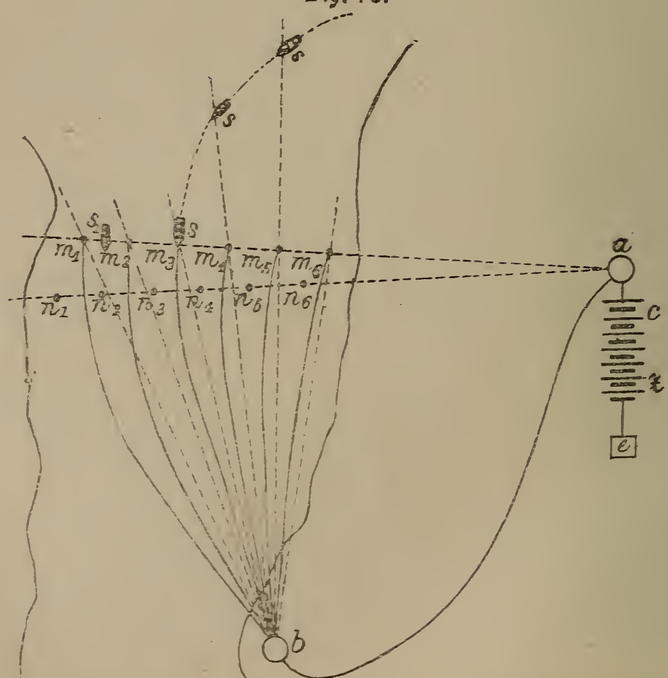
Having got our mines placed in position, established the conducting-cables to connect them with our testing-room, and selected the most approved form of battery or igniting agent, it now becomes necessary to discuss how any particular charge of a group may be fired at the right moment. This may be done at will, the position of the ship being determined by intersection, or the vessel herself may be made to complete the circuit by striking a circuit-closer.

Firing by cross-bearings or intersection.

In firing at will, the vessel's position being determined by intersection, several expedients may be adopted.

The most simple is that in which an observer can be placed on the prolongation of a line of mines, as at (*a*,) Fig. 78,

Fig. 78.

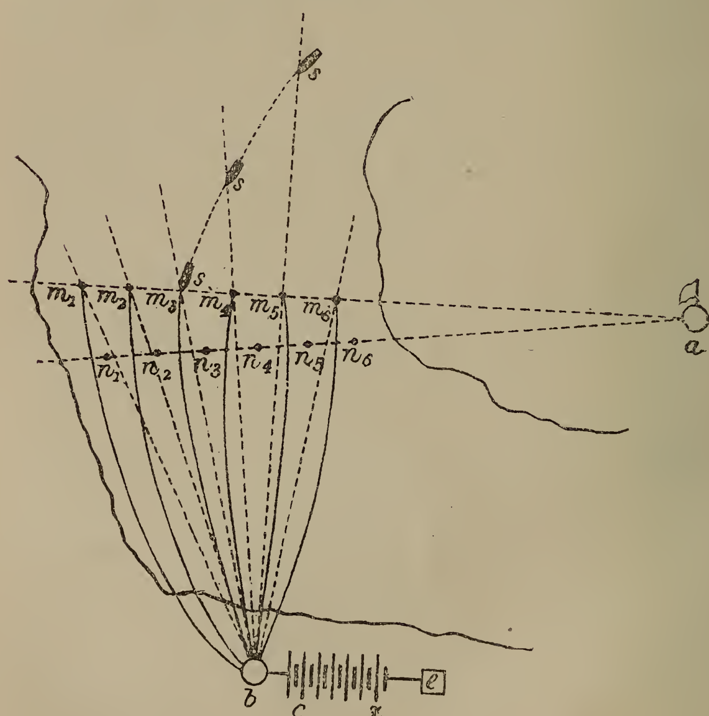


commanding the mines (m_1, m_2, &c.,) and on the prolongation of their direction a second observer being stationed at the point (*b*;) (*c z*) represents the firing-battery, having one of its poles (z) connected to the earth at (e,) the other pole being attached to one point of contact of a firing-key at (a.) From the pivot-point of the key an insulated cable, in connection therewith, passes to the pivot-points of a series of keys at (b.) Till the key at (a) is pressed down, no current can pass from the battery (c z) past the station (a,) but directly it is pressed down, the circuit is so far completed, and the line is charged up to the station (b.) From the station (b) a series of electrical cables, (b m_1, b m_2, &c.,) attached to a series of contact-points, perfectly distinct and carefully insulated from each other, passes to the mines (m_1, m_2, &c.,) through the fuses in connection with them, and to earth. At this second station (b) we have therefore a second break in the electrical circuit, and it is easily seen that, in order to pass the current through and fire any particular fuse, both these breaks must be bridged over, under which circumstances the circuit of the battery will be completed and the mine fired. Let us now suppose a vessel to be approaching this line of mines, as her bow passed across the production of the line (b m_5,) the observer at (b) would put down the key No. 5, in connection with (m_5;) but as the ship had not come into the line from (a,) passing through the line of mines, the observer at (a) would not put down his key, a break would still exist in the circuit, and no current could pass to fire the mine. When the vessel had passed the line (b m_5,) the observer at (b) would allow the key to spring up and break the connection. As the vessel passed the line (b m_4,) the observer at (b) would press down key No. 4, but as she would still not come on the intersection of the lines (b m_4) and (a m_4,) the same result as before would be obtained, and the charge (m_4) would not be fired. Let us now suppose that she passes on in her course till she arrived over the mine (m_3;) in this position she would be on the intersection of the two visual lines (a m_3) and (b m_3;) the observers at (a) and (b) would in this case both put down their respective keys simultaneously, the circuit of the battery would be completed through the mine (m_3,) and that mine would be fired. In the case of a vessel passing through an interval between any two mines, at such a distance as to be out of the radius of destructive effect of either of them, as, for example, at the point (s_1) between (m_1) and (m_2,) it is easily seen that at the moment of passing the line (a m_1,) when the observer at (a) would have his key down, she would not be on the production of any of the lines (b m_1, b m_2, &c.,) and as the observer at (b) would not under such circumstances press down his key, she would pass on to the second line (n_1, n_2, &c.,) and having passed safely through the interval of the first line would stand a good chance of coming within striking distance of one of the mines of the second. For this second line (n_1, n_2, &c.) a similar but separate arrangement should be prepared.

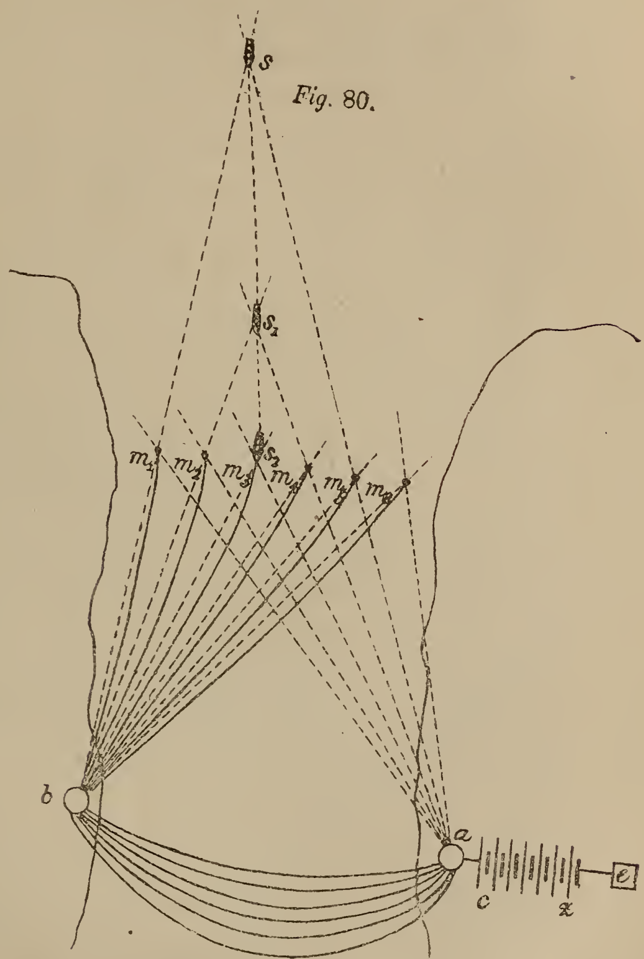
Firing by a preconcerted signal at one station.

A simplification of this plan may occasionally be adopted by employing a preconcerted signal at the point (*a*) when the bow of a vessel came on the line (*a* m_1.) For instance, if, when the bow of the vessel (*s*) arrived on the line (*a* m_3,) a flag were raised at the point (*a*,) the observer at(*b*) would instantly notice whether she was on any of the lines of sight passing over his mines, and if she were, would at once press down the key corresponding therewith, as No. 3, shown in the Fig. 79. Directly she had passed the line (*a* m_1,) the flag at (*a*) should be dropped, as she would then be safe

Fig. 79.



so far as that line was concerned. This latter system requires great coolness and nerve on the part of the observer at (*b*,) as he has two things to do, viz, to watch the vessel passing across his intersections, and to be on the alert to receive the signal from (*a*.) In such a case it has been found best to employ two men at station (b,) one exclusively to watch the station (a,) and on the flag being raised to give the word "fire," and on the flag being dropped to give the word "stop," the second man would keep his eye on the vessel, and be ready to fire the right mine at the right moment. A separate signal-flag and firing arrangement would, as before, be required for the next line (n_1 n_2, &c.) of mines.



As in many cases it would not be practicable to have a station in such a position as (a) so far advanced toward the point of attack, with the corresponding danger of being cut off by an enemy, another combination becomes necessary; this is shown in Fig. 80. Two stations (a) and (b,) well within the defensive works, are selected in such a position that the

Arrangement of separate intersections for each mine.

lines, passing from them over each charge, shall intersect in such a manner as to give what is termed a well-conditioned triangle, or, in other words, that they shall not intersect each other at too oblique an angle. The battery is placed at the point (*a*,) one pole being attached to earth, while the other is connected with a center from which radiate a series of contact-keys. From the studs or contact-points of these keys a series of cables, corresponding in number to the charges in position, pass to the similar contact-points of a similar set of keys at the station (*b*,) and from the pivots of the keys at (*b*) an electrical cable passes to each charge. In this case, therefore, each charge has a separate key at station (*a*) and a separate key at station (*b*,) each perfectly distinct from every other, and well insulated therefrom, but the whole culminating at (*a*) in the single battery (*c z*.) In each circuit, corresponding to any particular mine, there are therefore two breaks, one at its particular contact-key at the station (*a*,) and the other at its corresponding key at station (*b*,) and till these breaks are bridged over, by pressing down the contact-keys simultaneously, the circuit of the battery will not be closed and the mine will not be fired. In this way it is easily seen that if, for example, key No. 1 is put down at the station (*a*,) and key No. 2 at station (*b*,) there still remains a break in each circuit; in circuit No. 1 at station (*b*) and in circuit No. 2 at station (*a*,) and neither of these mines will be fired. The object of this arrangement is easily seen if we trace the course of the vessel (*s*) approaching the line of mines. She first comes on the line of (m_5) from station (*a*,) and simultaneously on that of (m_1) from station (*b*;) the observer at (*a*) puts down key No. 5, and the observer at (*b*) key No. 1, without of course firing any mine; again, as she reaches the position (s_1,) the observer at (*a*) would put down key No. 4, and the observer at (*b*) key No. 2, without any circuit being closed. Let us now suppose her to reach the point (s_2) when the lines from both stations over the charge (m_3) intersect; both observers would now put down keys No. 3 simultaneously, the circuit of mine (m_3) would be closed, the charge would be fired, and the vessel struck.

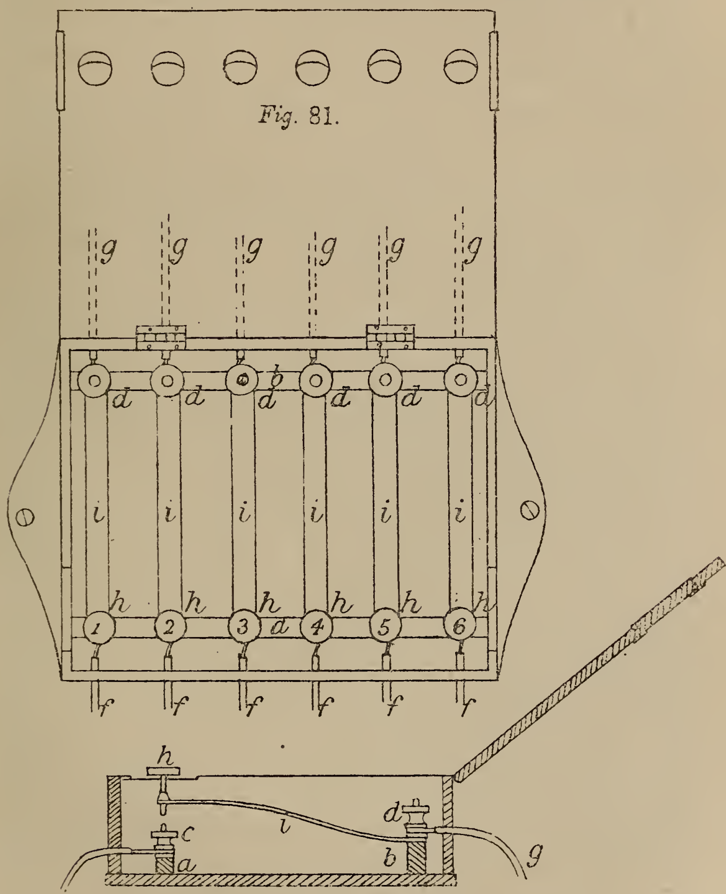
Pickets may be used for intersection at short distances.

In carrying on the system above described, it has been found that with a series of small wooden pickets, placed in a radiating form from a central point of observation, at a distance of about twenty feet, and with pieces of twine passing from the center over the pickets in the direction of the charges, to indicate the bearing more accurately, very good practice has been obtained, all the charges having, at a distance of a quarter of a mile, been exploded within a radius of six feet of the object aimed at. The observer, with his eye at the central picket and his right hand on the contact-keys, puts the corresponding one down as the object passes the bearing of each. A man soon learns by practice the distance he may allow on one side or other of the bearing-line, and with ordinary care and nerve is soon able to make contact at the right moment. There is no doubt, however, that on actual service the steadiest and coolest men would be required to work such a system effectually.

Firing-keys.

The following is a description of the firing-keys recommended, and shown in plan and section in Fig. 81. The

Fig. 81.



apparatus consists of an oblong wooden box, 8 inches long by 6 inches broad, and 2¾ inches deep, within which are firmly fixed two ebonite bars, (*a*) and (*b*,) one close to each of the larger sides; the object of these is to insulate the several wires, connected to binding-screws (*c c c*, &c.,) on the bar (*a*,) and (*d d d*, &c.,) on the bar (*b*,) from each other. One set of insulated wires (*f f f*, &c.) may be carried into the box and attached to the binding screws (*c c c*, &c.,) another set (*g g g*, &c.,) may be connected with the binding screws (*d d d*, &c.) The firing-key (*i*) consists of a strong metal spring, in metallic contact with the binding screw (*d*) and thence to the cable (*g*) attached to it, and with an insulated knob, (*h*,) by which its metallic point may be pressed down upon the binding screw, (*c*,) which latter is in metallic contact with the cable (*f*) attached to it. It is thus easily seen how by pressing down any one of these keys a metallic circuit is established from the cable (*f*,) on one side, to the corresponding cable (*g*,) on the other side of the box, and that before the key is pressed down there is no metallic circuit, and consequently no path for the electric current.

The box is provided with a wooden lid to keep the keys safe when not in use, and there is an India rubber diaphragm let into this lid, just over the keys, through which they may be depressed when the lid is shut. Two screw-holes are also provided by which the whole box may be firmly fastened to a table or bench when required.

Connections of keys for use.

In the combination shown in Fig. 78, a single key only would be required at the station (*a*;) this would be similar in construction to any single key of the set shown in Fig. 81, one pole of the battery (*c z*) being put to earth; the other would be connected to the binding screw (*c*,) while the cable connecting stations (*a*) and (*b*,) Fig. 78, would be connected with the binding screw (*d*,) Fig. 81, and the power of changing the cable from the firing-battery would be obtained by simply putting down and holding down the firing-key. At station (*b*,) Fig. 78, one firing-key would be required for each mine. All the wires (*f f f*, &c.,) Fig. 81, having been denuded of insulation close to the box, would be brought together and soldered carefully to the single conductor, carried from station (*a*) to station (*b*,) Fig. 78, while from the binding screws (*d d d*, &c.,) Fig. 81, a separate insulated cable would be laid to each mine. For the arrangement shown in Fig. 79 only one set of keys would be required, the battery being connected to the whole of the rear binding screws, with the separate cables radiating from the point. If used in the combination shown in Fig. 80, two complete sets of keys would be required, arranged as described for Fig. 78, with this difference, that a separate connection for each mine would be necessary from the front binding screws of the firing-keys at station (*a*) to the rear binding screws of the set of keys at station (*b*,) the battery being in connection with each and every one of the rear binding screws of the set of keys at station (*a*.)

In using the keys it is necessary to press them firmly down and hold them firmly down, in order to insure good contact at the proper moment.

To work efficiently it does not seem desirable that more than six keys should be intrusted to the management of any one man.

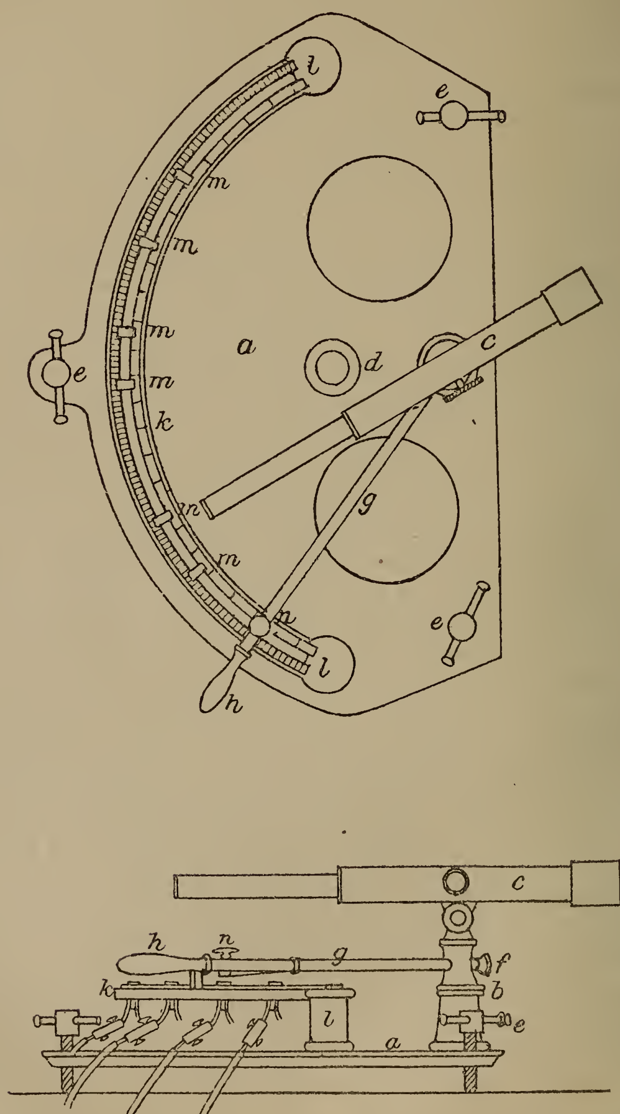
Telescopic firing-keys.

The system of pickets, above described, for giving the bearings, might probably be used effectually up to half a mile, but at greater distances a more accurate means of obtaining the intersections becomes necessary; the pickets have, moreover, the disadvantage of being easily disturbed and difficult to replace in an accurate position if once moved. In order, as far as possible, to obviate these defects, a telescope with cross wires has been mounted in connection with a series of contact-points and a movable key, as shown in Fig. 82.

Details of telescopic firing instrument.

It consists of a solid and somewhat heavy cast-iron stand, (*a*,) on which is placed an iron upright (*b*) arranged to carry a telescope with cross wires, (*c*,) the latter having a horizontal and vertical motion. The object of giving considerable weight to the cast-iron stand is to obviate, as far as possible, the chance of the displacement of the whole instrument by the concussion of guns fired in its vicinity. Two circular holes are cut in the body of the stand to reduce its weight, which would otherwise be unnecessarily great. A circular level (*d*) attached to the cast-iron stand gives the means of leveling it with sufficient accuracy, by means of three capstan-headed screws, (*e e e*.) Though this instrument, in consequence of its weight, is not very susceptible of displacement by concussion, it would always be advisable to place it as far as possible from the neighborhood of heavy guns in action, the concussion produced by their discharge being very great. Between the iron upright (*b*,) and insulated from it and the telescope by a ring of ebonite, is a brass portion, (*f*,) into which fits a brass arm, (*g*,) at one end of which is a wooden handle, (*h*,) and at the other a binding-screw. This arm and the portion (*f*) of the upright in connection with it forms, as will be hereafter explained, a portion of the electric circuit when the instrument is connected up for certain operations; it is therefore made of brass to prevent the chance of oxide in the connections, which might increase the electrical resistance. The arm (*g*) is rigidly connected, through the upright (*c*,) with the telescope and moves with it. It traverses over an arc (*k*) described with a radius of not less than eighteen inches, and supported at its two extremities by thick iron uprights (*l l.*) This arc consists of an iron frame, in two pieces, divided longitudinally in the center, the upper portions being faced with ebonite, in order to insulate the two parts from each other and from the metallic contact points (*m m*, &c.) in connection with them, for reasons to be hereafter explained. The arc is marked with divisions by means of which the position of the contact points (*m m*, &c.) may be registered,

Fig. 82.



so that, in the event of their being accidentally displaced, they may again be fixed in true relative position with facility.

These divisions serve also to determine the position of the whole instrument in the following manner: The telescope is directed on some distinctly marked object, such as a flagstaff or the defined angle of a building, and the number of the division under the guiding spring of the handle (*h*) of the brass rod, with the telescope in that position noted, it is thus easily seen how, even if the whole apparatus is moved, it may be replaced in the same position with facility, provided the position of the point immediately beneath the upright (*b*) supporting the telescope and on which the instrument revolves, or of the three capstan-headed screws, has been carefully marked. Fixed to the lower part of the brass arm (*g*) is a metal spring, in connection with a metal contact point; motion is given to this latter by an ebonite knob (*n*) attached to it by a small upright bar, passing through the arm (*g*.) In a state of rest the spring holds this contact arrangement up close to the arm (*g*,) but the depression of the knob (*n*) moves it downward sufficiently to bring it in connection with any of the contacts (*m m*, &c.) which may be directly beneath it. The knob (*n*) is made of insulating material, because the arm (*g*) is always charged with electricity at the moment of action, and the operator would receive a shock were the knob allowed to remain uninsulated. For the same reason it is necessary to insulate the eye-piece of the telescope, because it, too, is in metallic connection with the arm (*g*,) and would consequently be similarly charged. The extremity (*h*) of the arm (*g*) is made of an insulating material (wood) for the same reason.

Detail of contact-points.

Fig. 83 shows an enlarged section of the extremity of the arm with the contacts and other arrangements in its vicinity; (*g*) is the brass arm, and (*h*) the wooden extremity or handle; in connection with the latter is an ebonite block (*a*) just long enough to rest upon the outer iron arc (*c*,) and thus to prevent the contact point (*d*) being brought down except by the depression of the knob (*n*;) (*b*) is a small steel spring attached to the ebonite block (*a*) which, by touching a projection of the lower contact arrangement, gives an indication that the latter is vertically under the upper contact-point (*d*;) (*e*) is a brass ring which fits tightly over the arm (*g*,) and the spring (*f*) connecting it with the upper contact point (*d*.) When this is drawn back to the position shown in Fig. 83, no accidental depression of the knob (*n*) could occur, and no accidental ignition of a charge could take place. For work, the ring (*e*) is pushed forward and the spring (*f*) released. The lower contact arrangement consists of two metallic portions (*i i*,) separated and insulated from each other by an ebonite dividing-piece (*k*.) These metallic portions are provided with shoulders made to fit upon them the upper ebonite portions of the arc (*l l*,) and with a thin projecting arm, giving the means of making contact with the spring (*b*,) as already described. The lower contact arrangement is fixed firmly in position by means of an ebonite wedge (*m*,) passing through it and pressing against the metal portions of the arc (*c c*.) In metallic connection with the brass portions (*i i*) of the lower contact arrangement are two thick copper wires (*o*) and (*p*) to which the battery or line circuits, &c., may be attached. When the upper contact point (*d*)

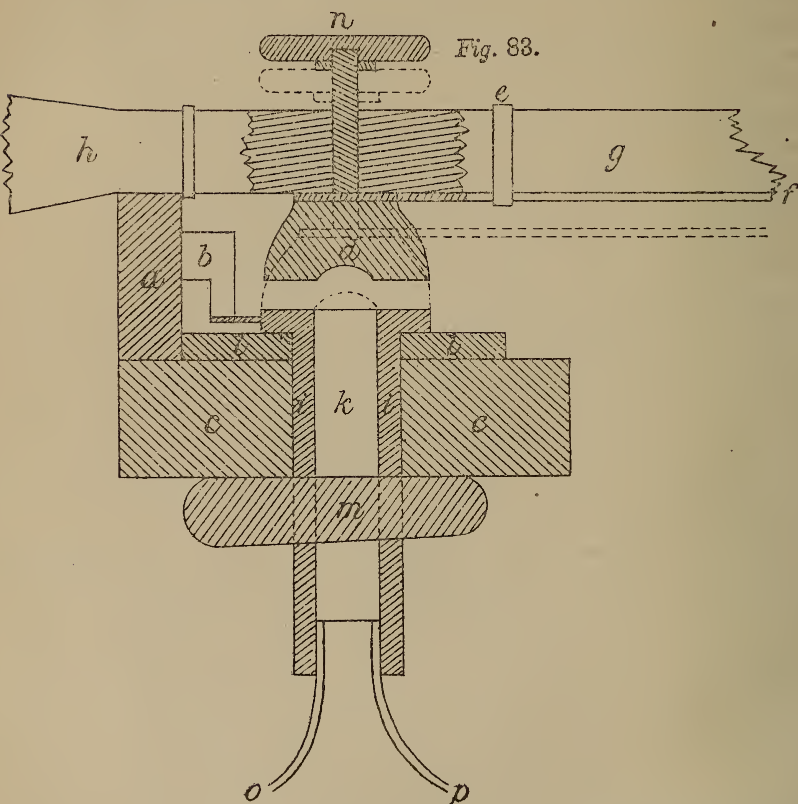


Fig. 83.

is depressed, as in the position shown by the dotted lines, it will be observed that the insulated space (*k*) between the two sides (*i i*) is bridged over.

To place the instrument in position.

To place the instrument in position, a point from whence the lines of mines are clearly distinguishable should be chosen. This point should be as far as possible from heavy guns, and the foundation should be moderately solid. A broad flat stone, for example, would furnish a convenient foundation on which to place the apparatus. The iron stand of the instrument having been leveled, by means of the circular level and capstan-headed screws, the telescope should be directed on some fixed and well-defined object, and the number of the division under the spring of the handle registered. The telescope should then be directed on each mine or line of mines, as the case may be, in succession, the position of the mines having been marked by buoys or other similar means for purposes of identification, and one of the contact arrangements brought into proper position for each, and keyed firmly up, and the number of the mine and the number of the division on the graduated arc registered. This having been done at one or both stations, as required, the buoys marking the position of the mines may be removed. The points where the capstan-headed screws, carrying the instrument, rest, should be carefully marked, so that the whole may be replaced in the same position if accidentally disturbed. Should it stand on a stone, small shallow holes might be cut to receive the points of these screws with advantage.

Mode of using the instrument.

The mode of using this instrument is similar to that for the firing-keys, Fig. 81, already described. It is, however, adapted for longer distances.

For such a combination as that shown in Fig. 78, two instruments would be required; for that used at station *(a,)* the battery would be connected with each of the rear wires *(o, o, &c.,)* Fig. 83, of the lower contact arrangement; the electric cable from *(a)* to *(b,)* Fig. 78, would be attached to the binding-screw in connection with the upright *(f,)* Fig. 82, carrying the telescope. At station *(b,)* Fig. 78, the electric cable arriving from station *(a)* would be attached to the binding-screw *(f,)* Fig. 82, while the cables connecting its several mines would be attached to the rear wires *(o,)* Fig. 83, of the lower contact arrangement. It is thus easily seen how the depression of the key of the instrument at station *(a,)* Fig. 78, would change the cable from *(a)* to *(b,)* and, through it, the brass arm of the instrument at station *(b,)* and that the depression of the key at station *(b)* would pass the charge on and complete the circuit through any one of the mines *(m m, &c.)* required. Unless both keys were down simultaneously no current could pass, and, as already explained with reference to the firing-keys, Fig. 81, both keys would not be down together unless an enemy's vessel were at the point of intersection of the two lines passing over a mine, and the telescopes were both directed on her.

For the combination shown in Fig. 79, the firing-battery would be connected with the binding-screw (*f*,) Fig. 82, and the cables connecting the mines with the rear wires (*o o*, &c.,) Fig. 83, of the lower contact arrangement.

For the combination shown in Fig. 80, the battery at station (*a*) would be connected with the binding screw (*f*,) Fig. 82, the cables connecting stations (*a* and *b*) with the rear wire (*o o*, &c.,) of the lower contact arrangements; while at station (*b*,) Fig. 80, the electric cables arriving from station (*a*) would be connected to the front wires (*p p*, &c.,) Fig. 83, of the lower contact arrangements, and the conductors thence to the charges would be connected with the rear wires (*o o*, &c.) In this case the necessity for dividing the metallic portion of the lower contact arrangement, by means of the insulating ebonite center, becomes evident.

The description given is that of an instrument now in use at the School of Military Engineering, Chatham, for instructional purposes. This is probably one of the first that has ever been made, and though it works with considerable accuracy, improvements will, no doubt, in time be introduced. For example, with a radius of eighteen inches, an interval of 50 yards between two mines in a line subtends a very small arc at a distance of a mile, and the contact arrangements are brought very close to each other. This defect may be remedied by making the contact points smaller, or by using a second instrument for every alternate mine.

Arrangement of fixed telescope and firing keys for a line of mines.

For a line of mines a fixed telescope, with a single firing key, might be employed with advantage. With such an arrangement it would be only necessary for the observer to keep his eye on a vessel, and, the moment she arrived at the cross wires of his telescope, to press down his key and keep it down until she had fairly passed.

Simplicity is essential in all arrangements for firing by cross-bearings.

It has even been suggested that each mine, in the combination shown in Fig. 80, should be provided with two fixed telescopes, one at each of the stations (*a*) and (*b*.) In this way an observer would have but one object to engage his attention and but one duty to perform, viz, to put his key down when a vessel arrived on the line of his own particular mine. There is no doubt that simplicity of arrangement is most essential in firing by visual intersections, and it is very probable that if several vessels were simultaneously approaching a line of mines, which were connected with a telescopic or other arrangement, in which one man had charge of several firing keys, he might be engaged in observing one vessel, while his fellow-workman was directing his instrument on another, and many ships might thus pass through uninjured. It unquestionably requires much more dexterity, nerve, and training to work a number of keys, combined with a movable telescope in one instrument, than to watch a vessel approaching a mine, on which a single fixed telescope was directed, and to put down a single key on her passing the cross-wires.

We now come to the different modes of firing electrical submarine mines mechanically, that is to say, by an arrangement through which the vessel herself closes the circuit, by means of an apparatus called a circuit-closer. Mechanical cuit-closers.

A great number of different forms of this instrument have been made, each possessing certain advantages.

In the Austrian section of the Paris exhibition a circuit-closer was exhibited in connection with the torpedoes. Austrian circuit-closers.

In this system the submarine mine and circuit-closer are in the same case. The details of the circuit closer are shown in Fig. 84; (*b b b*) are the buffers, held in position by strong

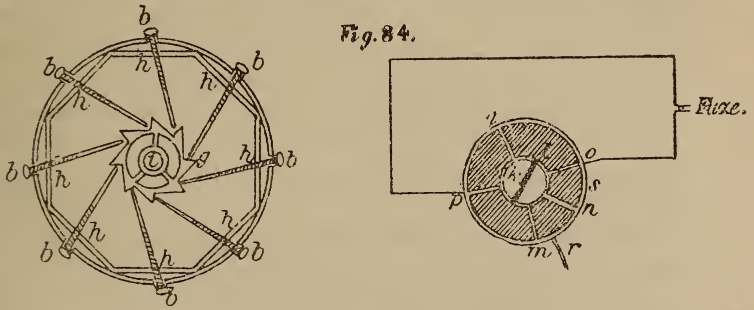


Fig. 84.

brass springs, the openings through which they pass being kept water-tight by means of strong mackintosh cloth; when pressed in they would come in contact with, and cause to revolve, a brass rachet-wheel (*g*,) also kept in position by a strong spring.

Strong pieces of wood (*h h h*) round the circuit-closer keep the buffers and their attached arms in the proper direction, and give rigidity to the part of the iron cylinder through which they pass.

The brass ratchet-wheel (*g*) being put in motion, carries round with it a central arrangement (*i*,) the lower part (that nearest the fuse) of which is shown in detail in Fig. 84. This central portion consists of a brass cylinder (*k*,) divided into two portions, insulated from each other by a division of ebonite (*l*,) shown in black; one side of this cylinder is fitted with three arms of brass (*m*, *n*, and *o*,) and the other with two arms (*p*, and *q*,) all of which are carefully insulated from each other by India rubber. The arm (*m*) is close to, but insulated from, a metal plate (*r*,) which latter is permanently connected with the conducting wire from the battery, and thus in its state of rest remains electrically charged. Beyond the arm (*n*) is a small spring (*s*,) permanently connected with the earth, and in such a position that when the central portion is moved round, this spring (*s*) comes in contact with the arm (*n*) and the plate (*r*) with the arm (*m*) simultaneously, and the circuit is completed through earth to the battery, without, however, passing through the fuse.

Referring again to Fig. 84, the arms (*o* and *p*) on opposite sides of the brass cylinder and consequently insulated from each other, are connected with the fuse, and the arm (*q*) is permanently connected with the earth.

We left the current passing from the battery through the arm (*m*) by the brass cylinder to the arm (*n*) and by the spring (*s*,) then in contact therewith, to earth, and completing the circuit; but by a still further pressure of the vessel on the buffer, the arm (*h*) is pushed beyond the spring, and in contact therewith, and consequently circuit by earth to the battery is broken, while the contact of the arm (*m*) and plate (*r*) is still retained, and the current is passed by the arm (*o*) through the fuse to the arm (*p*,) and then to earth through the arm (*q*,) completing the circuit through and firing the fuse.

The action of the spring, in breaking the circuit, has the effect of intensifying the current (by means of an intensity-coil in connection with the firing battery) to its utmost extent, and at the moment when this intensity is highest, passing it through the fuse.

To render a channel safe for a friendly vessel.

Should a friendly vessel be approaching a line of mines arranged on this system, it would only be necessary to detach the firing battery, by removing the connecting plug, to render her passage perfectly safe. Should she make contact with any of the mines in her course, the ratchet-wheel (*g*,) Fig. 84, would be pushed round, the spring (*s*) would make and break contact, as before described, but no current would be circulated; and on the vessel leaving the mine the ratchet-wheel would be drawn back to its original position, by means of a strong spring in connection with it, and be ready again to act when required. The arrangement for closing the circuit is made sufficiently strong to prevent chance of injury from contact with a friendly vessel.

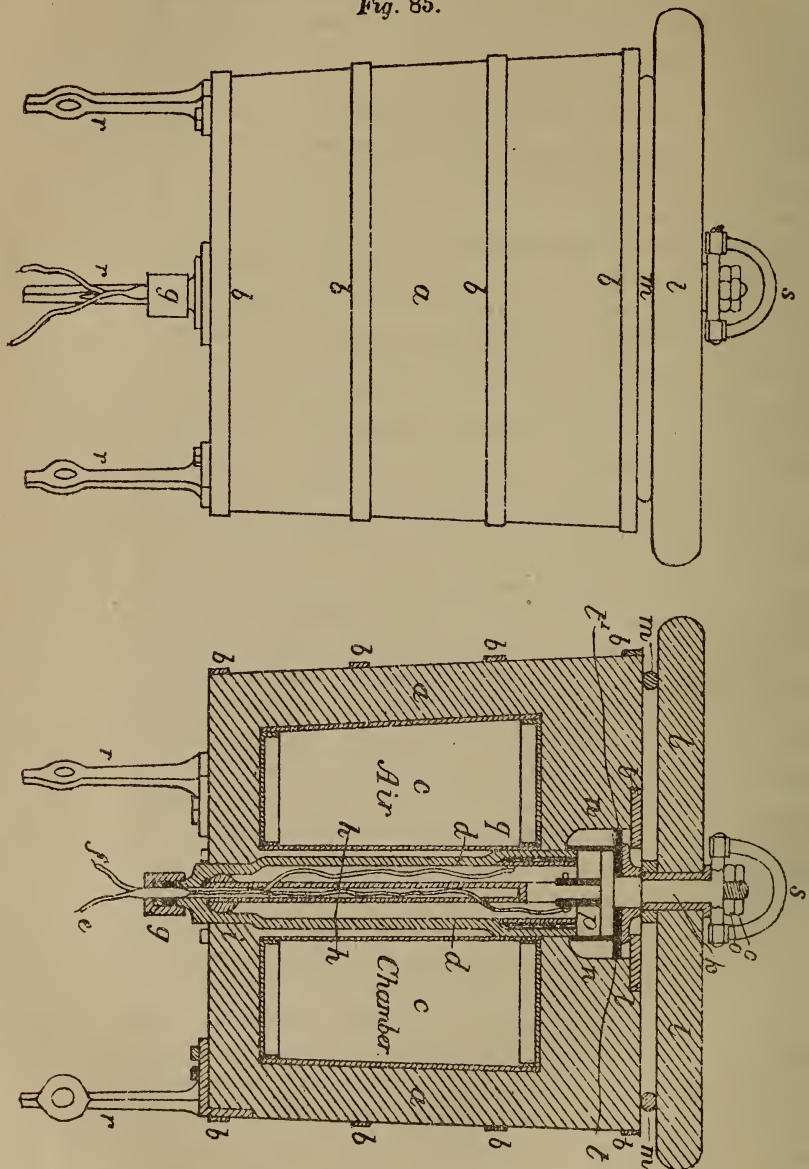
Fuse only in circuit at the moment of firing mine.

It will be observed that, in the Austrian system, the fuse is only put into the electrical circuit at the moment when it becomes necessary to fire it. This arrangement was considered necessary, to obviate the chance of the accidental ignition of a change from induction, caused by atmospheric electricity. According to Baron Von Ebner, accidents of this nature have occurred to mines used by him. This mode of cutting the fuse out of circuit till the moment of ignition, guards most effectually against such an occurrence, but, at the same time, it renders it impossible to fire the charge at will, and the ignition of the mine is thus reduced to that single condition in which the action of the circuit-closer, by the contact of a vessel, is essential.

Abel's circuit-closer.

Another form, designed by F. Abel, esq., F. R. S., chemist of the war department, is shown in section and elevation in Fig. 85. It consists of a strong wooden case (*a*,) bound with four iron bands (*b*, *b*, *b*, *b*,) buoyancy being given to it by means of an air-tight chamber (*c*.) Within the apparatus is a brass tube (*d*,) into the lower extremity of which a pair of insulated wires (*e*) and (*f*) are introduced, by means of a joint (*g*) inclosed in a stuffing-box. This latter is rendered water-tight by a ring of India rubber, shown in black in section, compressed against the insulation of the conducting wires by the action of a screw working on the extremity of the brass tube (*d*.) In order to render this joint thoroughly water-tight, the insulation of the two wires (*e*) and (*f*) is, at this point, welded into one, and made into an elongated oval form, thicker than the original insulation, by the addition of layers of Chatterton's compound and gutta-percha in a plastic state. In thus welding the insulation care must be taken to prevent the two conducting wires from being accidentally pressed into contact while the gutta-percha is softened by the heat necessarily applied. Within the brass tube (*d*) is another tube of brass or iron (*h*,) extending vertically through the whole apparatus, and working on an universal joint (*i*) at its lower extremity. The upper portion of this tube is rigidly connected with a metal bar (*k*,) which latter is firmly attached to a strong teak top (*l*,) supported on the wooden case (*a*,) and separated from it by a vulcanized India-rubber ring (*m*.) It is thus easily seen how any blow on the top would be transmitted to the metal cylinder (*h*.) The interior of the brass cylinder (*d*) is kept water-tight by means of a vulcanized India-rubber collar (*n*,) shown in black in section, connecting it with a ring projecting from the metal bar (*k*.) A couple of metal screws (*o o*) are made to fit on a screw tapped on to the upper portion of the metal bar (*k*,) and, by means of a spanner, these may be screwed down so as to firmly connect the top of the arrangement with the wooden top (*l*.) One of the insulated conducting wires (*e*,) having been carried in through the metal tube (*h*,) is soldered on to a copper ring (*p*) incircling the bar (*k*,) but insulated therefrom. The insulated conducting-wire (f) is passed through a hole in the tube (h,) and its bared extremity is attached to a binding-screw (g) in connection

Fig. 85.



with an insulated brass band, let into a broad ebonite ring which passes completely round a hollow, in the brass tube, made to receive it. To the base of the apparatus feet (r, r, r)

are attached, on which it may stand in such a way as to keep the projecting piece (g) clear of the ground. Rings are formed in these feet for the attachment of the mooring-chains. A ring (s) is attached to the upper portion of the apparatus to facilitate manipulation and moving the circuit-closer. A metal ring (t) is let into the opening of the upper portion of the case (a) to take the weight of the outer case when the circuit-closer is lifted by the ring (s.) A thick ring (t') of vulcanized India rubber keeps the whole combination rigid, and by its resistance, dependent on its thickness, regulates the force which must be used to set the apparatus in action.

Mode of using the apparatus.

This circuit-closer is designed for use, so that the fuse may either be kept entirely out of the circuit till the moment when it is required to be fired, as in the Austrian system, or it may be employed in the ordinary manner with the fuse in circuit as usual. In the latter case only one wire is required, and this is connected with the copper ring (p;) the insulated brass band is not then required, and the space allotted to it is filled by metal.

Connection with the fuse and of circuit till the moment of ignition.

For the former combination the electric cable from the firing battery is connected with the insulated wire (e,) the other pole of the battery being to earth, the wire (f) being attached, through an insulated conductor, to one pole of the fuse, and a metallic connection being arranged from the other pole of the fuse to earth. In order to fire the fuse it is easily seen that it is only necessary to bridge over the space between the copper ring (p,) to which the wire (e) is connected, and the brass ring (q) attached to the wire (f.) This would be done by a vessel striking the top (e) of the apparatus in any direction, which, being pressed on one side, would carry with it the bar (k,) and, by the action of the universal joint (i,) bring some part of the copper ring (p) in contact with the brass band (q,) thus completing the electrical circuit. In this combination it is easily seen how the fuse is only introduced into the circuit at the moment when it is required to be fired.

Connection with the fuse in circuit as usual.

When it is desired to arrange the fuse in connection with this circuit-closer in the ordinary manner, the combination is as follows: One pole of the firing-battery being to earth, the other is connected, through the electric cable, with one pole of the fuse, the other pole of the fuse being placed in metallic connection with the insulated wire (e,) while the insulated wire (f) is put to earth by being connected with the metallic portion of the case (a.) In this combination it is easily seen that, in order to fire the fuse, it is only necessary to bridge over the space between the two brass rings (p) and (q,) which would be done, as already described, by the action of a vessel striking the top of the apparatus.

Advantages and defects of combinations, with fuse permanently in or out of circuit.

When the fuse is entirely out of the circuit till the moment of ignition, it cannot be fired at will, and cannot be tested except when a return wire is used; it is, however, manifestly very safe from accidental ignition. On the other hand, when the fuse is arranged between the firing battery and the circuit-closer, any considerable fault in the insulation, between the fuse and the circuit-closer, would be very likely to cause an accidental explosion.

To render a channel safe for a friendly vessel.

In order to render a channel safe for a friendly vessel, it would only be necessary, in either of these combinations, to detach the firing battery, in which case, should a circuit-closer be struck, it would re-establish itself in its former condition by virtue of the action of the flat India-rubber ring (t') and the collar (n,) and be ready to act effectively as before.

Efficiency of Abel's circuit-closer.

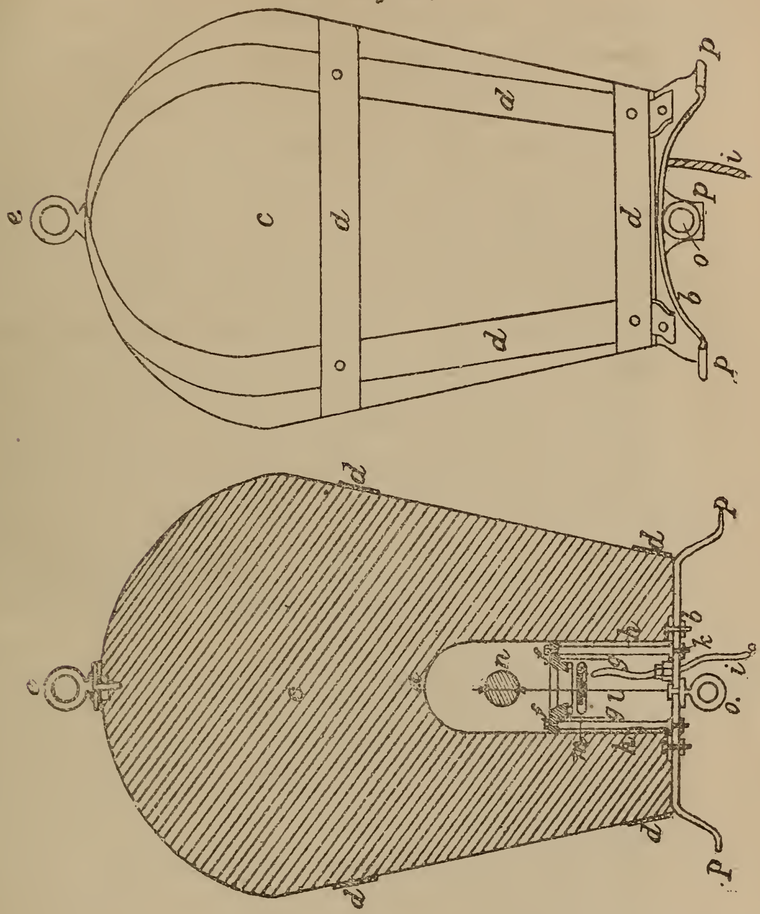
From experiments carried on at Chatham with several circuit-closers of the form described, it has been proved that they are very efficient in action, and that the strong external wooden case possesses sufficient resisting power to enable them to stand a good deal of knocking about and rough usage, without damage to the internal circuit-closing arrangements. This power to resist heavy blows is essential to the efficiency of any form of circuit-closer, as, when in position in a channel through which there is much traffic, they are always liable to be struck with considerable force by blades of screws, floats of paddles, and other hard and sharp bodies. It would be an improvement if the stuffing-box (g) were arranged to be flush with, or at least to extend as little as possible below, the bottom of the apparatus. Its projection, as shown in Fig. 85, renders it very liable to injury from a side blow. This improvement might no doubt be very easily effected, but the same object has been attained, in the most recent pattern of this circuit-closer, by fixing a stout metal cap over this stuffing-box, the conducting cable being brought out through a lateral opening.

Mathieson's inertia circuit-closer.

Another form, designed by Quartermaster-Sergeant J. Mathieson, R. E., is shown in Fig. 86.

It consists of a wrought-iron dome (a,) with a flange at its foot, to enable it to be attached to an iron bottom piece (b,) by means of screws and nuts, in such a manner that it may be removed at will, the whole top coming bodily off, so as to give easy access to the inside where the circuit-closing apparatus is arranged. The joint between the flange and bottom piece is made water-tight by means of an India-rubber ring, compressed between the two portions at the joint; (*c*) is a strong wooden cover, made of deal, saturated with tar, fitting closely over the dome, and bound by strong iron

Fig. 86.



bands (*d*, *d*, *d*,) which latter, being attached by screws and nuts to the foot plate (*b*,) connect the whole apparatus firmly together, and enable it to be moved with safety by the ring (*e*,) which is strongly fixed on to the iron bands (*d d*) at the top of the apparatus for this purpose. The cover (*c*) is made of light wood, in order to assist in giving buoyancy to the whole, in addition to which it must be strong enough to protect it from heavy blows, such as those which would be given by the blade of a screw or any similar hard and sharp substance. The circuit-closing arrangement consists of a brass ring (*f*, *f*) with four metal springs (*g*, *g*) attached to and projecting below it, at equal distances from each other, (every quarter of a circle.) This metal ring is supported by four uprights (*h*, *h*,) made of brass, so that the ring itself is kept in metallic connection with the iron bottom piece (*b*,) and at the same time firmly attached thereto. Within the apparatus is a strong flexible iron rod (*l*,) to the top of which is attached a ball of lead (*n*,) while at its center is a brass disk (*m*,) the outer rim of which, as well as the inner surfaces of the four projecting springs (*g*, *g*,) is platinized, to prevent oxidation, which would impede metallic contact; the center of the disk (*m*) is of ebonite, to insulate it from the rod (*l*.) The insulated wire (*i*,) for connection with the electric cable from the fuse and firing battery, passes in through the bottom piece (*b*) at the point (*k*,) by means of a joint on Mathieson's principle, somewhat similar to that described at page 134. From the joint (*k*) the insulated wire is carried to a binding-screw on the disk (*m*,) the whole being thus kept insulated till the moment it becomes necessary to close the circuit. A ring (*o*) is provided at the bottom for the attachment of the moorings, and the whole is supported on three feet (*p*, *p*, *p*,) for facility of working on shore. These feet prevent any chance of injury to the electric connection (*i*) by the apparatus resting upon it. Holes are provided in these feet to which the moorings may be attached. All the iron work connected with the apparatus is galvanized.

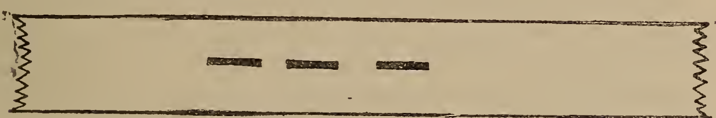
Connections for use.

The general principles on which the instrument is connected for use may be described as follows: One pole of the firing battery being to earth, the other is connected with the insulated electric cables, and through it with one pole of the fuse; the other pole of the fuse being attached to an insulated wire, to connect it with the conductor (*i*) permanently fixed in the instrument. This last connection is made by means of Mathieson's joint, as described at page 134.

Mode of action.

The apparatus is put in action by a blow in the external wooden case (*c*,) which causes the flexible rod (*l*) to move on one side from the inertia of the weight (*n*) at its upper extremity. This brings the platinized brass disk (*m*) in contact with one of the projecting springs (*g* *g*.) The whole of the iron work of the bottom plate and instrument generally forms, when immersed in water, an excellent earth-plate, and the ring (*f*) being in metalic connection with it, it is easily seen how, by the motion of the disk (*m*,) the insulating space between it and one of the four springs attached to that ring (*f*,) is bridged over and the circuit closed for an instant. A vessel striking a circuit-closer of this nature would thus mechanically fire a charge in connection with it, and to render it safe for a friendly ship it would only be necessary to detach the firing battery.

In order to regulate the sensitiveness of the instrument, two screws, with washers, one above and the other below the ball (*n*,) give the power of regulating its position on the rod (*l*.) To make the apparatus more sensitive the leverage is increased by fixing the ball high up on the rod; to make it less sensitive it is placed low down. The means of regulating it in this manner is given by a screw tapped on to the upper extremity of the rod (*l*.) The duration of the contacts made by this apparatus have been measured by means of a Morse recording instrument placed in a circuit with it. When struck by a passing vessel a succession of contacts occur, the first much shorter than the others. The following is a *fac simile* of a strip of paper, on which the contacts were thus recorded, which will give a very good idea of the action of the instrument: Regulation of sensitiveness of instrument.



Result of contact made by a Schooner.

This circuit-closer may be used either with Abel's or the platinum wire fuse, and is especially efficient with the latter, in consequence of the comparatively long duration of its contacts. This effect of a somewhat prolonged contact is no doubt due to the flexibility of the rod (*l*,) which, after the first blow, carries the weight (*n*) rather beyond that point where a simple light contact would result, and the small interval of time is that necessary for the apparatus to recover itself. May be used with Abel's or platinum wire fuse.

This circuit-closer has been very severely tried at Chatham, and has proved itself very efficient. Several specimens have been moored in the ship channel of the river Medway, opposite Gillingham, during the years 1869 and 1870. In this position they have been subjected to rough weather and hard knocks from passing vessels, and experiments have been made in moving them and hauling them up for examination. Some of them have been kept submerged for several months, during which time they have proved efficient when tested, and, when taken up, been found to have resisted successfully the very severe usage to which they had Advantages of the instrument.

been subjected, and to be as fit for work as when first put in the water. There appears to be no action of the ball, caused by the regular swing of such a sea as occurs in this part of the Medway, and indeed it would seem to be quite safe for use in any sea, however heavy, for it has been swayed about, when afloat, by means of a boat-hook, so as to bring it down nearly to a horizontal position. When this motion is given smoothly and regularly no contact, as indicated by a galvanometer or other instrument in circuit, has ever occurred when the ball has been properly adjusted. The slightest concussion, however, will set the apparatus in action; circuit-closers, which had successfully resisted the operation of swinging down on their sides by means of a boat-hook, having been in every case set in action by the impact of a small boat rowed against them. The external wooden covering has also proved a most efficient protection against rough usage. The wood and iron work of many of these circuit-closers have been found deeply indented by blows from the screws and paddles of steamers when they have been taken up after long submergence, while the interior has remained quite uninjured and in as good working order as when first put in the water. The proportion of the diameter of the pear-shaped upper portion may be increased considerably over that shown in Fig. 86. A greater diameter at this point would increase the chance of contact with a passing vessel, as well as tend to make the apparatus float more vertically in the water.

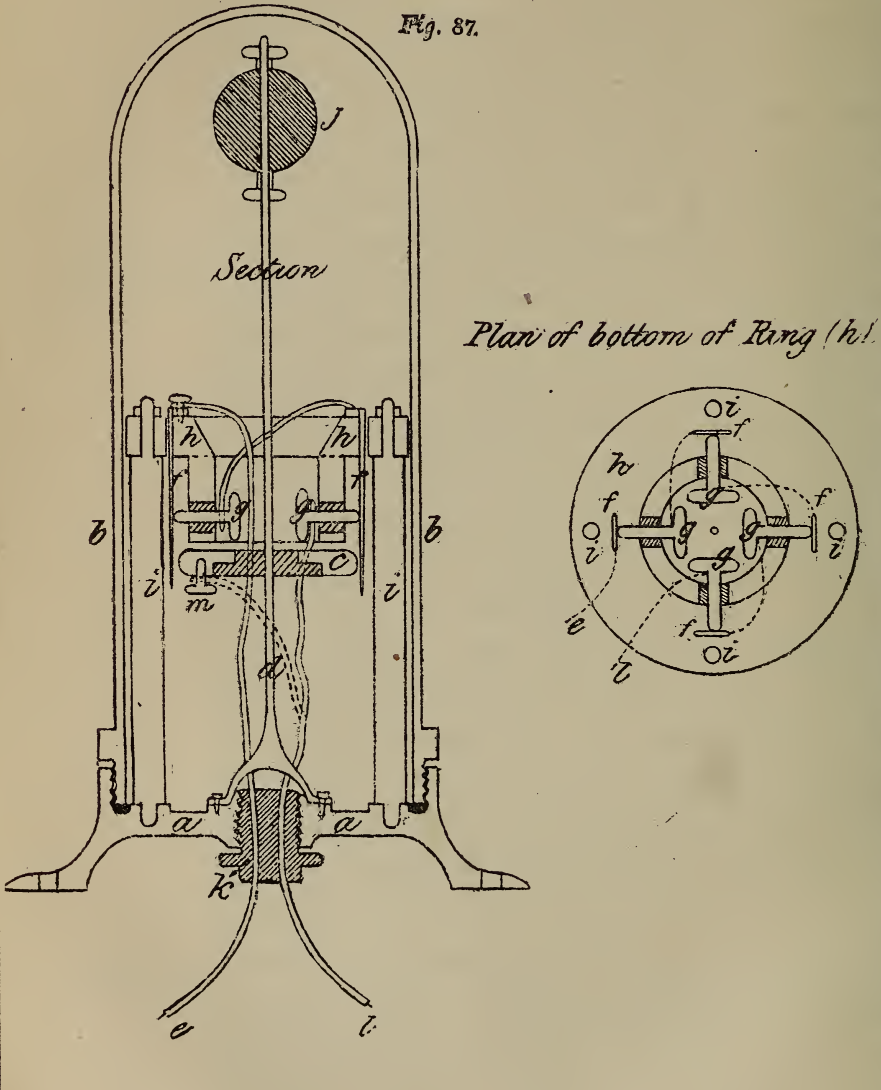
External covering an efficient protection against rough usage.

This apparatus, which has been entirely designed by Quartermaster-Sergeant J. Mathieson, R. E., is a very efficient piece of mechanism. While possessing sufficient solidity of construction to resist external injury, it has proved itself so sensitive that a very slight blow will put it in action, and though it is possible that improvements may hereafter be made in it, or that other forms of circuit-closers may be designed, there is no doubt that it might be at once used with success in connection with any system of submarine mines.

Mathieson's circuit-breaker.

Another similar apparatus, differing however in its mode of action, has been designed by Quartermaster-Sergeant J. Mathieson, R. E. In it the current is allowed to circulate continuously, and the effect of a blow is, for an instant, to interrupt the electrical current with a corresponding cessation of the current; it is easily understood how this cessation of current would convey a signal to the testing-room, and how it might, by means of a relay, be made available for

Fig. 87.


Section
J
h
h
f
f
g
g
b
b
c
i
i
m
d
a
a
k
e
l
Plan of bottom of Ring (h).
i
f
h
f
f
g
g
g
g
i
i
e
f
i
l

throwing a firing-battery into the main circuit. From its mode of operation it has been called a "circuit-breaker."

Its general arrangements are shown in Fig. 87; (*a*) is a brass casting, forming the base of the instrument, with a projecting rim to supply the place of the feet in the original design; (*b*) is a brass dome similar to that already described; (*c*) is a disk firmly attached to a steel rod (*d*;) the center of this disk is composed of ebonite to insulate it from the rod, while its outer portion is of brass as before; (*e*) and (*l*) are the earth and line wires arranged for introduction into the apparatus by means of an ebonite screw-piece (*k*;) (*h*) is a cylindrical ebonite block, shown also in plan, to which are attached four strong brass springs (*f*, *f*, *f*; *f*) projecting downward somewhat below the level of the disk (*c*,) and in such a position that any deflection of the rod carrying the latter would bring it in contact with the springs and press them outward. The lower portion of this block (*h*) is of smaller diameter than the upper, and through it pass four brass screws (*g*, *g*, *g*, *g*) corresponding to the brass springs, and with their points outward and in contact with them; (*i i*) are brass pillars supporting the ebonite block (*h*;) (*j*) is a ball of lead firmly attached to the steel rod (*d*.) The electrical connection between the screws (*g*, *g*, *g*, *g*) and the springs (*f*, *f*, *f*, *f*) is made in the following manner: the line wire (*l*) is attached by means of a binding-screw to the first screw, which presses against the first spring; from the top of this first spring an insulated wire is carried to the second screw, which presses against the second spring; the top of this second spring is similarly connected by an insulated wire with the third screw pressing against the third spring, the top of which is again connected with the fourth screw pressing against the fourth or last spring, the top of which being connected, by means of a binding-screw, with the earth wire (*e*,) completes the combination. These connections are shown by the dotted lines in the plan of the lower portion of the ebonite block; there is no connection between the top of the fourth or last spring and the first screw; any current, therefore, arriving along the line-wire passes to the first screw, thence to the top of the first spring, thence to the second screw and second spring, and so on to the last spring and to earth, and a deflection of any one of the springs, causing an interval between it and its corresponding screw, would, as may be easily understood, break the electrical circuit and cause a cessation of the flow of the current. The whole is inclosed in a solid wooden covering, as described for the original apparatus.

Construction of instrument.

Several improvements have been made in the construction of this instrument. It will be observed that the dome (*b*) is connected with the foot-plate (*a*) by means of a screw, on the diameter of the former, which brings pressure to bear upon a gutta-percha ring permanently and firmly imbedded in a circular recess formed in the latter, making the whole water-tight. The wooden covering is strongly attached by means of bolts, passing through the projecting foot of the base piece and secured by nuts.

Quartermaster-Sergeant Mathieson proposes to cover the point of entry of the earth and line wires with wood, to protect the conducting wires; it is doubtful whether a metal dome would not be more efficient for this purpose.

Connections for work and mode of action.

To connect the instrument for work, the signaling battery is attached, through the relay or other signaling apparatus and electric cable, with the line wire (*l*,) and the current passes thence by the insulated wire to the first brass screw, and as long as the points of the screws (*g*, *g*, *g*, *g*) corresponding to the springs (*f*, *f*, *f*, *f*) remain in contact with them, it passes freely through the combination and to earth by the earth wire (*e*,) completing the circuit through the earth connection of the other pole of the signaling battery. Should the apparatus receive a blow from a vessel, the action of the weight (*j*) would deflect the rod (*d*) and bring the disk (*c*) in contact with one of the springs (*f*,*f*,*f*,*f*,) pressing the latter away from the point of the screw (*g*) in contact with it, and, for an instant, creating a break in the electrical circuit and making a signal on the instrument in the testing-room of the fort connected with it. The mass of the cylindrical block (*h*) being of ebonite, it is easily understood how the electrical circuit is only completed by the contact of the springs (*f*, *f*, *f*, *f*) and the points of the screws (*g*, *g*, *g*, *g*,) and that pressure, forcing any one of these springs on one side, must cause a break in that circuit till, by its elasticity, the instrument had recovered its normal position.

Regulation of sensitiveness of instrument.

The mode of regulating the sensitiveness of this instrument is an improvement on that originally designed. The ball (*j*) is permanently fixed on the steel rod (*d*,) and the screws (*g*, *g*, *g*, *g*) are capable of being moved in or out, so as to exercise more or less pressure on the springs in contact with them; the amount of pressure thus regulates the degree of sensitiveness with very great nicety.

Contacts of screws and springs platinized.

In order to insure good metallic contact between the points of the screws (*g*, *g*, *g*, *g*) and the springs (*f*, *f*, *f*, *f*,) and to prevent chance of oxide or other interruptions to the passage of the current, the points of the screws and the faces of the springs in contact with them are platinized.

Arrangement for converting instrument into a circuit-closer.

The instrument may be converted into a circuit-closer by simply detaching the line wire (*l*) from the screw (*g*,) and connecting it, by means of the binding-screw (*m*) with the metal disk in connection with the flexible steel rod (*d*.) With this arrangement a blow from a ship would close the circuit by establishing a metallic contact between the metal edge of the disk (*c*) and one of the springs (*f*, *f*, *f*, *f*,) from whence the current would pass through the combination of screws and springs attached to the ebonite block (*h*,) and thence to earth by the earth wire (*e*.) To fit the apparatus for use as a circuit-closer, the edge of the metal disk (*c*) must be platinized, for the same reason as given in the case of the screw points.

Pendulum circuit-closer.

Quartermaster-Sergeant Mathieson's original idea, on which the instruments above described are improvements, was that of a weight arranged in the form of a pendulum. It was, however, too sensitive for actual practice; though excellent in still water, it was easily affected by a comparatively slight swell, and was consequently abandoned.

Pendulum circuit-closer suggested by Lieutenant R. F. Moore, R. E.

Lieutenant R. F. Moore, R. E., has suggested a circuit-closer on the pendulum principle. It is simply a common bell, the clapper of which is insulated from the body, and the circuit is closed by bringing the former in metallic contact with the latter. This apparatus has not been sufficiently tried; being similar in principle to Mathieson's pendulum, it is to be feared that it would fail from similar causes.

It would no doubt stand the regular and uniform swing produced by a sea, as Mathieson's did, for a considerable time, but the slightest deranging influence caused the latter to close the circuit, and it is difficult to understand how it could act in one case and not in the other.

Mathieson's dual-electric circuit-closing arrrangement.

Another form of circuit-closer, suggested by Quartermaster-Sergeant Mathieson, R. E., may be described as follows: It consists of a glass vessel containing, and at the same time insulating, the earth connection. This glass vessel is so arranged that a ship would come in contact with and break it, when the circuit would be completed by the earth plate through the water, and the charge fired.

He proposes to moor his mines in pairs, at a depth of about 3′ below the surface of the water, and to sustain them in that position by means of small surface floats, possessing just sufficient buoyancy to keep them in position without being too conspicuous, as described in page 82. Though this arrangement has not been found to answer, in consequence of the reasons given in the description referred to, there is no reason why the mines themselves might not be floated up from sinkers on the bottom in the usual way, though they would not, under such circumstances, be effective at all times of tide. He proposes to connect each of the mines to a hermetically-sealed vessel, placed midway between them, by means of strong lines. He proposes to carry his electric cable from the firing battery on shore to a point on the bottom nearly midway between the pair of mines, containing the electrical connection by branches thence to the fuse in each mine, and from each fuse to an earth-plate inclosed within the glass vessel between them.

Mode of action.

A ship passing between a pair of such mines would throw a strain on the lines connecting them with the glass vessel, the mines themselves would be drawn toward the ship's sides, the glass vessel would be broken, the earth-plate contained in it would be brought in contact with the water, and the pole of the firing battery not connected with the electric cable being to earth, the charge would be fired.

In the event of a vessel being observed to pass without exploding the mines, Quartermaster-Sergeant Mathieson proposes an alternate mode of firing by the frictional electrical machine; by means of a switch-pin the battery would be disconnected and the frictional machine, with its condenser ready charged and earth connection made good, thrown into circuit. On the condenser being discharged, the small length of cable beyond the fuse would act, in conjunction with the surrounding water, as a Leyden jar, and the tension of the charge produced by this very powerful machine, combined with the inductive action set up between the metallic conductor forming the inner, and the water, forming the outer coating of the Leyden jar, would be sufficient to fire a high-tension fuse. The platinum-wire fuse could not be used in this combination.

Experiments to test power of firing by frictional machine with small length of electric cable used as a Leyden jar.

Experiments were tried at Chatham on the 18th of May, 1870, to test the power of the frictional machine to fire a charge by induction in this way. A cable, half a mile long, consisting of a strand of 7 No. 22 B. W. G. copper wires, insulated to $\frac{3}{10}$ inch with Hooper's patent di-electric, was laid out on the ground and a fuse attached to the fuse end with 12 feet of electric cable beyond it, the latter immersed in water, but with its end carefully insulated. Under these conditions Abel's fuses were fired with certainty by a portable ebonite Austrian frictional machine, not only when applied directly to the cable to which the fuse was attached, but by induction when a charge was passed through half a mile of similar cable, laid parallel to it on the ground at a distance of three feet. A battery of 100 Daniell's cells failed to fire the fuse by induction under either of the circumstances specified.

In such a combination care must be taken to leave plenty of slack in the electric cable, so that the strain may not come on them, but on the lines connecting the glass vessel with the mines.

Disadvantages of the system.

This system possesses the disadvantage that, unless it was so arranged that the mines could be drawn down out of the way, the first vessel, friendly or otherwise, which passed through would break the glass vessel and probably also the electric cables connecting it with the mines. By simply detaching the firing-battery no injury need occur to a friendly vessel; but even if the electrical connections remained in working order, the mines would be reduced to the condition of being capable of being fired at will only. Charges might be arranged to be hauled down, under certain circumstances, to allow friendly vessels to pass, but as a rule this would be a very difficult operation and probably not applicable to the majority of cases. The power of the frictional machine to fire charges arranged in this way is, no doubt, very great, but the danger of induction when using it must not be lost sight of,—see description in pages 170, 171, and 172,—and its employment must therefore be limited to conditions in which this serious disadvantage may not be productive of unintended results.

These are some of the most practical forms of circuit-closers capable of application under various conditions, but no doubt others might be designed suitable for the purpose.

Circuit-closer may be combined with mines or detached from them.

Most circuit-closers are capable of being used either in the same case as the charge, or detached from it and only connected by a suitable mooring line and electric cable. In the Austrian system the circuit-closer and charge are in part of the same case, and are so arranged that the charge will only explode when a vessel is in actual contact with it, or nearly so. The reason of this is that the Austrian military authorities were of opinion that, to be effective, a charge must be fired in very close proximity to a vessel's hull.

One advantage arising from a combination, in a single case, of the circuit-closer and charge, is the additional inertia thus obtained proportioned to the weight of the latter. The general tendency of any body floating in water, on being struck by a ship, is to move easily on one side, and thus to lessen the force of the blow; the greater inertia of the combined charge and circuit-closer is therefore in favor of the effective action of the circuit-closing apparatus.

Detached circuit-closer proposed by floating obstruction committee.

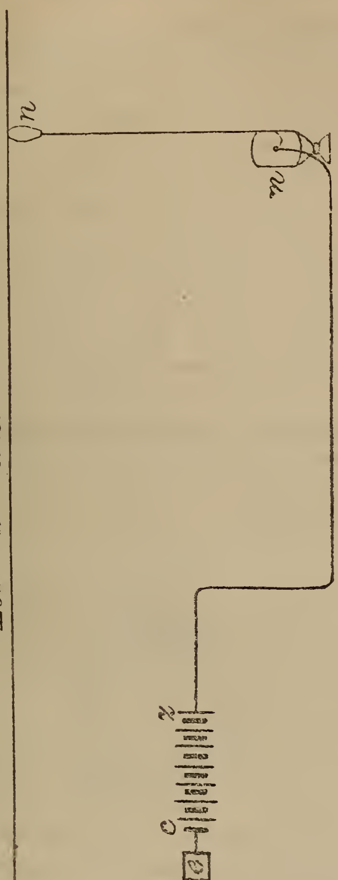
The floating obstruction committee have proposed a detached circuit-closer, trusting to the extension of the destructive effect due to the explosion of any given charge extending to a certain distance from it. What this distance is has yet to be definitely determined, but experiments prove that it is not limited to actual contact with the charge, though it diminishes rapidly in proportion to the increased cushion of water intervening, as the distance from the side of a vessel increases. There is no doubt that in a tidal harbor or estuary, a detached circuit-closer presents many advantages, one of which is that the position of the actual charge may be arranged so as to suit the ever-varying depths of water over it with greater facility, when the circuit-closer is detached from it. It is probable that neither detached circuit-closers nor those permanently combined with the charge can be universally adopted; measures have therefore been taken to design different cases for each combination. Mathieson's circuit-closer is readily adaptable to either.

Enemy would endeavor to render mines ineffective.

The first object of an enemy in attacking a harbor defended by submarine mines would be, if possible, to explode those mines, and thus render the ground in his front safe; or, failing to do this, to get hold of and carry off the circuit-closers, and, if possible, to dispose of the electrical cables in connection with them in such a way as to render the charges unexplodable; and as is it not desirable to throw away large charges upon boats and small craft, such as would be employed in the duty of searching for mines, means must be taken to retain the charges intact and effective, even should the circuit-closer be carried away.

Power of firing mine should be retained, if possible, after removal of circuit-closer.

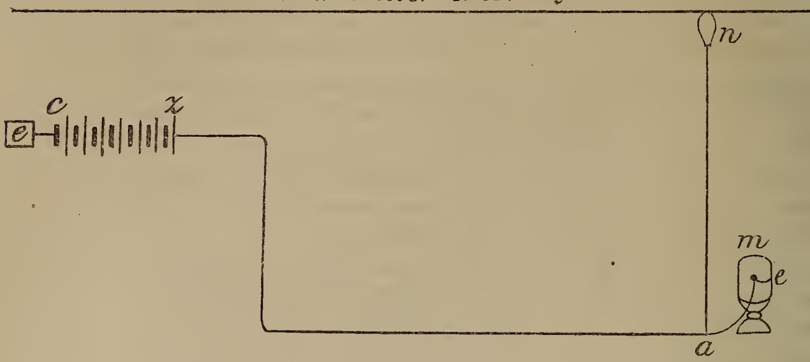
Should an enemy simply break away a circuit-closer, and allow the end of the electric cable to fall off, there would, of course, be no difficulty in still firing at will, if the fuse were arranged in circuit as in Fig. 88. Supposing the circuit-closer (n) removed, the fractured conducting cable would still, in most cases, be sufficient to pass the current to earth in the circuit of the battery (c z) being completed, and this operation could easily be performed within the testing-room. Under these circumstances the mine would remain as effective as ever, provided the means of ascertaining the position of a vessel existed. Supposing, however, that an enemy, knowing the arrangements prepared for his reception, were, before casting off the broken end of the conductor, after detaching the circuit-closer carefully to insulate the fracture, the charge (m) would, under such circumstances, be almost harmless. It might possibly be fired by induction with the frictional machine, as already described, if there were a sufficient length of conductor beyond the fuse and a high-tension fuse were used, but this would be a difficult and uncertain result to obtain.



Low water line. Fig. 88.

In order to obviate such a contingency a different combination has been proposed by Quartermaster-Sergeant Mathieson, R. E., which is well deserving of attention, from the great ingenuity displayed in all its arrangements. Fig. 89 shows the general design of the system. The electric cable passes direct from the battery (c z) to one pole of the fuse in the charge (m,) the other pole being directly connected to earth, and there is a branch to the circuit-closer (n,) starting from a point (a) between the battery and the fuse. In this case the circuit-closer is simply used as an indicator, and may be made to work a relay in a manner to be hereafter described. When in a state of rest the extremity of the cable, passing from (a) to (n,) is manifestly insulated, and it is evident that the charge (m) may be exploded at any moment at will, by simply completing the circuit of the battery (c z) in the testing-room. Let us now suppose that an enemy, knowing the system of firing adopted by the defenders, has got possession of the circuit-closer (n,) he would, under such circumstances, detach, and having removed the insulation from a considerable portion of the extremity of the conducting wire, he would throw it into the sea, so that the current, finding an easier path through the bare end of the wire than through the fuse, would pass almost entirely in

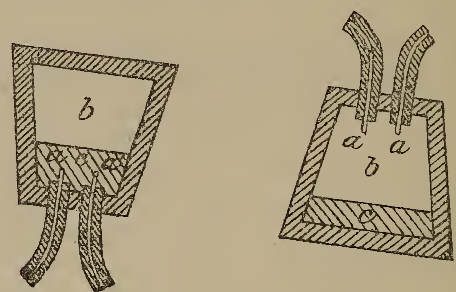
Low water line. Fig. 89.



Mathieson's disconnector.

that direction and not fire the fuse. The following arrangement would, however, prevent such a contingency. Fig. 90

Fig. 90.



shows in section a combination by which the two extremities (*a* *a′*) of a break in the electric cable, leading from the fork or branch in the vicinity of the charge, are introduced into an ebonite vessel (*b*,) so that, when held in an upright position, a small quantity of mercury (*c*) placed therein would complete the circuit. If the vessel (*b*) were inverted the mercury would fall down to its larger extremity, and the circuit would be broken. Should the vessel only fall over on one side the same effect would be secured, for directly the contact between the mercury and the two extremities of the wire (*a* *a′*) ceased, the electrical circuit would be broken, and the extremity (*a*) of the cable, to all intents and purposes, effectually insulated. If an enemy, therefore, were to get possession of a ciruit-closer attached to a cable arranged in this way, and cut and cast it off, under the supposition that he was connecting the circuit to earth and thus rendering himself secure, the falling away of the mercury would insure the insulation of the point (a,) and the mine (m,) Fig. 89, would still remain as efficient as ever.

A modification of the device above described, suggested by Lieutenant Anderson, R. E., consists in the substitution of a platinized metal ball in a platinized metalcup for the mercury. One of the wires is attached to each side of the metal cup, and the two sides of the cup, and consequently the points of the wires are insulated from each other. As long as the ebonite vessel remains upright, the ball completes the circuit between the two extremities of the wire, but directly it is turned over the ball falls out, and the two sides of the cup, one attached to each wire, being insulated from each other, the circuit would be immediately broken.

Disconnector designed by Lieutenant Anderson, R. E.

Suppose now that an enemy, knowing that an arrangement of the nature above described was used, were to get possession of a circuit-closer, he would carefully detach it, make the end of the wire bare, so as to complete the circuit to earth, and bury it, so as to keep the ebonite cup upright, and retain the mercury or platinized ball in such a position as to complete the circuit. To guard against such a contingency another arrangement has been suggested by Quartermaster-Sergeant J. Mathieson. He proposes to introduce an electro-magnet between the point (a,) Fig. 89, and the circuit-closer, the armature of which should be in connection with a spring, arranged as in the primary circuit of Rhumkoff's induction coil, so that it would make and break the circuit mechanically with great rapidity. With such a combination as this it is easily seen that every alternate instantaneous current would pass through the fuse in the mine (m) and fire it. With such arrangement it would not matter whether an enemy were to insulate the wire, after detaching the circuit-closer, or not, as the power of firing the charge at will would remain in the hands of the defenders under both conditions. It would not, however, be available for use with the frictional machine.

Electro-magnetic disconnector.

These disconnecting arrangements, in the form described, have none of them been sufficiently tried to enable a definite opinion to be given as to their practical use. They are, nevertheless, interesting, as illustrations of the general form of combinations which might be used to counteract an enemy's attempts to render a system of submarine mines ineffective. Should any modification of the branch system,

Further trials required.

shown in Fig. 89, be adopted, it is manifest that some disconnecting arrangement must be employed, in order to meet the contingency of a removal of a circuit-closer, and there seems to be no reason why one or other of the very ingenious expedients proposed may not be made capable of practical application.

There is no doubt that it would be a very great waste of power to fire large mines, of 500 pounds of gun-cotton, for example, at boats engaged in searching for them, and such boats might, relying on the immunity thus secured, carry on their operations with comparative boldness. In daylight it is probable that they might be kept off by the guns covering a system of mines, or by boats manned by the defenders; but at night, or in a fog, they might carry on their operations in comparative security as regards such means of defense; the question is, therefore, whether some plan might not be adopted to act as a deterrent without, at the same time, sacrificing the principal mine. It has been suggested, for example, that a small charge, sufficient to sink a boat without damaging the large charge, might be placed in the circuit-closer and arranged to be fired when that circuit-closer was touched. In order to secure this effect some such combination as the following might be adopted: A single fuse might be placed in the charge in the circuit-closer, the latter being connected, as shown in Fig. 89, with a branch circuit from the point (a,) while in the main charge a number of fuses might be placed in continuous circuit, or with a considerable electrical resistance, in the shape of a coil, or an ordinary lightning protector might be arranged between the point (a) and the fuses in the charge (m.) Now, if a battery sufficient to fire a single fuse were arranged in connection with a circuit so constituted, directly the circuit through the circuit closer was completed, by touching the latter the charge therein would be fired, and any small boat in its vicinity sunk or damaged, while from the great resistance introduced between the point (a) and the fuses in the main charge these latter would remain intact, but could still be fired by a considerable increase in the power of the firing-battery, or by the frictional or dynamo-electric machine, provided the end or the branch connecting the point (a) with the circuit-closer were insulated when blown off, and this could be effected by means of the mercury-cup or other arrangements already described.

Arrangement of small charges in circuit-closer.

Such a combination, however, must be attended with difficulties. In the first place, it becomes necessary so to balance the respective resistances of the fuse in the circuit-

Difficulties attending use of charge of circuit-closer.

closer and those in the main charge, as to render the simultaneous explosion of the two charges impossible. To do this a largely preponderating resistance must be given to the circuit in the main charge, and in order subsequently to fire the latter with certainty a large increase of battery-power would be necessary. This adjustment of resistances in the fuses, as well as subsequently in the battery-power, would at all times be a delicate operation and require the greatest care. Again, the circuit-closer must be at such a distance from the mine itself that the explosion of the charge contained in it shall not damage the case or connections of the latter. A charge of 5 pounds of gun-cotton would probably be sufficient to sink any boat, but it would be necessary to ascertain how far such a charge must be placed from others in its neighborhood to insure their safety. Again, it is not desirable to expend the circuit-closer attached to a mine, except as a last resource, because as soon as it is gone the mine can only be fired by judgment. It is a choice of evils, however, and preferable to allowing an enemy to carry off the circuit-closer without damage to himself.

In order to determine whether such a system can be practically worked, carefully conducted experiments are necessary.

Advanced line of contact mine for defense against boats.

Another mode of keeping off boats would be to place a line of small contact charges in advance of the main line, a line of supports as it were. There can be no doubt that the sinking of a few boats would produce a very salutary effect as regards the defense.

If these charges were sufficiently large to damage, if not to sink, vessels of any size, a further advantage would accrue. Contact charges of 100 pounds of gun-cotton would not be very bulky to handle, and would no doubt be effective in an advanced system of this sort, even against vessels of the largest size; and if exploded by the smaller craft their loss would not materially affect the main defense.

CHAPTER XII.

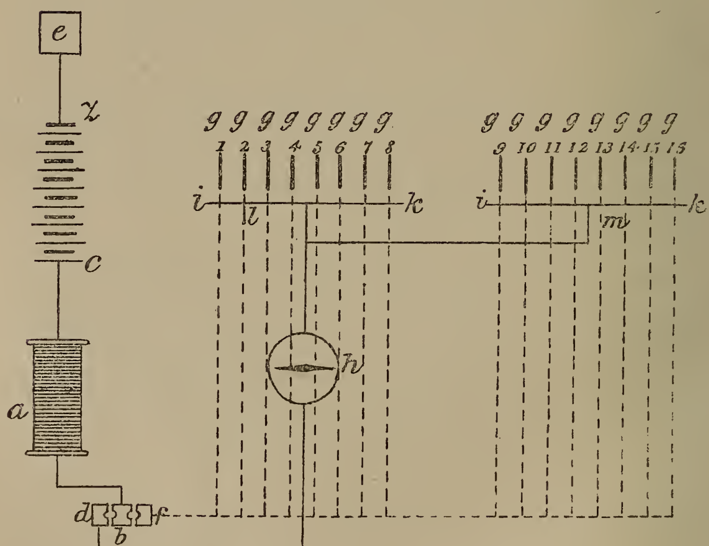
ELECTRICAL TESTING-TABLES.

We now come to the consideration of testing-tables, or, in other words, the mode of arranging the wires in connection with the charges in a convenient form in the electrical-room within a fort. When a very large number of wires must be introduced into a fort, it becomes necessary to arrange them in such a manner that they shall be easily identified, and that the operations of testing and firing, &c., may be conducted with the greatest amount of simplicity. Several forms of tables have been designed with this object in view. The Austrian government exhibited several instruments of this nature at Paris in 1867. One of these, which gives a good general idea of their system, may be described as follows:

Austrian testing-table.

Its design is shown in Fig 91; (*c*, *z*) represents the bat-

Fig. 91.



tery with one pole to earth at (*e*,) and the other in connection with an intensity coil (*a*,) through which the current passes to the contact plate (*b*.) When it is desired to put the system of mines, in connection with the table, in a state of preparation to be fired by the contact of a vessel, a plug is inserted between the contact plates (*b* and *f*,) and the current passes through and electrically charges the conducting wires, shown by dotted lines, connecting the charges with the battery, through the several binding screws (*g*, *g*, *g*, &c.;) as soon, therefore, as a vessel makes contact, the circuit is completed, as already described, (see page 186,) and the charge fired.

Test to discover an exploded charge.

It then becomes necessary to ascertain which particular mine of the system has been exploded; for this purpose the plug is placed so as to connect the contact plates (*b* and *d*,) the current is then passed on to the testing circuit, shown by the firm lines, in which a galvanometer, (*h*,) is placed, and which is in connection with two metal bars (*i k*, *i k*;) on these bars, and slipping freely along them, are metal keys (*l* and *m*,) sufficiently long to complete the circuit from them to the binding-screws (*g*, *g*, *g*, &c.)

In a state of rest these keys are thrown back into the position in which (*l*) is shown, and no current passes beyond the bars (*i k*, *i k*;) when, however, the key is turned over into the position in which (*m*) is shown, the current passes into and electrically charges the insulated wire communicating with the mine; in this way each of the binding-screws (*g*, *g*, *g*, &c.) is put in circuit in succession, and on arrival at that lately in connection with the charge that has been fired, the galvanometer will be deflected, as the circuit will be completed by the broken end of the conducting wire, through the water, and back by the earth-plate to the battery.

Insulation test.

In order to test the insulation of the electric cables connecting the mines with the battery, (the firing circuit,) it is only necessary to place the plug between the contact-plates (*b* and *d*) and touch each of the binding-screws (*g*, *g*, *g*, &c.,) in succession with the testing key; should the galvanometer (*h*) remain stationery, the insulation is good; but should a leak exist, the current passing through it would act on and deflect the galvanometer, indicating the particular line in which it exists, and, roughly, the extent of the leak in proportion to the deflection shown; should the leak be considerable, the defective cable should be at once detached, as the current lost through it might so diminish the working power of the battery as to prevent its firing any of the fuses attached to the group in connection with the same battery. For the same reason the conducting wire of an exploded charge should be at once disconnected from its binding screw. By the above arrangement the insulation of each line can be tested at any moment required.

To render a channel safe.

In order to make the channel safe for a friendly vessel, it is only necessary to remove the plug from between the contact plates (b and f) and insert it between (b and d,) or leave it out altogether; this disconnects the battery from the firing circuit.

Great care should be taken to keep the metal keys (l and m) always thrown back, except at the moment when required for use in testing, in order to avoid the chance of accidents.

Separate testing-battery generally used.

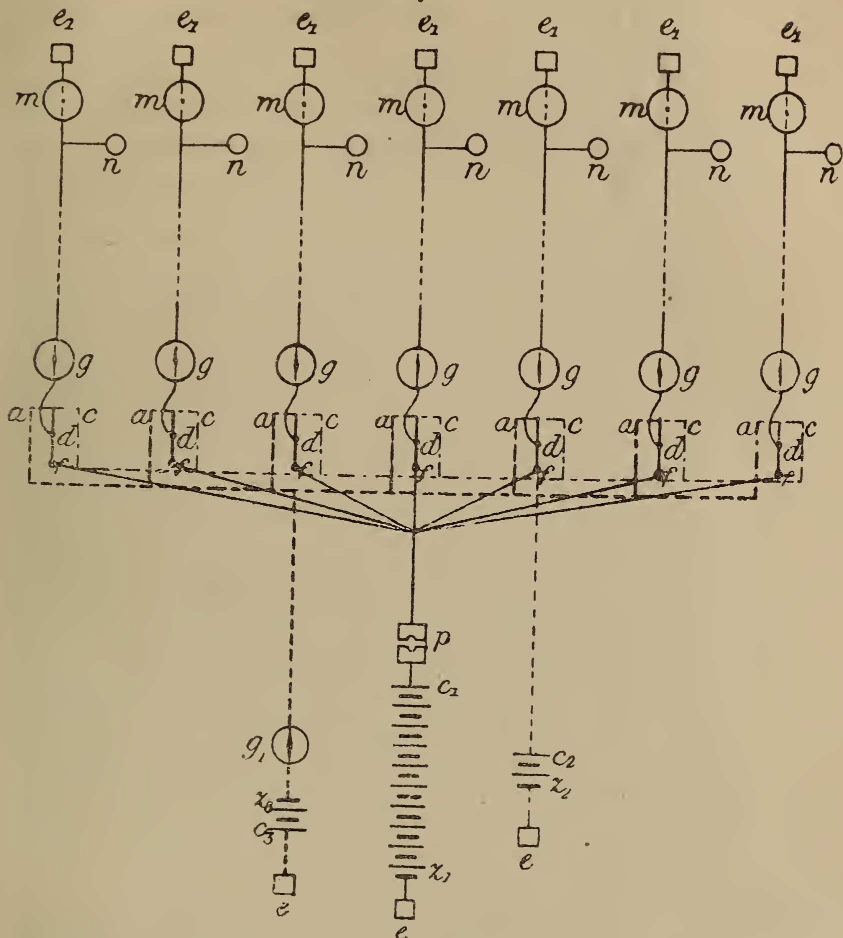
It would be convenient in most cases to employ a separate battery for testing; this might easily be done by arranging a special battery in connection with the galvanometer and testing circuits. Should hostile vessels be in the act of passing over the system of mines, it would not do to detach the firing battery for testing purposes, and yet it might become necessary to ascertain which electric cable should be detached in the event of a charge being fired; in such a case a special testing-battery would be indispensable, and in some of the instruments exhibited such a battery was provided. To test the insulation of the electric cables, however, which would, except on an emergency, always be done when an enemy's vessel was not in the vicinity of the mines, the greater electro-motive force of the firing-battery would be advantageous, a smaller leak in an electric cable would be more readily discovered; and as that cable would, in actual work, always be charged with the full power of the firing-battery, the value of its insulation to resist an electrical charge at such a high potential would be an important point to determine. The fuses being entirely out of circuit until the moment of action arrives, no danger of a premature explosion need be apprehended; if a fuse were in such a position as to be fired prematurely, it would be exploded, in connection with the firing-circuit, independently of the operation of testing the insulation of the cables.

The form of testing-table described is that used in connection with the Austrian self-acting system of contact mines. Other combinations adapted to various conditions, such as firing by judgment, &c., were also exhibited.

Testing-table where firing-battery is put in circuit by hand.

A simple arrangement of testing-table is shown in Fig. 92. In this combination a series of metallic points (d d d, &c.,) are in metallic connection, through a series of galvanometers (g g g, &c.,) with the line wires, fuses (m m m, &c.,) and earth-plates (e_1 e_1 e_1, &c.) The galvanometers (g g g, &c.) are not very sensitive, just sufficiently so to indicate directly the passage of such a current as would be produced by closing the circuit of a battery of two or three of Daniell's cells, as (c_2 z_2,) by the action of a circuit-closer, one of a set placed on a series of branches, as (n n n, &c.,) so as for the moment to cut out the fuses (*m m m*, &c.) in the manner already described. Another series of contact points (*f f f*, &c.) are in connection with one pole of a firing-bat-

Fig. 92.

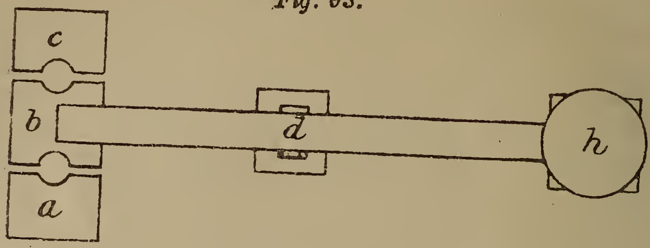


tery (c_1 z_1,) the other pole being to earth. In order to fire any of the mines at will, it is evident that it only remains to close the circuit of the battery (c_1 z_1) by completing the connection between the points (*d d d*, &c.) and (*f f f*, &c.;) this is effected by the simple depression of a key which is arranged to be done by hand. Another set of contact points (*a a a*, &c.) are in connection, through a very delicate galvanometer (*g*,) with a testing battery (c_3 z_3.) Fig. 93 shows an enlarged plan and elevation of a firing-key. Contact plugs are provided, which, in their ordinary position,

Testing and signaling circuits.

would remain between the contact plates (*b* and *c*;) and the front arm of the firing-key being in connection, when in a state of rest, with the point (*b*) and pivoted on the contact

Fig. 93.



point (*d*,) the current of the signaling battery (c_2 z_2) would be free to pass through the contact points (*c b*) and (*d*,) and along the line wire; and the completion of any individual circuit, through its own circuit-closer, would be indicated on its corresponding galvanometer of the series (*g g g*, &c.) In order to test any individual line and fuse it would only be necessary to remove the contact plug from between the plates (*b* and *c*) and insert it between (*a* and *b*,) by which operation the signaling-battery (c_2 z_2) would be thrown out, and the testing-battery (c_3 z_3) and galvanometer (*g*) would be thrown into the circuit, and the deflection of the latter would indicate whether all was right as regards insulation and conductivity. During this process of testing, it will be observed that the line and charge tested would only be thrown out of the ordinary conditions; the remainder of the charges would remain in *statu quo* and be ready to indicate that a vessel was within the radius of destruction at any moment. The ordinary galvanometers (*g g g*, &c.) would at all times give a rough indication of the effectiveness or otherwise of the line and fuse.

Firing-key.

The key employed for firing is precisely of the form used with the ordinary Morse telegraph instrument. In a state of rest the front contact is held down on the plate (*b*) by means of a spiral spring (*s*,) and to fire it is only necessary to depress the handle (*h*) and make contact with the plate (*f*,) and, the key being pivoted on the point (*d*,) the effect of this depression would be simultaneously to break contact with the point (*b*.) Thus, the firing-battery would be thrown into circuit and the signaling-battery cut out simultaneously by the depression of the key.

To detach circuit of expended charge.

When any given charge has been fired, it would only be necessary to remove the plug from between the plates (*b* and *c*) in order to cut off the conducting cables which would otherwise interfere detrimentally with the action of the intact circuits, and which, after a charge has been fired, should be detached with as little delay as possible. If the circuit were cut off in this way the line wire itself would be disconnected from the system at leisure, an operation which it might not be convenient to perform immediately, in the heat of action with an enemy's vessels in the act of passing over the mines. In this system it will be observed that the firing battery is only thrown into the circuit at the wish of the operator, and that no mine can be exploded without the depression of its corresponding key. In order, however, to render the system perfectly safe, and to guard against the accidental depression of the key, which would produce a premature explosion, a plug has been provided between the firing-battery and the apparatus, at the point (*p*;) when this plug is out the firing-battery cannot be accidentally thrown into circuit.

The construction of a testing and firing table of this nature is so simple that it could be very easily put together by an ordinary workman, and the materials of which it is composed are obtainable anywhere. The mines in connection with it are capable of being fired by judgment, and, for this purpose, would only require the addition of signaling apparatus, somewhat similar to that described on page 186 and those following, to complete the system, which could thus be used for firing by intersection when the position of the mines was clearly visible, while capable of being used at night or in a fog, on the signal being made by a vessel in contact, as first described. It is, however, dependent for effective service upon the vigilance and dexterity of the man in charge, which is a defect common to all systems in which firing by judgment is employed.

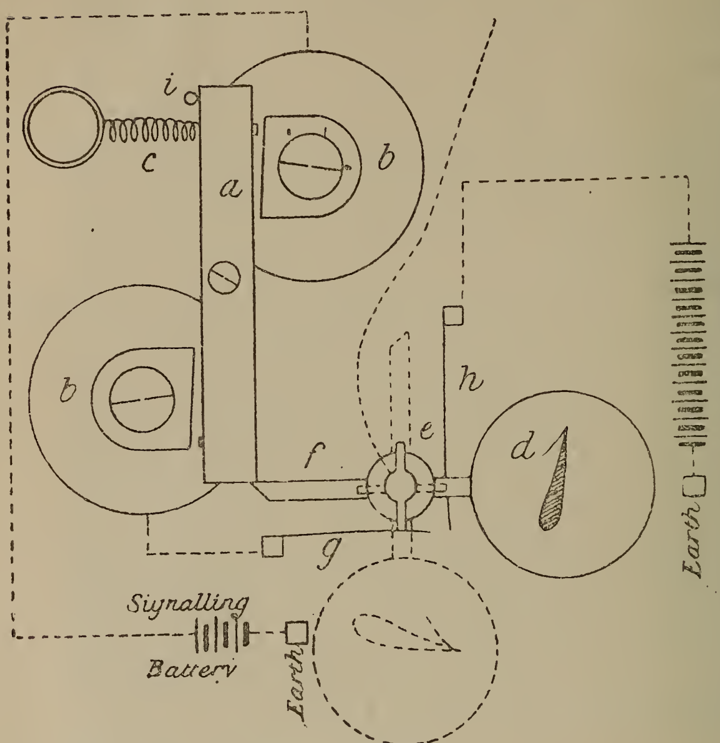
Construction of such a test-table very simple.

This arrangement of testing-table may be used either on the circuit-closing or circuit-breaking system. With the circuit-closing system it would be connected precisely as shown in Fig. 89; with the circuit-breaking system, the circuit-breaker would be placed beyond the fuse, and this signaling current, passing through it, would keep the galvanometers deflected on a vessel striking any one of them, the action on the galvanometer would cease, and its needle would fall back to the position due to terrestrial magnetic attraction, and this motion of the needle would indicate the fact of the ship's contact.

May be used either with a circuit-closing or circuit-breaking system.

The system above described is so arranged as to indicate a vessel in contact with a circuit-closer, and as in many cases it may be convenient or even necessary to perform the operation of throwing in the firing-battery without the aid of a personal operator, the following self-acting system has been devised: By making the apparatus purely self-acting, all chance of error, consequent upon the inattention or want of dexterity of the man in charge, is, of course, eliminated, and this may be done without complicating the connections of the instrument to any considerable degree.

Fig. 94.



Shutter-signaling and firing-apparatus.

Fig. 94 shows a diagram of the arrangements by which a vessel striking a circuit-closer may be made to shift, by means of a relay, the conducting cable from the signaling to the firing-circuit and explode the charge; called the "shutter-signaling and firing-apparatus."

(*a*) is an armature, working on a pivot between the two horns of an electro-magnet (*b b*,) and held in position by a spiral spring (*c*;) the latter is in connection with a regulating screw, by which more or less pressure may be brought to bear in an opposite direction to that of the attractive action of the electro-magnet. A small stud (*i*) regulates the distance to which the armature may be drawn back; (*d*) is a shutter, on which a reference number is clearly indicated, attached to a lever pivoted at the point (*e*,) the inner arm of which is just long enough to catch under the point of the armature (*a*;) when a current is passed through the coils (*b b*) of the electro-magnet, the armature (*a*) being attracted, the lever attached to the shutter is released, and the latter falls by its own weight into the position shown by the dotted lines. The pivot (*e*) is formed of an ebonite cylinder, with a metal center, from which latter two metal points project through the ebonite. When the lever (*f*) is held up by the armature (*a*,) one of these metal points projects downward and is in contact with a metal spring (*g*,) which forms a portion of the circuit of the signaling-battery. When the shutter falls into the position indicated by the dotted lines, the other metal point, projecting through the ebonite cylinder, comes in contact with a metal spring (*h*,) which forms a portion of the circuit of the firing-battery, while the connection between the spring (*g*) and its corresponding point is broken in consequence of the revolution of the pivot bringing the ebonite part of the cylinder upon it. The metallic portion of the axis (*e*,) being permanently connected with the line wire terminal, and through it with the electric cable and fuse in the charge, it is easily understood how the action of dropping the shutter throws the firing-battery into circuit, and simultaneously cuts out the signaling-battery and explodes the mine. The points of the metal projections on the pivot (*e*) and the faces of the springs (*g* and *h*) are platinized, to prevent oxide and insure good metallic contact between the parts. The armature (*a*) is prevented from coming into actual contact with the horns of the electro-magnet, by two small studs. The object of this is to prevent any effect of residual magnetism which might interfere with the rapidity of action of the armature when released and drawn back by the spring (*c*.)

Constitution of signaling-battery.

The signaling-battery should be so constituted as to be capable of working the electro-magnet effectually when the circuit is closed direct to earth, and attracting the armature with sufficient force to release the lever (*f*) with certainty, and yet not so powerful as, by the continuous passage of the current generated by it, to fire the fuse in the mine. Plenty of power may be given to this battery, when used in connection with a platinum fuse, without any chance of accidental explosion from this cause, but when Abel's fuse is employed it is necessary to be very careful in order to guard against such a contingency.

Testing arrangements.

The testing arrangements are precisely the same as those shown in Fig. 93; it is, however, necessary to disconnect the firing battery in this latter combination, when testing, as any accidental dropping of the shutter would produce a premature explosion.

Firing-battery. The firing-battery should be suited to the nature of the fuse employed, and should possess considerable excess of power in order to overcome accidental defects, such as increased resistance in the connections or defective insulation in the electric cable in connection with the mine. A battery, just sufficiently powerful to fire a fuse on shore, with the electric cable, &c., in circuit, but not submerged, would not be unlikely to fail after the cable had been immersed in sea-water; in such a case it is recommended that the battery power determined by such an experiment on shore should be doubled for actual work.

Mode of action of the apparatus. If used in connection with a group of mines, arranged with circuit-closers on the branch system, as shown in Fig. 89, the mode of action of the apparatus would be as follows: while at rest the current of the signaling-battery would be divided between the several fuses in circuit; each of these fuses, possessing a very high electrical resistance, would, by its presence in the circuit, prevent the battery current, passing the coils of the instrument, acting with sufficient force to form an electro-magnet, sufficiently powerful to overcome the resistance of the spring (*c*) and draw the armature (*a*) over to it. Directly, however, one of the circuit-closers on a branch was struck, the whole of the fuses would be, for an instant, practically cut out of circuit, because the resistance of those fuses, compared with that of the earth connection of the circuit-closer, is so great that practically the whole current would pass through the one particular circuit-closer that had been struck. When this took place the comparatively feeble current of the signaling-battery would therefore practically be passed through a single electro-magnet, (that in connection with the circuit-closer struck,) and would consequently act with sufficient force to attract the armature, which it had not power to do when divided between the several fuses (each possessing a very high electrical resistance) in the group. The armature (*a*) being attracted, the lever (*f*) would be released, the shutter would fall, and the firing-battery would be thrown into circuit, through the spring (*h*,) and the metal point in contact with the pivot (*e*;) the coils of the electro-magnet being simultaneously cut out of circuit, as already described, the current of the firing-battery, having a direct metallic circuit through the fuse to earth, would pass instantaneously through and fire the mine. The action of the whole is so rapid that practically the instant a vessel struck the circuit-closer the mine would be fired.

Experiment to test the stability of shutter-signaling and firing-apparatus during concussion produced by firing guns.

In order to test the capabilities of the shutter arrangement for standing the concussion of heavy guns fired in its vicinity, experiments were tried at Sheerness with a working model constructed on the principles above described. It was placed on the parapet of the work, at a few yards distance, during artillery practice with a seven-inch muzzle-loading rifled gun; subsequently advanced close to the muzzle of the gun, and finally placed on the gun platform, and the only case in which the shutter fell was when the whole apparatus was knocked over by the recoil of the gun. The instrument was made to work by closing the circuit electrically between each round, in order to ascertain that its stability was not caused by any undue tension of the regulating spring.

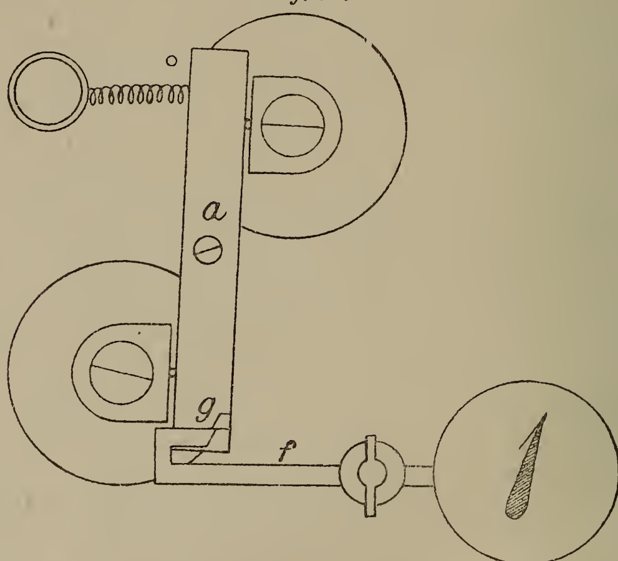
It would seem therefore that, with moderate care, there would be no danger of a shutter dropping by concussion, but experience has proved that it is necessary to balance the force of attraction, exercised by the electro-magnet, against the mechanical effect of the spring, with some degree of nicety, as in guarding against an accident due to the falling of a shutter, one is sometimes apt to apply the spring too strongly.

Several modifications of the shutter-signaling apparatus have been made, but before any one of them can be considered sufficiently perfect to be received into the service, further experiments to determine their action when subjected to the effect of concussion, produced by the firing of heavy guns, must be made. Though the experiments tried at Sheerness were sufficiently conclusive as to the particular specimen tested, it is necessary that the instrument should be thoroughly tried under every possible condition which might occur in actual work. The stability of the shutter is a point vitally essential to its use, as in many instances it would be impossible to put it in such a position as to be out of reach of concussion. The question of the stability or instability of the shutter involves a condition of balance between the force exerted by the regulating spring pulling the armature in one direction, and the attraction of the electro-magnet acting in the opposite direction. In the circuit-closing system the spring must hold the armature sufficiently firmly to prevent the accidental fall of the shutter by concussion, while the battery must be so constituted as to act effectually when the circuit is closed. In the circuit-breaking system the battery must, on the contrary, hold the armature steady, while the spring ought to be able to act with sufficient force the moment the circuit is broken. It is not desirable to draw absolutely definite conclusions from the single experiment referred to, even though it was a very severe one on the instrument, and the conditions were infinitely less favorable than those which would ever occur on service.

Shutter-signaling apparatus for circuit-breaking system.

When the circuit-breaking system is used with the shutter-signaling apparatus, the action of the armature in releasing the lever must be reversed; that is to say, that when the current is passing and the armature attracted to the horns of the electro-magnet, the shutter must be held up, and when the current ceases and the armature is drawn back by the action of the spring, it must release the lever and allow the shutter to fall. This is done by the arrangement shown in Fig. 95. The extremity of the lever (*f*) is bent up and passes round and under a projection (*g*,) attached to the lower portion of the armature (*a*;) when,

Fig. 95.

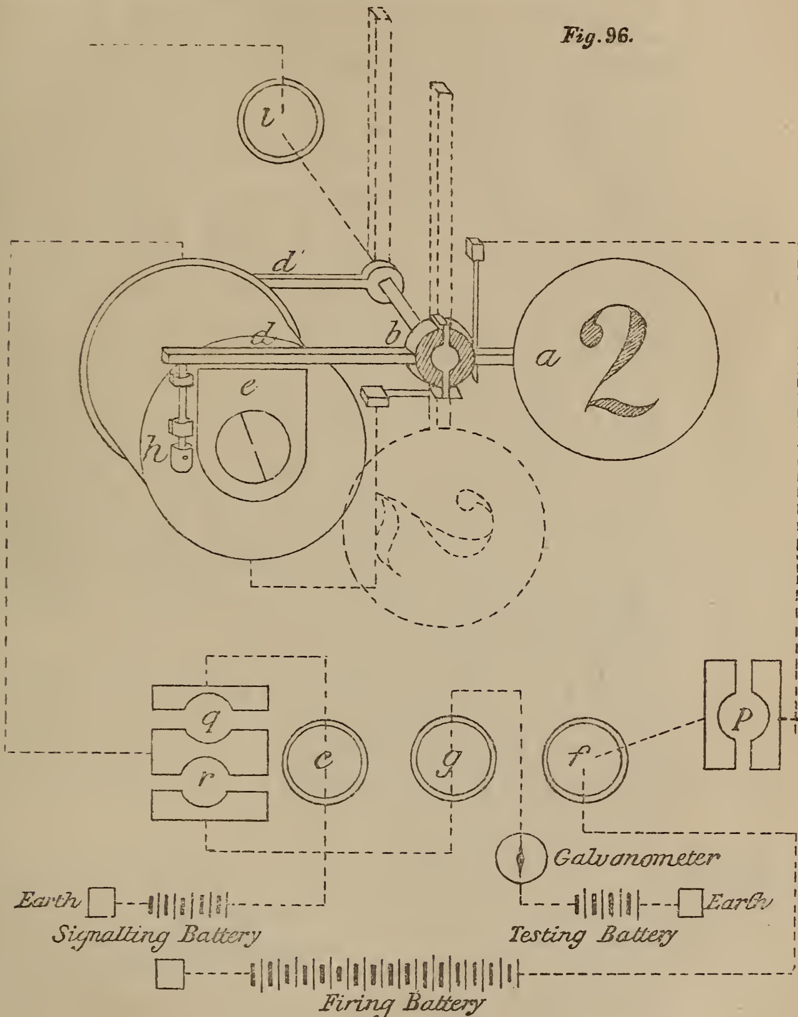


therefore, the current ceases for a moment and the armature falls back, carrying the projection (*g*) with it, the lever (*f*) is detached and the shutter becomes free to fall. The projection (*g*) and the extremity of the lever (*f*) are made wedge-form, in order the more readily to become disconnected from each other when the apparatus is put in action.

Another form of shutter-signaling apparatus, designed for use with a circuit breaker, is shown in Fig. 96. In this instrument the shutter (*a*) is pivoted on a metal axis (*b*) with two projections, insulated as before, with ebonite. The electro-magnet (*e*) is, in this case, composed of a single coil, and two levers, (*d*) and (*d'*,) one attached to each extremity of

Shutter signalling apparatus with straight electro-magnet.

Fig. 96.



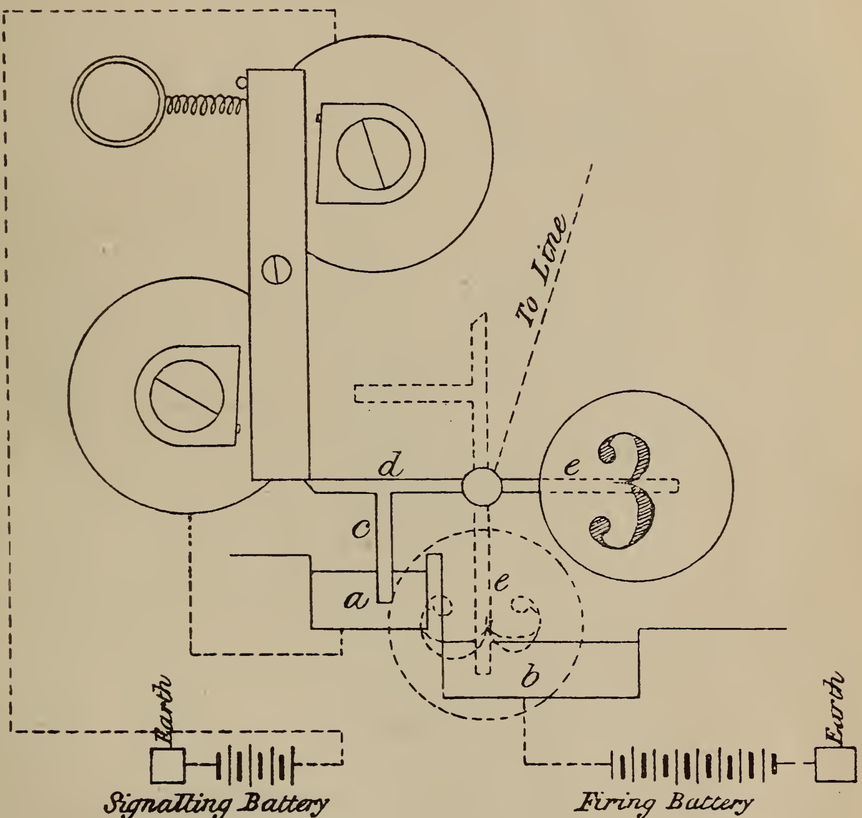
the axis (*b*) on which the shutter is pivoted, are so arranged that they may be attracted to and held by the electro-magnet as long as the current is passing, (*d*) being held by the front and (*d'*) by the rear point of the electro-magnet. A small capstan-headed screw (*h*) regulates the distance between the electro-magnet and the armature; it prevents absolute contact, which might be detrimental in the case of residual magnetism, and by it the sensitiveness of the apparatus may be regulated. When the current ceases the shutter falls down into the position shown by the dotted lines, and, the springs and connections being precisely similar to those already described, the firing-battery is thrown into circuit as before. Fig. 96 shows the connections of the apparatus; (*f*) is the terminal to which the firing-battery must be attached, (*g*) the terminal for the testing-battery and galvanometer, (*c*) the terminal for the signaling-battery, and (*l*) for the electric cable to connect the fuse in the charge. A plug (*p*) provides the means of rapidly detaching the firing-battery; this latter is entirely out of circuit, and no mine in connection with the group can be fired unless the plug (*p*) is inserted between the two brass plates provided for it. A second plug is used to connect the signaling-battery by insertion between the brass plates provided for that purpose; if removed from (*q*) and inserted at the point (*r*,) the signaling-battery is cut off from the circuit and the testing-battery is thrown in. When the plug (*q*) is taken out for testing purposes there would, of course, be a cessation of current through the coils of the electro-magnet, and the shutter would fall down and complete the circuit of the firing-battery; to guard against such an accident it would be necessary, therefore, when testing, previously to remove the plug (*p*.)

With the exception of the action of the electro-magnet in dropping the shutter being the reverse of that previously described, that is to say, dependent upon the cessation of the current and not on its action, the mode of operation of this apparatus is precisely similar to that already given, and need not therefore be again described.

Shutter signaling-apparatus with mercury connections.

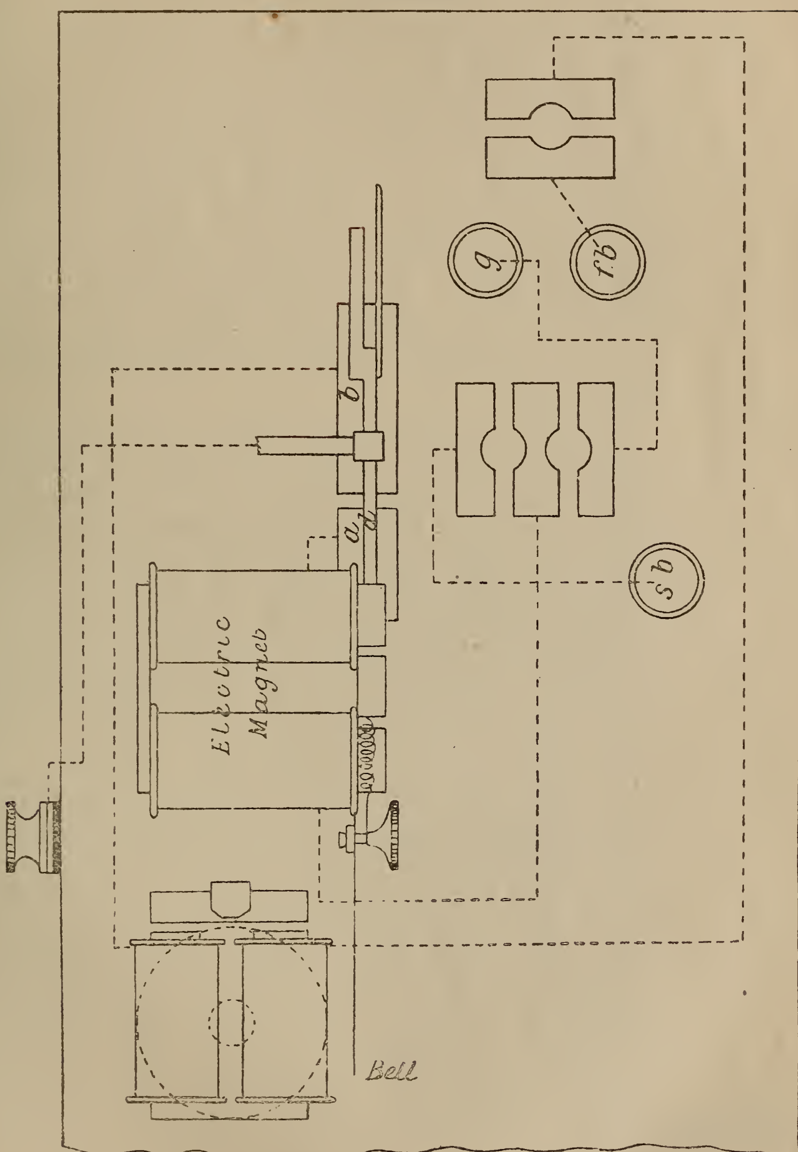
Another form of this instrument is shown in Fig. 97. Its armature, electro-magnet, regulating spring, stud, shutter, and attached lever are precisely similar to those first described, (see page 226,) but the connections are made by two mercury cups, (*a*) and (*b*.) When the lever is horizontal and the shutter drawn up and ready for action, the circuit of the signaling-battery is completed through the mercury-cup (*a*,) along an arm (*c*) projecting downward from the lever (*d*,) and thence to the shutter-pivot and line terminal as before. When the shutter is down, as shown by the dotted lines, another arm, (*e*,) a prolongation of the lever (*d*,) falls into the mercury cup (*c*,) which latter is permanently connected with the firing-battery. The object of the mercury-cups is to get rid of the springs in the original design,

Fig. 97.


To Line
d
e
c
e
a
b
Earth
Earth
Signalling Battery
Firing Battery

electrical circuits, dependent on the pressure of spring, being always liable to interruption from dirt or oxide intervening between the points of contact. There would be much less danger of such a contingency if mercury-cups were used. Fig. 98 shows a plan of the apparatus; (*f b*) is the firing-battery

Fig. 98.



terminal, (*s b*) the signaling-battery terminal, and (*g*) the testing-battery and galvanometer terminal. These are connected with brass plates, as shown by the dotted lines, and plugs are provided, as before, for altering the connections. There is an electrical bell in the firing circuit to give notice by striking when a mine has been fired.

Shutter-signaling apparatus combined with firing keys.

The shutter-signaling apparatus may be so arranged as to be worked on the circuit-closing system, by a combination of firing-keys, in connection with observant stations, in any of the systems described at page 186, and those following, (Figs. 78, 79, and 80.) It would only be necessary to connect a battery of similar constitution to the signaling-battery, so that its circuit might be closed and current passed through the coils of the electro-magnet of the shutter apparatus, by means of the depression of firing-keys, and the shutter, corresponding to the particular mine to be fired, would thus be released at the proper moment and the firing-battery thrown in. In this way a system might readily be used, if required, for firing by intersection when the position of the mines are distinctly visible, while a simple change of connections would render itself acting at very short notice.

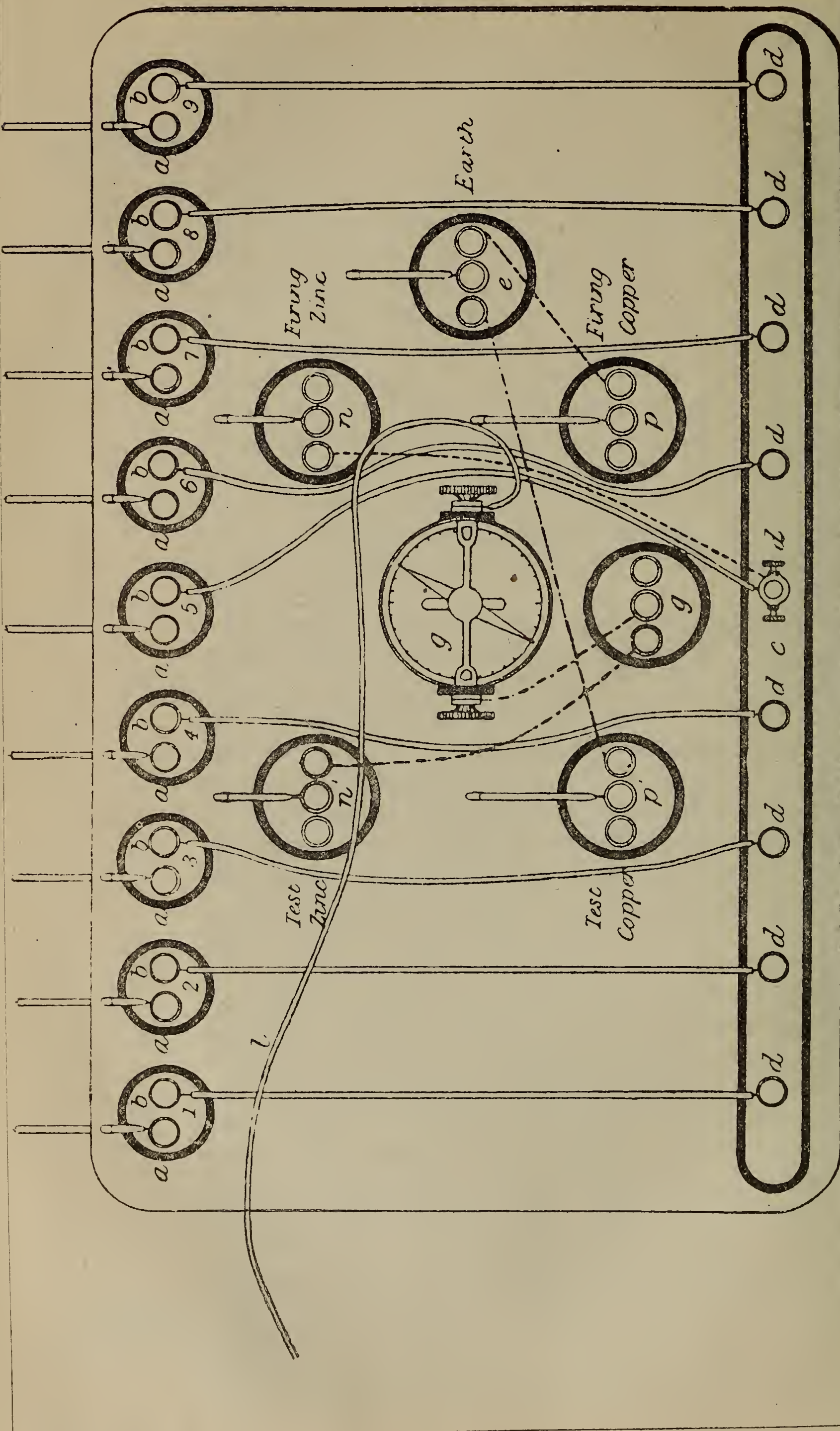
Should the circuit-breaking system be used, the combination would not be so simple. The visual circuit-closing system is dependent, in two out of three of the cases described, (Figs. 78 and 80,) on the closing of the circuit at two distinct points, while the breaking of the circuit at one point would cause the shutter to fall. If, therefore, a circuit-breaking combination were used, it would be necessary to arrange an entirely separate system on the circuit-closing principle for signaling; in this way the number of a mine might be readily indicated to an operator, and he might throw down the shutter by hand.

If a system of firing by intersection, combined in this way with a self-acting system, were used, the observing-stations would frequently be some distance from the testing-room; they (the observing-stations) ought to be, if possible, well clear of the smoke of guns in action, while the testing-room ought to be within a fort and in a bomb-proof casemate, well covered from an enemy's direct and vertical fire. It ought not, in point of fact, to present any opening in the direction of the enemy's guns. There would, however, be no difficulty in arranging a combined system under such conditions, either for the circuit closing or breaking system.

Arrangement of shutter-signaling apparatus in box.

The shutter-signaling apparatus may be conveniently arranged in a compact form, with a long box to contain the coils, which box should be made to shut up and lock, to prevent interference by unauthorized persons. The battery

Fig. 99.


Earth
Firing Zinc
Firing Copper
Test Zinc
Test Copper
a
b
c
d
e
g
l
n
p
n'
p'
1
2
3
4
5
6
7
8
9

terminals, brass plates, plugs, &c., should be placed on a board in front and outside the box itself, so as to be accessible at all times. The coils of the electro-magnets may be conveniently placed side by side; in this way six coils, with their necessary terminals, brass connecting-plates, &c., would occupy a space of 30 inches in length, 9 inches in breadth, and 7 inches in height. The bell would stand 6 inches high over the top of the center of the box.

A form of testing and firing table has been designed in the chemical department, Woolwich, adapted for a self-acting system of mines, the general arrangement of which is shown in Fig. 99. The electric cables, in connection with the mines, having been brought into the fort, are each attached to a series of screw-plugs, inserted into perforated metal plates insulated by ebonite rings (*a a a*, &c.,) which latter are numbered to correspond with the number of the mine or system of mines to which each belongs. A second series of screw-plugs (*b b b*, &c.,) in metallic connection with (*a a a*, &c.,) is arranged to receive a series of insulated wires, connecting the electric cables with a metal plate (*c*,) by means of a series of binding-screws (*d d d*, &c.) This metal plate (*c*) is permanently connected with the firing-battery; if, therefore, a vessel were to strike one of the circuit-closers of the system, the circuit of the firing-battery would be completed through the fuse and the fuse would be fired. The positive (copper or carbon) pole of the firing-battery is connected with the plate (*p*,) containing three holes for screw-plugs, which are brought into metallic connection by it; the negative (zinc) pole of the battery is connected with a similar plate (*n*.) Another insulated plate (*e*,) made to receive three plugs, the center one of which is connected to earth, is placed in a convenient position on the table to facilitate such changes of connection as may be required in using the apparatus; three holes are supplied in each case, so that one or more connections may be made at each of the points (*p n e*) if required, as it may be necessary to use more than one such connection at a time in testing the condition of the lines. When arranged for action, the positive pole (*p*) of the firing-battery is connected to (*e*,) and the negative pole (*n*) to the plate (*c*,) as shown by the dotted lines. The positive (copper) pole of the testing-battery is connected by means of a screw-plug with the plate (*p′*,) and the negative (zinc) pole with the plate (*n′*,) two other screw-plugs in each case being, as before, disposable for any required connections. Another insulated plate (*g*) is in connection with one binding-screw of an astatic galvanometer (*g′*) placed in a

Woolwich testing and firing table.

convenient position on the table, while an insulated wire, (*l*,) long enough to reach to any one of the screw-plugs of the combination, is attached to the other terminal of the galvanometer. The positive pole (p') of the testing-battery is permanently connected for work with one of the earth terminals at (*e*,) while the negative pole (n') is connected with one of the terminals at (*g*.) The whole object of these numerous binding-screws is to give facility for changing the several circuits with the least possible delay.

Use in testing.

In order to test any one of the electric cables for insulation, conductivity, or for any other purpose, it would only be necessary to disconnect it for the time from the firing circuit, by removing the connection between the screw-plug (*b*) and the plate (*c*,) and to insert in its place the wire (*l*;) the testing-battery would thus be put in the circuit, through the galvanometer, with the particular line to be operated upon, and its efficiency as regards insulation, conductivity, &c., indicated by the movement of the needle of the instrument.

Arrangements for testing firing-battery.

To test the condition of the firing-battery, Mr. Abel proposes to use a small set of resistance-coils in connection with a thermo-galvanometer or bridge, in which he proposes to place a definite short length of fine platinum wire of known electrical resistance. The working power of the battery would be tested by the fusion of the thin platinum wire through a given electrical resistance, as indicated by resistance-coils put in circuit, and a practical test of its efficiency would thus be obtained with great facility. This test would of course only be applicable in the case of a battery possessing the power to fuse a fine platinum wire, and it would be necessary actually to fuse and not to simply heat the wire more or less red, in order to obtain definite knowledge concerning the battery, as previous to actual fusion no definite information as to the degree of heat produced by the battery could be obtained by this means, as a measure of its working powers. To test a battery which would not fuse a short length of fine platinum wire, some other means must be adopted, but the same kind of information might be obtained by firing an ordinary tension fuse, of known resistance and through a known resistance as indicated by the resistance-coils. The battery power required to fire a tension fuse would not perhaps be determined within such small limits as that necessary to fuse the platinum wire, but it would answer perfectly well for practical purposes. Whether the platinum or tension fuse were employed, it would not do to rely on the results of such an experiment to determine absolutely the number of battery-cells to be used in practice. If a certain number of cells, tried in this way, just fired the fuse through a resistance equivalent to that of the electric cable, &c., it would be desirable in practice to double that number of cells. It must be remembered that the conditions in the experiment are always far more perfect as regards insulations, &c., than can ever occur in practice, where all sorts of deteriorating influences must necessarily exist to mar, at least in a degree, the perfection of the combination.

The resistance coils and connections for this test must be suited to the nature of the firing-battery used, for example, thick wires in the resistance coils if a quantity battery is employed, and fine for a battery of high electromotive force. The whole might be arranged in any convenient position on the testing-table.

Wire of coils must be suited to battery current.

It is also proposed to provide the testing-table with a commutator, by which means the number of battery-cells used for testing purposes may be rapidly and conveniently altered.

CHAPTER XIII.

MECHANICAL AND ELECTRICAL TESTS.

Having now given a general description of the arrangements which seem to be best suited for working out any system of defense by submarine mines, it only remains to explain how the several component parts of the system may be put in proper practical working order and kept so after submersion.

Tests employed. To insure this it becomes necessary to test the different component parts of the system carefully before they are placed in position, and to retain the power of ascertaining their efficiency, as far as possible, at any period after they have been combined and put in the water. The tests employed are of two kinds, mechanical and electrical.

Mechanical tests. Mechanical tests should be applied to ascertain that the mechanical arrangements of the shutter apparatus, circuit-closers, and all similar appliances work easily and efficiently; that the several parts of the case to contain the charge, when put together complete, are water-tight; and that it is sufficiently strong to bear the external pressure due to the depth at which it is to be submerged, for a considerable time without leaking.

Electrical tests. Electrical tests are those which must be applied to the several component parts of the system to ascertain that the electrical conditions, necessary to a successful result, exist; for example, that the electric cable possesses a sufficient amount of insulation and conductivity; that the firing-battery is in such order as to insure certain ignition; that the electrical connections of the circuit-closers are correct, and other similar information. By means of certain electrical tests we can also ascertain after immersion, with a considerable degree of certainty, whether the several combinations of a system are in such a condition that it will work efficiently. This is a very important fact; for the whole thought, trouble, and previous preparation bestowed on a submarine mine is undertaken in order that it may act efficiently at a single instant of time, and it becomes valueless unless it does so act without failure.

Tests before and after submersion. Each portion of the apparatus should be tested separately, and combined in the form in which it is to be used before submersion, and the whole should be again tested immediately after submersion.

As a preliminary to all electrical testing it is necessary to ascertain that the instruments, batteries, &c., used in making the tests, are themselves in good working order, otherwise defects which exist in the testing instruments may produce results which might be mistaken for defects in the apparatus under trial; for example, a want of proper connection in the construction of a galvanometer might be mistaken for want of conductivity in an electric cable, or for a high condition of insulation which might not exist. Tests of instruments.

The following modes of testing the several component parts of the system may be adopted:

The explosive used would be either gunpowder, gun-cotton, or some similar compound; as a general rule these might be accepted as of good quality, but should any suspicious appearances present themselves, or should facilities be at hand, tests should be made. Gunpowder may be tested by an eprouvette, or by firing small charges out of a mortar and measuring the range obtained. Gun-cotton may be tested chemically, or practically, to see that it possesses detonating qualities. Any other explosive of a similar nature could be tested in a similar manner. Tests of explosives.

The case to contain the charge should be tested to ascertain that it is thoroughly water-tight, and capable of bearing external pressure to the extent required, according to the depth at which it is to be submerged. This test may be applied by forcing in water by means of a hydraulic press, to any given pressure, and observing the joints, &c., to see that nothing comes through them or through the body of the plates themselves. This should be done during the process of manufacture, and the leaks at the joints, should any exist, should then and there be calked. Any leak through the body of the metal itself would necessitate the rejection of the entire case. Cases of $\frac{1}{4}$-inch boiler-plate iron should bear a pressure from within of forty pounds on the square inch without a suspicion of leak. To test for capacity to bear external pressure, the cases, having first been made complete with mouth-piece, &c., to close the loading-hole, as for service, may be submerged to a depth somewhat exceeding that at which they are eventually to be used. After remaining thus submerged for not less than forty-eight hours, they should be lifted, opened, and carefully examined, to see that they remain perfectly dry inside. In making this examination it would be necessary, in the event of damp having penetrated, to ascertain whether it had forced its way in at the junction of the mouth-piece, or through the joints or metal plates composing Tests of case.

the body of the case. No electrical test can be applied as far as the simple metal is concerned; when complete, however, with mouth-piece, fuse, &c., before submersion an electrical test, to be hereafter described, should be applied to ascertain the condition of the apparatus as a whole.

Tests of mooring apparatus.

All mooring apparatus should be tested mechanically; first, to ascertain that the weights of anchors or sinkers are such, considering the buoyancy of the case, rate of current in which it is to be moored, and nature of bottom or holding ground, as to keep the mine in its proper position after submersion. Second, the chains, wire cables, and ropes to be employed should be examined to see that they are of sound construction; and, if the slightest doubt exists as to their quality, they should be further tested mechanically, by applying a strain of a measureable nature, to ascertain whether they are fit to perform the work required. No electrical tests are applicable to this part of the apparatus.

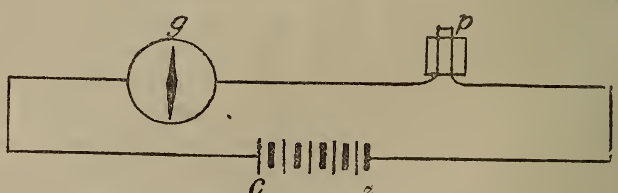
Tests of mechanical fuses.

Mechanical fuses, such as the sulphuric acid fuse, &c., might often be improvised and should be practically tested in course of construction. A fuse of this nature which may at any future time be made an article of store, to be drawn out as required for use, must be tested practically, by selecting a certain percentage of those issued and firing them; should the results be good the whole may be accepted as of good quality; if failures to fire occurred they would indicate more or less deterioration or imperfection in the whole. Abel's torpedo primers should be tested in this way. Mechanical fuses cannot be tested electrically.

Tests of platinum wire fuse for conductivity.

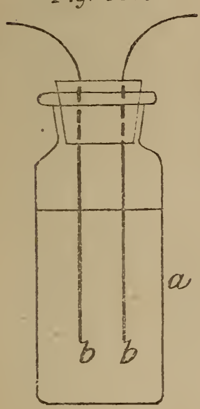
The platinum wire fuse may be very simply tested electrically. If placed in circuit with a few cells of a battery (*c z*,)

Fig. 100.



and a common detector galvanometer (*g*,) as shown in Fig. 100, before the fine platinum wire (*p*) is soldered across between the wire points there should be no deflection of the needle, for no metallic circuit should exist; if it did it would be fatal to the efficiency of the fuse. If placed in circuit with the same battery and galvanometer, after the fine platinum wire had been connected to the extremities of the larger wire points, a considerable deflection of the needle should result, such deflection being due to the current passing through the platinum wire bridge, which, to be efficient, ought to be the sole medium through which the circuit is completed. This test should be made with a few cells of Daniell's, or other similarly constituted battery, the current generated by this form of battery being of such a nature that no sensible heat would be produced in the platinum wire, and no chance of an explosion of the fuse incurred. This is especially necessary in testing the fuse after it has been placed in the charge, when a premature explosion would of course be a very serious matter. The current of Grove's, or other battery, so constituted as to fire a platinum fuse, would moreover injure, if not destroy, the coils of the galvanometer unless specially constructed for use with it, and should never be thus employed: The continuity of a platinum wire fuse may also be tested by means of a water-decomposer, as shown in Fig. 101. The passage of the electric current through the water would decompose it, and hydrogen bubbles would be deposited on the point in connection with the negative pole of the battery. Should a want of continuity exist in the fuse, no current would pass and no water would be decomposed. The apparatus consists simply of a glass bottle (*a*) to contain the liquid, into which a pair of wires, (*b b*,) insulated from each other, have been introduced, by simply passing them through a cork. A single cell of Grove's, or any battery by which a platinum wire may be fused, may be used in testing for continuity with this apparatus, provided the insulation between the wires passing into the bottle is sufficiently good, and the space between them, within the bottle, is sufficiently great to obviate the chance of premature explosion. In testing with a Grove's cell, extreme care is necessary to prevent the accidental closing of the circuit directly through the fuse by bringing the terminals in contact with each other, without the intervention of the resistance of the liquid in the bottle; in order to guard against this the wire terminals, outside the bottle, should be bent well apart. Salt, or acidulated, water is better than fresh for testing

Fig. 101.

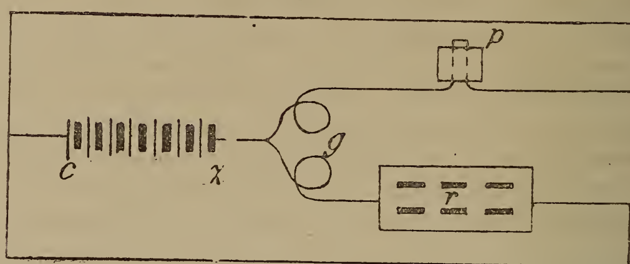


purposes, as exhibiting the effect of its decomposition more rapidly.

Test of resistance of platinum wire fuse.

The electrical resistance of a platinum wire fuse may be ascertained by balancing, by means of a set of resistance-coils (r) and a deferential galvanometer (g.) Any number of Daniell's cells required may be used for this operation, but, for the reasons already given, Grove's battery is inadmissible for such a purpose. Fig. 102 shows the connections to be employed for a test of this nature. The resist-

Fig. 102.



ance of the coils is adjusted, by taking out plugs till the needle of the galvanometer is brought to zero, when the sum of the resistances indicated by the unplugged coils will be equal to that of the fuse. The electrical resistance of $\frac{3}{10}''$ of fine platinum wire, weighing 1.9 grains to the yard, is $\frac{8}{10}$ of a B. A. unit nearly, (Schaw ;) this is its resistance at the moment of fusion. The resistance of $\frac{3}{10}''$, obtained by balancing with a set of resistance-coils, as in Fig. 102, is about $\frac{2}{10}$ of a B. A. unit; $\frac{3}{10}''$ is a good length of wire to employ as a fuse, and may be adopted as a standard.

Tests of high-tension fuses for conductivity.

Fuses adapted to be fired by electricity of high tension, such for example as Abel's fuse, require much more careful and delicate management in order to test them; they may, however, be tested for conductivity and resistance, and this must always be done before they are used in any operations connected with submarine mines, to insure the maximum of efficiency at the proper moment. The test for conductivity must be made with a few Daniell's or other similar batten cells of small surface, adapted for tests of this nature, and an astatic galvanometer. The high electrical resistance of fuses of this nature, amounting in the case of Abel's fuse to as much as 1,500 or 2,000 B. A. units of resistance, combined with the danger of premature explosion when testing with even a small number of battery cells, renders it necessary to employ the astatic galvanometer, on which, in consequence of its greatly superior sensitiveness, a deflection is produced by a comparatively small current. A reflecting galvanometer would of course be preferable for such work, but is much more expensive and not a very portable instrument.

The resistance of a high-tension fuse may be obtained in connection with a differential galvanometer, by balancing by means of a set of resistance-coils, as in the case of the platinum wire fuse. For the reasons already given, a very moderate battery power must be employed, and a more sensitive galvanometer used in this operation. The resistance of this form of fuse may be very accurately determined by means of Wheatstone's bridge and a reflecting galvanometer. For general work, however, an astatic galvanometer will give results sufficient for all practical purposes. The precautions necessary in testing Abel's fuse are given at pages 94 to 96, and these must be adopted generally in testing high-tension fuses of any form.

Tests of resistance of high-tension fuses.

The tests to be employed for detonating fuses would be precisely similar to those for ordinary fuses of the same construction, the only difference being in the priming, (fulminate of mercury instead of gunpowder.) They should, however, be subjected to a further test to ascertain that their detonating properties are sufficient to insure success; a deficiency of detonating composition will often produce imperfect detonation in the explosive itself, when used with compressed gun-cotton. A percentage should, therefore, be tried to ascertain their efficiency in this respect.

Tests of detonating fuses.

Each fuse should be tested before and after it is placed in the charge, subsequently as a part of the general combination in which it is to be submerged, and finally, directly it has been placed in position for work. Any change in the results obtained by the first and subsequent tests applied would indicate a change in the electrical conditions, as well as give such information as would indicate efficiency or otherwise of the system, as will be hereafter explained.

It is, perhaps, almost unnecessary to test electric cables, suitable for submarine mining purposes, mechanically for tensile strength; extraordinary precautions are taken by giving them strong outer protecting covering of iron wire, hemp, &c., intended not only to give tensile strength but to protect them from injury by rubbing against rocks, &c. Special precautions too are employed to prevent any great strain being brought to bear upon them, either during or subsequent to submersion. Should, however, any doubt arise as the ability of a cable to sustain a strain likely to be put upon it, it may be tested for tensile strength in the same manner as an ordinary rope. When an improvised

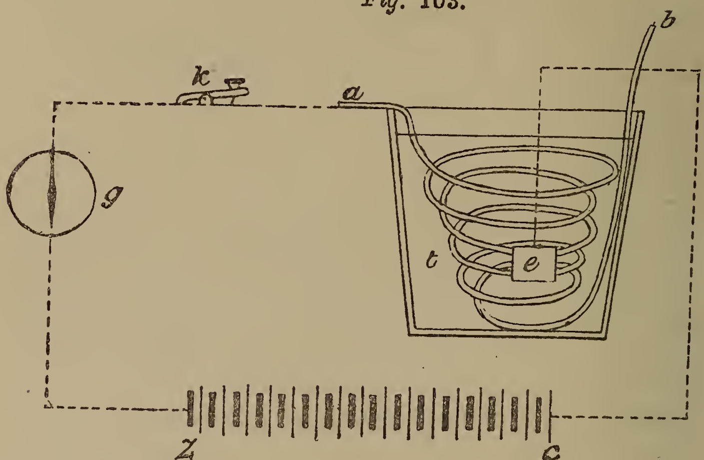
Tests of electric cables. Mechanical tests.

electric cable is employed it would always be advisable to ascertain its tensile strength before putting it to practical use.

Insulation test for electric cables.

Electric cables should be tested electrically for insulation, conductivity, and electrical resistance. To test for insulation the cable should be put in a tank of water and allowed to soak for 48 hours. The object of this soaking is allow the water to penetrate through the outer protecting covering of hemp and iron wires, and to search out and get into any weak places there may be in the insulation. After soaking, one end (*a*) of it should be reconnected, as shown in Fig. 103, with an astatic galvanometer (*g*,) and

Fig. 103.



battery (*c z*) of not less than 50 Daniell's cells, while the other end (*b*) should be carefully insulated. The battery circuit should be completed by an earth-plate (*e*) in the tank (*t*) through the galvanometer (*g*,) and the deflection of the latter should be observed. It is manifest that in such a combination any current, passing through and deflecting the galvanometer, could only complete the circuit by passing through the insulation of the cable. A very slight deflection would frequently be observed on a moderately sensitive galvanometer in such a combination as that indicated in the figure, even with a well insulated cable. This would be due to the current passing through the insulation; its whole length being immersed, the surface through which such a current would pass would be large, and the sum of the infinitesimally small quantities, escaping over the whole length, would, in the aggregate, be sufficient to deflect the galvanometer to a small extent in completing the circuit of the battery. Should any considerable deflection occur, it would indicate a defect, or leak, in the insulation of the cable, the extent of which would be roughly measured by the amount of such deflection. In making a test of this nature a large number of battery-cells, at least 50, and, if possible, more should be used, the object being to obtain high electro-motive force to drive the current through any defects which may exist. The battery-current should not be kept circulating longer than necessary during a test of this nature, and in order to close and break the circuit with facility, it would be convenient to insert a manipulating key, (*k*,) Fig. 103, in the combination. Should a leak exist in the cable, the effect of the continuous passage of electricity would be to polarize that leak, and thus to introduce a conflicting element into the combination which would be likely to interfere with the value of the test. If the tank in which the cable was coiled away were of iron or other metal, the earth-plate (*e*) might be dispensed with, and the circuit simply connected by a wire to the tank itself. When no tank is available an electric cable may, for testing purposes, be immersed in the sea or in any water, and equally good information obtained by testing it in the manner described.

Test of electric cables for conductivity.

Having completed the test for insulation, an electric cable should next be tested for conductivity. To do this it would only be necessary to remove the insulation from the end (*b*,) Fig. 103, of the cable, so as to expose the metallic conductor, and put it in the water of the tank. If the conductivity were good, the whole of the battery-current would then pass through the cable, and the galvanometer would be violently deflected. If the continuity were broken no deflection of the galvanometer would occur.

Very much more delicate tests for insulation might be obtained by substituting a reflecting for an astatic galvanometer, but for the comparatively short lengths of electric cable required for use in submarine mining operations, such minute accuracy is seldom necessary, though, at important stations, the more delicate apparatus might be very usefully employed.

Sensitive galvanometers best for testing purposes.

It must be borne in mind, however, that whatever instrument is used, the deflection of a galvanometer only conveys a comparative idea of a current passing through its coils. A current which would produce absolutely no motion on an insensitive galvanometer, would cause a considerable deflection in the needle of even a moderately sensitive instrument. An operator should, therefore, know the nature of the instrument with which he is working, and it is preferable for him to employ a tolerably sensitive instrument, with the use of which he is thoroughly acquainted, than a rough one with which the more delicate observations could not be made.

Negative current best for testing purposes.

The negative (zinc) pole of a battery should always be attached to a table for testing purposes, because if the positive (copper) pole were attached, a salt of the metal of which the conductor was formed would be immediately deposited in any defect which might exist in the insulation if the metallic conductor were in the slightest degree exposed. This would occur in any water, unless absolutely free from impurities, and would be especially the case in salt water, in which a chloride of the metal would be quickly formed. This would almost immediately insulate the defect to a certain extent, and a true deflection would not be obtained on the galvanometer. The effect of a negative current would be to decompose any such salt and to deposit the metallic component on the conductor, and thus, so to speak, to clear the defect and expose a purely metallic surface at the point required.

Tests for multiple cables.

To test a multiple cable for insulation and conductivity, a similar course should be pursued with each conductor as has been described for a single cable. In testing each single core, the conductors of all the others should be put to earth to obviate the effect of induction which would, more or less, according to the length of the cable, interfere with the results of the observations obtained.

To discover position of a defect of insulation.

Should a defect in insulation be indicated by the tests above described, its position might be readily ascertained, by keeping a continuous current on from the battery, and gradually taking the cable out of the tank. If the imperfection existed at a single point, the defection of the galvanometer would be suddenly much reduced at the moment the defect was raised out of the water, and its position would thus be determined with considerable accuracy. Should several defects exist, as each was lifted out, a sudden reduction of deflection would occur.

Discharge test.

Want of continuity in an electric cable may co-exist with perfect insulation; for example, the conductor might be parted within the insulation, while the latter remained good. Under such circumstances the tests above described would indicate good insulation but no conductivity, without giving any information as to the position of the severance of the conductor. To ascertain this the following test may be applied: Having put one pole of a battery of 200 or more Daniell's cells to earth, charge one end of the defective cable, and immediately discharge through a reflecting galvanometer, noting the extreme limit of the swing of the needle, then charge the other end of the cable in a similar manner, and discharge it through the same galvanometer, noting the swing of the needle as before. This should be done three or four times, and an average of the deflections taken. The position of the break in the conductor would be indicated by the proportion between the average deflections in each case, and the cable might safely be cut at the point so determined, which, if the tests were carefully made, would not be very far from the defect. Should the precise position of the fault not be discovered in thus cutting the cable, each section should then be again tested for conductivity, and that in which the fault was still found to exist should be again tested by the discharge as before. In this way the exact point would finally be discovered.

The deflection of the needle is dependent upon the quantity of current, at a given potential discharged through the coils of the galvanometer, and the quantity is again dependent on the electrical capacity of the conductor of the cable to contain a charge forced into it at a given potential, and its electrical capacity is directly in proportion to its length, supposing the conductor to be of uniform size throughout. The swing of the galvanometer-needle measures the quantity of the charge passed through its coils, in proportion to the sine of half the angle deflected, (Jenkin;) hence on a reflecting galvanometer the information would be given directly, in proportion to the number of divisions on the scale, as indicated by the extreme motion of the spot of light, while on the galvanometer reading the angular measure in degrees, &c., the sines of half the angles deflected would give the required proportion. Few galvanometers, except the reflecting instrument, are sufficiently sensitive to enable the "discharge-test" to be employed.

Test of electrical resistance of cable.

After testing for insulation and conductivity, the electrical resistance of an insulated cable should be measured. This should be done by balancing it against a set of resistance-coils, in connection with a differential galvanometer, in a similar manner to that shown for the fuse in Fig. 102. The coils should be unplugged till its galvanometer-needle is brought to zero, when the sum of the unplugged coils would be equal to the electrical resistance of the cable. A more delicate test of this nature may be made by Wheatstone's bridge and a reflecting galvanometer. The electrical resistance of the conductor of a cable affords a very correct indication of the quality of the metal of which it is composed.

In making these tests Daniell's or some similar form of battery should be employed, so that the delicate coils of the galvanometers, &c., may not be injured.

Mechanical tests of water-tight joints.

Water-tight joints and connections should be tested mechanically, by immersion, for not less than 48 hours, at depths somewhat greater than those at which they are to be eventually used, after which they should be raised, opened, and examined to see that they remain dry.

Electrical tests of insulated joints.

Insulated joints and connections, whether of a permanent or temporary nature, should be tested electrically, in a precisely similar manner to that described for electric cables. They should be soaked for 48 hours and then tested for insulation, conductivity, and electrical resistance.

In testing the permanent joints made in a line of submarine electric cable, special precautions are taken, which are described by Mr. Culley as follows:

"A joint should insulate as well, or nearly as well, as an equal length of the perfect core, and the object of the test is to ascertain if this be the case. The leakage, even from a considerable length of good core, is too small to affect the galvanometer; although the electricity which escapes moment by moment cannot be measured, still, if it were possible to store up the loss during a minute and compel it to pass instantaneously through the coils, it would produce a sensible deflection.

Delicate test of joints by special apparatus.

"In order to effect this, recourse is had to induction. A metallic trough, sufficiently large to contain two or three feet of the core, is suspended by straps or rods of polished ebonite, two or three feet long. A small condenser is attached to increase its inductive capacity, and enable it to store up the electricity which may leak through the insulation. The testing-battery, of not less than 200 cells, is insulated in a similar manner, and all loss over the surface of the conducting wires is prevented by paring their ends, so as to expose a fresh clean surface, or even by coating them with hot paraffine.

To test the apparatus.

"To ascertain if the apparatus is sufficiently insulated, the trough and condenser are charged, and the swing of the needle, from an immediate discharge, noted. They are then recharged and left free for a time equal to that to be occupied by the test and again discharged. The difference in the swing shows the loss in the time, and should be very small.

"The joint is placed in the trough, a negative current is applied to the cable, and the positive pole of the battery is connected to the outside coating of the condenser. Any leakage which may occur through the insulation is, by this arrangement, accumulated in the condenser, and may be discharged through the galvanometer after any given interval.

"It is possible to find how much is lost by deflective insulation during the joint-test itself; but as both core and joint are subjected to the same conditions, and the object is simply to see if one insulates as well as the other, this precaution does not seem to be absolutely necessary.

"To make the test. 1st. Place the joint in the trough—leave one end of the cable free; connect the copper pole of the battery to the galvanometer; connect the other terminal of the galvanometer to the trough, and, finally, charge the cable by applying the zinc pole. Mode of makin the test.

"The charge within the cable acts inductively upon the natural electricity of the trough, the wire being in fact the inner, and the water the outer coating of a Leyden jar. A portion of the negative electricity of the water is set free, and an equal quantity of the positive is held fast or disguised by the negative charge within the cable. The free electricity is at once neutralized by the action of the battery; if it were not so arranged, it would increase the apparent leakage from the cable, being of a similar sign.

"The deflection or swing due to the discharge being instantaneous, it follows that if the needle *remains* deflected after the discharge, the joint is very bad or there is leakage over the surface of the insulation. The latter may be conducted to earth so as not to interfere with the test, by wrapping an earth wire round the core a few feet from the free end.

"2d. Without disturbing the charge of either cable or trough, connect one coating of the condenser to the trough, the other coating to the positive pole of the battery, the zinc being to the cable as before.

"Any negative electricity which may leak from the cable will now accumulate in the condenser. Allow one minute for this.

"3d. Disconnect the condenser from the trough and battery and discharge it through the galvanometer. If the trough and other parts of the apparatus have been well insulated, the swing will show the accumulated leakage from the portion of core under test. It is evident that these changes must be made by perfectly insulated keys and commutators.

Effect of induction when several joints are simultaneously tested.

"It often occurs, when there are several wires in the cable, that the apparent leakage is greater from the joint which is first tested than from any of the other joints tested at the same time. This arises from the charge in the first wire acting upon the others inductively. The wires not under test should therefore be put to earth until they are wanted, and the condenser and trough should be perfectly discharged between each test.

"It will be understood that the results are simply comparative, not absolute; all that the method effects is to show the difference between the insulation of a joint and that of any other part of the core.

"This method somewhat differs from that ordinarily adopted. It is usual to put one pole of the battery to earth; but in this case leakage takes place over the whole cable, however long it may be. By the plan described, the leakage is confined to the part in the trough; the whole force of the battery is concentrated there and the apparent leakage exaggerated."

Though such minute accuracy is not absolutely essential in the short lengths of electric cable used for submarine mining purposes, it must be borne in mind that the higher the condition of insulation, the greater will be the efficiency of the system, and the longer the line, the greater the necessity for perfection, as far as it can possibly be attained.

Tests of Wheatstone's exploder, frictional machine, and similar apparatus.

All electrical instruments used for firing mines at will, such as Wheatstone's exploder, Siemens's dynamo-electrical machine, and the Austrian frictional machine, should be carefully examined and tested to see that their mechanical arrangements are in good working order. They should further be tested, with a fuse and known electrical resistance in circuit, to ascertain their power to fire that fuse with certainty. If the electrical resistance in circuit is considerably greater, (say double,) than that through which they are required to work in practice, it may be assumed that they are in good order. The Austrian frictional machine has a special arrangement, by which its working condition may be ascertained, on short circuit, by the length of the spark passing across a given space on closing the circuit between the armatures of the condenser.

Tests of batteries.

Electrical batteries should be tested for potential, internal resistance, and electro-motive force.

For potentials.

To test the potential of a battery, one pole should be put to earth, and the other to charge one pair of the quadrants of a reflecting electrometer; when this is done a certain deflection of the spot of light will be observed, and the amount of the deflection, as compared with that produced by a standard cell applied to the instrument in a similar manner, would give the relative value of the potential of the battery. In making such observations it is necessary to take care that the condition of the electrometer, as regards charge in the Leyden jar, &c., is the same, while the deflections with the batteries under comparison are observed. The reflecting electrometer is not a very portable instrument, and requires very careful and delicate arrangements in connection with it, and the beautifully minute and accurate information obtained by it is not absolutely essential to efficiency, in connection with the comparatively short lines of electric cable necessarily used for submarine mining purposes; its employment may therefore be limited to the more delicate observations necessary at important stations.

Test of internal resistance of battery. Connections for test.

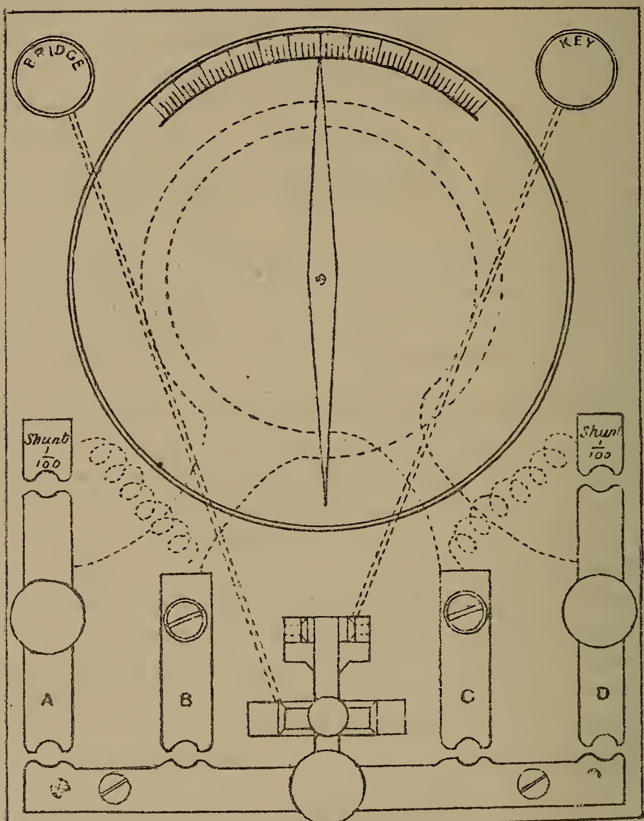
The internal resistance of a battery may be readily obtained by means of a double shunt differential galvanometer and set of resistance-coils, as recommended by Mr. Latimer Clark, in his book on electrical measurements in the following manner:

"Connect the battery and a set of resistance-coils in circuit between the terminals A and D, and insert plugs in the resistance coils so that they give no resistance; insert plugs at A and C, and also both the shunt plugs at A and D. The battery current will now flow through one-half of the galvanometer circuit only, being, however, reduced to $\frac{1}{100}$th of its amount by the shunt D: the deflection of the needle must be carefully read. The plug A must now be removed to B, which causes the battery current to flow through both halves of the galvanometer, (each being shunted.) The circuit will now be as shown in Fig. 105, and the needle will, of course, be deflected somewhat more than before. Now unplug the resistance-coils which are in circuit with the battery until the deflection of the needle is reduced to its original amount, and the resistances unplugged will be equal to the internal resistance of the battery. For example, assuming the resistance of the half coil to be ninety-nine ohms, and that of the shunt wire one ohm, the joint resistance of the two circuits will be:

$$\frac{\text{Galvanometer} \times \text{shunt}}{\text{Galvanometer} + \text{shunt}} \text{ or } \frac{99 \times 1}{99+1} = 0.99 \text{ ohm.}$$

Suppose the resistance of the battery to be four ohms, the two together=4.99 ohms, and the current acts on the galvanometer needle through one-half of its circuit only; when the second half of the galvanometer is thrown into circuit, by shifting the plug from A to B, the resistance becomes 4.99 + 0.99=5.98, and therefore less current passes; but, since it acts upon the needle through both coils instead of one, the deflection is greater than before. The resistance coils are now varied until the needle recedes to its original deflec-

Fig. 104.



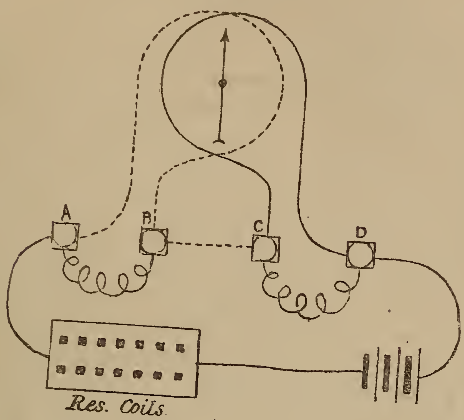
tion, which will necessitate the unplugging of a resistance of four ohms, making the total resistance now 5.98 + 4=9.98, which is exactly double the first resistance; that is to say, in the one case we had a current acting upon one coil through 4.99 ohms, and in the other case acting upon the two coils through 9.98 ohms, the deflecting power on the needle having been increased in the same ratio as the resistance."

This measure is obtained in terms of B. A. units of electrical resistance, and is thus at once comparable with any other electrical resistance required.

The comparative electro-motive force of a battery may be determined by means of a differential galvanometer and set of resistance-coils, in a very simple manner. Fig. 104 shows a diagram of a double-shunt differential galvanometer and the mode of finding the electro-motive force with

Electro-motive force, test of battery.

Fig. 105.



this instrument, as recommended by Mr. Latimer Clark, is as follows:

"This can only be done relatively in terms of some other standard battery. The method is as follows: Determine the resistance of the standard and of the other cells to be measured; insert the shunt-plugs at A and D, Fig. 104, and also at C and B, as in the former case, and join up the standard cell in circuit with a resistance-coil to the terminals A and D, and unplug the resistance-coils until a convenient deflection is obtained, say 15°; note the sum of the resistances in circuit, including that of the battery, galvanometer, resistance-coil, and connecting wires; now change the cell for another, and by unplugging the resistance-coils bring the needle again to the same deflection, 15°; having again found the total resistance in circuit, the relative electro-motive forces of the two cells will be directly proportional to these resistances."

Connections for the test.

The electro-motive force thus determined is comparative; that is to say, the result given by one battery may be compared with that obtained from another, and assuming any given cell as a standard, the value of each, as compared therewith, is obtainable.

The electro-motive force and internal resistance of a battery which is capable of fusing a fine platinum wire, may be found in the manner described in *The Course of In-*

Test of electro-motive force and internal resistance of quantity battery.

struction in Military Engineering, page 140, paragraph 303, for Grove's battery. Mr. Abel proposes to fit up a simple arrangement of thermo-galvanometer and resistance-coils, suitable for this purpose, on his testing-table. (See page 236.)

Tests of system combined as a whole.

Having carefully tested the several parts of the apparatus, both mechanically and electrically in the manner described, they may be put together precisely in the combination in which they are to be submerged. When electricity is to be the igniting agent the system should be again tested electrically, as a whole, for insulation, conductivity, and electrical resistance. The results thus obtained would at once indicate whether the whole was in working order or not, and would be strictly comparable with the information obtained by similar tests, applied at any period after the mines had been submerged. A careful record should be kept of the results of all of the electrical tests applied, as by preserving the electrical history, so to speak, of any combination a defect in its electrical condition may be readily discovered, and the nature, position, and extent of such defect indicated with a considerable degree of certainty, without the necessity of raising the mine out of the water, or in any way disturbing the arrangements employed.

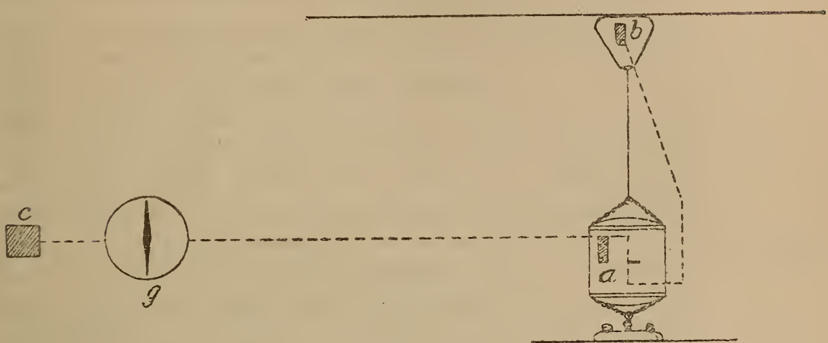
Tests after submersion.

After a mine has been submerged with electric cable, &c., complete, it should be immediately tested to ascertain that all is right, and similar tests should be applied at intervals to ascertain that the charge remains dry, and, in consequence, efficient; that the electrical resistance of the fuse is such as to indicate certainty of ignition; that the insulation and conductivity of the electric cable remains good, and that its electrical resistance indicates a state of efficiency. The nature of the tests applied to ascertain these points depends upon the nature of the combination in which the mine is arranged; that is to say, whether it is on a circuit-closing or circuit-breaking system, whether the circuit-closer is on a branch, or otherwise connected, and the nature of fuse used. The amount of accuracy with which the information, derived from electric tests, may be obtained, depends entirely upon the manner in which the several electrical circuits are connected up, and the nature of the tests to be applied must be determined accordingly.

Test to ascertain that the charge is dry.

The arrangements for testing to ascertain whether a charge is dry, at any period after submersion, are shown in Fig. 106. A plate of zinc is introduced at the point (*a*) within the charge, in connection with the conductor of the electric cable, and between the fuse and the shore, while a plate of carbon (b) is connected with the electric cable, beyond the fuse, to form the ordinary earth connection of the system at that point, and a copper earth-plate (c) is used at the home end of the cable. Taking advantage of the fact that if two plates, of suitable metal to form a voltaic battery, are placed in salt water and connected by a metallic conductor, a battery is at once formed, capable of producing

Fig. 106.



considerable deflection on a moderately delicate galvanometer; the combination shown in Fig. 106 has been made available for testing purposes. This arrangement has been termed the "sea-cell." The length of the conductor between the plates is, within reasonable limits, (up to two or three miles,) no practical impediment to the action of the current set up, as far as the deflections produced on the needle are concerned. Let us suppose in the first instance that the charge is dry, and the insulation and conductivity of the cable good; under these circumstances we should have a sea-cell, composed of a copper and carbon pair, (c and b,) which would produce a deflection on a galvanometer (g) in circuit, in a certain direction, say from right to left. Suppose now that the charge had become wet by leakage through the case; under these circumstances the zinc plate (a) would come in contact with the salt water, and a sea-cell, composed of a copper and zinc pair, would result; this would give a different deflection on the galvanometer, and the needle would swing in the opposite direction, or from left to right. This would at once indicate that the charge had become wet.

Again, suppose that the insulation of the electric cable had become damaged to such an extent as to expose the copper conductor. Under these circumstances the sea-cell would be formed of two copper plates, one the permanent earth-plate, the other the exposed copper conductor, and a

Sea-cell test for insulation of cable.

certain definite deflection would be observed. This deflection would differ in character from that produced by the copper carbon sea-cell, which would exist under the conditions of good insulation, and would thus indicate a change in the electrical conditions of the combination, at the same time giving such information as to lead to the supposition that an injury to the insulation of the cable had occurred. If the earth-plate at the home end of the cable were changed from copper to zinc, or to carbon, a fresh set of combinations would result giving different indications on the galvanometer, and these would provide the means of determining, with considerable accuracy, the reason for the change in the electrical conditions of the combination which they indicated. In this way the fact that a leak existed in the insulation of a cable might be discovered. Its extent and position might subsequently be approximately ascertained by tests to be hereafter described.

Sea-cell test for continuity.

Should the conductor of an electric cable be fractured within the insulation without injury to the latter, the fact would be ascertained by the sea-cell test. In such a case the continuity of the conductor being destroyed no deflection on the galvanometer would result. Want of conductivity or inefficient connections in the fuse would be similarly indicated.

Disturbing influences to sea-cell test.

In testing in this manner with the sea-cell, certain disturbing influences occur, which must be obviated as far as possible. For example, the carbon earth-plate (*b*) beyond the charge becomes polarized, and acts in opposition to the current produced by the copper-carbon sea-cell; in order to obviate this it is necessary to depolarize the system, by the application of a short current of opposite sign from a few cells of a voltaic battery, to bring the plate to what may be termed a neutral state, under which circumstances alone it is in a condition to give a correct deflection on the galvanometer. The exposed metallic conductor of an electric cable becomes similarly polarized when subjected to the passage of a continuous battery current, and it must be depolarized by similar means. The polarization of the carbon plates of any voltaic battery, into the composition of which this metal enters, is very rapid. The moment the battery-circuit is cl sed, the carbon plates become polarized, and much care and dexterity is required to depolarize them, when making the test for the internal resistance of the battery, as described at page 251. Unless they are carefully depolarized, the internal resistance of the battery, found in this manner, will appear to be very much larger than it really is. It will be, in fact, the resistance after the current has circulated, and not the resistance when the battery circuit is first closed.

The following demonstration of the general principle on which the liquid resistance of a battery is calculated by the differential galvanometer, shows that the result found by that method is not correct in the case of batteries in which the electro-negative plate is carbon, or any other element which assumes a different degree of polarity according to the altered resistance in the circuit in each case.

Let g be the resistance of each coil of the galvanometer.
s be the resistance of the shunt.
x be the resistance of the battery.
w be the resistance unplugged.
e be the electro-motive force when the current passes through one coil.
e_1 be the electro-motive force when the current passes through two coils.
c be the current in the first case.
c_1 be the current in the second case.

By Ohm's law we have

$$c = \frac{e}{x + \frac{g \cdot s}{g + s}} \quad (1) \text{ and}$$

$$c_1 = \frac{e_1}{x + 2\,\frac{g \cdot s}{g + s} + w} \quad (2)$$

But c_1 only equals $\frac{c}{2}$ as it passes through twice as many coils to produce the same deflection.

$$\therefore \frac{e}{x + \frac{g \cdot s}{g + s}} = \frac{2\,e_1}{x + 2\,\frac{g \cdot s}{g + s} + w} \quad (3)$$

Now if $e = e_1$ as is the case in the Daniell battery or others in which the electro-negative plate does not polarize rapidly, from equation (3) we get

$$2\,x + 2 \cdot \frac{g \cdot s}{g + s} = x + 2\,\frac{g \cdot s}{g + s} + w \;\therefore\; x = w \quad (4)$$

But if e were not equal to e_1, as would be the case when the electro-negative plate was carbon, equation (4) would not hold good.

In such cases the currents would have to be measured by the swing of a needle or the fusion of platinum wire for the establishment of equations (1) and (2.)

Contact of galvanized protecting wires.

The outer-protecting covering of the form of electric cable used for submarine-mining purposes, being partly formed of galvanized iron wires, any accidental contact of these, introduced into the system, would produce a copper-zinc sea-cell, and give a deflection similar in character to that produced by the zinc plate in a wet charge. This might be obviated by substituting a carbon plate, within the charge at (*a*,) Fig. 106, for the zinc, and putting a zinc one at (*b*.) The plan hitherto adopted in the experiments conducted at Chatham has been to place the carbon plate outside, because it is not liable to be decomposed, by the passage of a continuous current of electricity through it, when immersed in sea water.

Value of electrical tests depends on comparison.

All electrical tests, made at any period after the submersion of a charge, are simply comparisons with the electrical conditions necessary to practical working perfection, which, to insure success, must have existed when it was first placed in position. Any deviation from these conditions would indicate faults in the system, and would be demonstrated by the difference between the results of the tests obtained, as compared with those which ought to exist in a perfect combination. It is very essential, therefore, that a strict record should be kept of all tests applied to each mine and cable, with the results obtained.

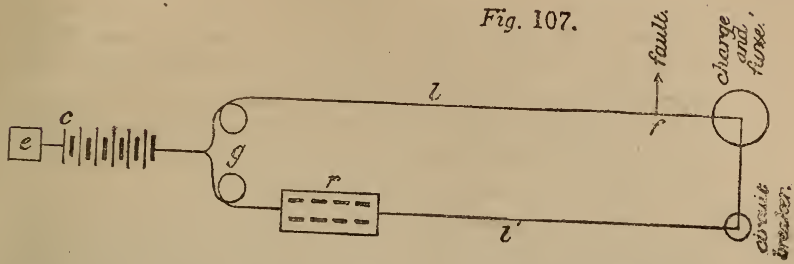
Testing arrangements for platinum and tension fuse differ.

Different testing arrangements must be adopted according to the system on which the mines are to be fired. If a platinum wire fuse and circuit-breaker be employed, as in Fig. 88, page 215, a large number of Daniell's cells may be employed without danger, and every part of the system may be tested directly, incluing the fuse and circuit-breaker beyond it. If a high-tension fuse and circuit-closer, arranged as in Fig. 89, page 215, be employed, a small number of Daniell's or some similar cells must be used with a very sensitive galvanometer. The system may be tested through the fuse on the direct circuit and to earth, but the continuity of the electrical connection to the circuit-closer, on the branch, can only be ascertained by actually sending a boat out and closing the circuit by running against it.

C. F. Varley's loop-test for discovery of position of fault.

Should an injury to the insulation of the electric cable, either between the fuse and the shore, or beyond and between it and the circuit-closer, be indicated by means of the sea-cell test, when the platinum wire fuse and circuit-breaker is used, its position may be discovered in the manner shown in Fig. 107. The positive pole of the battery (*c z*) being put to earth at (*e*,) the negative pole should be attached to a differential galvanometer, one terminal of which should be connected to the defective cable (*l*,) while the other should be connected with one terminal of a set of resistance coils (r.) A well insulated cable (l') of known electrical resistance should be attached to the other terminal of the resistance coils (r,) and should be paid out to

Fig. 107.



reach the circuit-breaker attached to the defective line. The electric cable attached to the circuit-breaker should be disconnected therefrom, and attached by a temporary insulated joint or Mathieson's connector with the line (l'.) Suppose the defect in the line to exist at the point (f,) it is easily seen, on reference to the diagram, that the current from the battery would divide itself between the two circuits open to it, returning through the leak at (f) to the earth-plate (e,) and if the resistance in these two circuits were equal, the needle would stand at zero, and this equality would be established by unplugging the coils (r.)

Let x = the distance, in terms of electrical resistance, of the fault from the galvanometer (g,) y=the distance from the fault to the circuit-breaker, L=the total resistance of the circuit (l,) including fuse and electric cable up to and connecting the circuit-breaker, (this should be ascertained by previous tests when the cable and connections were in good working order,) L_1=the resistance of the line (l',) and R=the unplugged resistance in the coils when the galvanometer needle stands at zero. In this way we obtain two equations, viz:

$$x+y=L$$

$$\text{and } x=R+L_1+y$$

from which the values of x and y, in terms of electrical resistance, which would be readily convertible into length, would be easily determined. Should the fault exist near the home-end of the line, it would be necessary to place the resistance, coils in connection with the same coil of the galvanometer as the defective line, in order to make the two circuits balance, the resistance of x being necessarily small under such circumstances. In this combination it will be observed that the electrical resistance of the defect is equally divided between the two circuits, and its effect does not in any way disturb the conditions necessary to the truth of the equations employed.

A large number of Daniell's cells may be used with platinum fuse.

A large number of Daniell's cells may be used in making this test with the platinum wire fuse, without any chance of an accident. In working a circuit-breaking system in connection with a platinum wire fuse, it would be convenient to keep an electric cable, from the electrical room in the fort to the vicinity of the mines, permanently in position, for the tests described. This line would also serve for telegraphic communication, which would in the majority of cases be required under any circumstances.

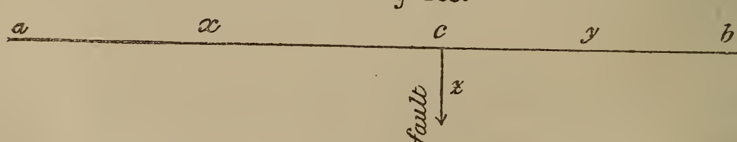
Earth connection in top of circuit-breaker for convenience of testing.

In order to render this system for the discovery of the position of a fault effective, some means must be adopted by which a connection with the electric cable in the vicinity of a circuit-breaker may be rapidly made. The circuit-breakers of a system would generally be very close to the surface at low water, and a little extra length of electric cable, sufficient to enable its extremity to be brought well above the surface, with a joint capable of being readily opened—one of Mathieson's connectors, for example—would, answer every purpose. This and other testing arrangements might be much facilitated by arranging the connection with the earth-plate in the top of the wooden jacket of the circuit-breaker. Experiments should be made to test this system, and to bring it into a good practical working form.

Blavier's formula for discovery of extent and position of a fault.

When no return wire, as (l',) Fig. 107, is used, the position and extent of a fault may be determined by means of Blavier's formula, as follows: Let ($a\ b$,) Fig. 108, represent the line, (a) being the home and (b) the distant extremity, and suppose a fault of unknown electrical resistance to exist at (c.) Let $x =$ the resistance of the portion ($a\ c$) from the home

Fig. 108.



end to the fault; let $y =$ the resistance of the portion ($c\ b$) from the fault to the earth connection of the circuit-breaker; and let $z =$ the electrical resistance of the fault itself. Let R = the resistance of the line and fuse when in good working order, derived from previous experiment; let S = the resistance of the faulty line when to earth at (b;) and let T =

the resistance of the faulty line when insulated at (b.) From these we derive the following equations:

$$x + y = R \qquad (1)$$

$$x + z = T \qquad (2)$$

$$x + \frac{y . z}{y + z} = S \qquad (3)$$

$$\text{From (1) } y = R - x \qquad (4)$$

$$(2)\ z = T - x \qquad (5)$$

Substituting these values in equation (3) we have

$$x + \frac{(R - x) \times (T - x)}{R - x + T - x} = S \qquad (6)$$

Multiplying both sides by the denominator, we get

$$(R + T)\, x - 2\, x^2 + R . T - (R + T)\, x + x^2 = (R + T)\, S - 2\, x . S \qquad (7)$$

From which we obtain

$$R . T - x^2 = (R + T) . S - 2 x . S \qquad (8)$$

$$\text{and } x^2 - 2\, S . x + R . S + T . S - R . T = 0 \qquad (9)$$

$$\therefore\ x = S \pm \sqrt{S^2 + T . R - T . S - R . S} \qquad (10)$$

$$\text{or } x = S \pm \sqrt{(R - S) \times (T - S)} \qquad (11)$$

Substituting this value of x in equation (3) we have

$$Z = T - S \pm \sqrt{(R - S) \times (T - S)} \qquad (12)$$

From these equations the values of x, y, and z, in terms of electrical resistance, are readily obtainable, and the position of the fault may be discovered by converting the values of x and y into length.

If the value of x has been previously obtained, by means of Varley's loop-test, that of z is readily obtainable from equation (2.)

In making tests of this nature much dexterity and previous practice is required, as well as considerable electrical skill. The difficulty of the problem arises from several causes, described by Mr. Culley as follows:

"1. As the metallic conductor is exposed it forms galvanic elements or batteries with the iron sheath and salt water, so that a positive current flows from the cable, through the testing galvanometer, to earth; this is steady and constant if the cable is not disturbed. Cable current.

"2. We have to deal with two unknown resistances: that of the wire itself and that between the exposed part and the earth; the first is constant, the second very variable, because—

"3. The action of the current alters the resistance at the point at which the metal touches the water, by coating it with substances which differ in conductibility; and, at the same time, the apparent resistance is still further altered by the currents of polarization set up by these substances.

"The action which takes place can be shown by placing a piece of cable in a glass filled with salt water and applying a current from 40 or 50 cells, one pole of the battery being connected to the iron sheath, the other to the copper conducting wire. The portion of the cable connected to the zinc gives off a stream of hydrogen, while the other becomes coated with a chloride of the metal. Thus, if the negative pole is connected to the conductor and the positive to the sheath, chloride of iron is formed; and if the connections are reversed, chloride of copper is produced.

"Let us now connect a galvanometer to the cable in such a manner that the current from the cable-battery of copper and iron in salt water, called the 'cable-current,' shall deflect the needle to the *right;* the iron element being, of course, always on the earth.

"If a negative current is now sent into the cable, its direction coincides with that of the cable-current, and does not affect the direction of the deflection.

"But the superior force of the testing-battery overcomes the cable-current and polarizes its elements. The copper wire becomes coated with hydrogen, the iron sheath with chloride of iron, so that when the testing-battery current is cut off and the cable-battery is again free to act, its action is reversed, and the needle moves to the *left*, under the influence of the current of polarization.

"But the hydrogen gradually enters into combination and disappears from the wire, the polarization ceases, the needle returns toward zero, passes it, and finally takes up its former position to the right, under the influence of the cable-battery in its normal state.

"On the other hand, if we test with copper instead of zinc, the needle is deflected to the left, the cable-battery again acts as a decomposition cell, but the polarization is now in an opposite direction, the copper being coated with its chloride, and the iron with hydrogen. When the testing current ceases, the needle therefore moves to the right, and continues permanently deflected in that direction, because the normal current from the cable-battery is now in the same direction as the current of polarization.

Condition of cable best suited for resistance-test.

"If we apply a succession of short zinc currents after the wire has been coated with the chloride, the needle will still take up a right-hand deflection after the battery contact has been broken; but the deflection will decrease after each test, and will finally be reversed. The deflection to the right is due to the polarization set up by the chloride of copper; each application of the zinc current reduces a portion of this chloride, and assists also in removing it mechanically by the action of the hydrogen, until after a time the chloride disappears and is replaced by hydrogen. The sign of the polarization is then changed and the direction of the needle is changed also. But there is a moment when the opposite actions of the hydrogen and chloride are apparently balanced, so that the cable battery is inert and the end of the wire unpolarized and probably uncoated. Then, and then only, can its correct resistance be determined. The object of the special method of test is to produce this condition.

"The test for distance is best made with a differential galvanometer. First ascertain the approximate resistance in the ordinary way, and clean the exposed wire from the dirt and the salts with which it will be coated, by applying a zinc current for several hours, occasionally reversing it to get rid of any deposit of soda which may occur. The surface will be roughened by the redeposit of the copper which has been dissolved, and will therefore more readily throw off the hydrogen evolved by the zinc current. Next apply a positive current for the purpose of coating the wire with chloride of copper, and finally test with the negative current. The action of the current set up by the chloride of copper will make the resistance appear less than it really is; but as the chloride is gradually reduced by the testing current, in the manner which has just been explained, the resistance will appear to increase, moment by moment, and the resistance-coils must be lengthened, unit by unit, to balance the resistance of the cable, so as to keep the needle at zero, until it passes over to the opposite side suddenly, under the influence of the change of polarization, caused by the copious evolution of hydrogen which will follow. The increase of apparent resistance, and the consequent movement of the needle, is slow and gradual so long as the hydrogen is employed in reducing the chloride, but after the reduction is complete and the chloride has disappeared, the increase in resistance is enormous and almost instantaneous. Unless, therefore, the resistance of the cable has been carefully balanced, so as to follow the variation of the current throughout, the test will not succeed, because the neutral condition lasts too short a time to permit the adjustment of the resistance-coils.

Mode of applying resistance test.

"In any case a certain dexterity is required, which can only be obtained by practice; but fortunately the practice may be had conveniently upon an artificial fault, or a piece of insulated wire in a tin can filled with salt water and connected to a set of resistance-coils. Induction does not

Much dexterity required in making resistance-test.

affect the test, and as in any ordinary cable the insulation is practically perfect, its resistance can be represented as accurately by a rheostat as by an actual cable. The higher the tension of the battery the less does the opposing current of polarization affect the result, for its force seldom exceeds two or three cells. The measurement is therefore made with a battery of as high a tension as can be conveniently procured, 60 cells or more.

Behavior of a fault depends on length of wire exposed.

"The behavior of a fault varies with the length of wire exposed; a short fault polarizes and depolarizes very rapidly; its changes in resistance are correspondingly rapid, and its resistance great. If the exposed wire is long, the changes are slower and more readily observed; the resistance of the fault is also less.

"After having well studied the changes of the fault itself, make an artificial fault by placing a piece of the cable core in a tin can filled with salt water, and alter the length of the exposed wire until it behaves in the same manner as the cable, and then find its resistance, which will be very nearly the same as that of the real fault; so that the distance of the break will be the tested resistance of the cable less that of the artificial fault.

"It is a convenient plan to form a table of the resistance of exposed wire of various lengths with 6 and 60 cells, adding resistances by a rheostat, using the negative current and allowing the exposed wire to take up its maximum resistance. The tests with the 6 cells will be always higher than those with 60, that is to say, the resistance of the fault will always appear higher when tested with the lower power, and the difference between the apparent and real resistance will also increase gradually, as the length of the cable itself, or the resistance added by a rheostat, increases; the length of exposed wire being constant.

"If a cable is found to give, with 6 and 60 cells, two results corresponding to some two in the table, it is probable that the length and resistance of the exposed wire is the same as that of the artificial fault used in the formation of the table, and therefore that the resistance between the testing station and the fault is equal to the resistance added to the artificial fault.

Personal equation of observer.

"So much, however, depends upon the manner in which the tests for the table were taken, or upon what we may call the 'personal equation' of the observer, that every one should form a table for himself. The cable must be treated in precisely the same manner as the artificial fault, and therefore no table will be perfectly correct unless it is made just before the cable is tested, in order that the precise manipulation may not be forgotten."

The above remarks are made with reference to the tests of submarine cables of considerable length, and though there is not so much difficulty in testing the short lines used for submarine mines, still the same conditions exist and must be guarded against and taken into consideration on all occasions. Unless this is done, anomalous results, caused by the disturbing influences above mentioned, will be obtained, and it is necessary to guard against their acceptance as due to defects of insulation alone.

Insulation injured at points where motion occurs.

Injury to the insulation of the electric cable necessarily occurs at those points where it is subjected to friction, and in practice the points where it is attached to the sinker or mooring apparatus, where it enters the case and where it joins the circuit-closer, are those where injury has been most frequently found. This is due to the slight motion produced by the action of the water, and special precautions must be adopted to protect the cable at such points.

Tests of combination when a high-tension fuse is used.

The high electrical resistance of the tension fuse, combined with the necessity for using a very small battery-current in connection with it for testing purposes, renders it necessary to adopt a totally different arrangement for testing when a tension fuse and circuit-closing system is adopted. If used with the circuit-closer on a branch, as in Fig. 89, p. 215, any test current employed would show a certain permanent definite deflection on the galvanometer, due to the passage of such current through the fuse itself. Any increase in this deflection would indicate a fault in the insulation of the electric cable, and the extent of such fault would be roughly determined by the amount of deflection of the needle. Its position could not be determined in the manner described for the circuit-breaking system, even with very delicate instruments, because the nature of the fuse precludes the use of any considerable battery power for testing purposes, and there is a permanent passage for the current to earth, through the fuse, at a point considerably below the surface of the water, where it would be impossible temporarily to insulate for testing purposes without bringing the entire charge to the surface, a proceeding entailing much trouble, and to avoid which is one of the principal objects of test of this nature.

A want of conductivity in the conductor of the electric cable would be indicated by a cessation or considerable diminution of deflection in the galvanometer. To test the conductivity of the portion of the electric cable between the charge and circuit-closer on a branch, as in Fig. 89, it would be necessary to send a boat out and close the circuit by running against it.

If a circuit-closer were employed beyond the fuse, a defect in the electric cable would be indicated by a deflection of greater or less amount on the galvanometer. If a fuse of high electrical resistance were employed in such a combination, it would be extremely difficult to detect a defect in the insulation of the cable beyond it. A want of conductivity in such a combination would not be indicated on the galvanometer on the application of a testing-battery current, and the efficiency of the system, in this respect, could only be determined by sending out a boat to strike the circuit-closer, on which, if the conductivity were good, the galvanometer needle would be deflected.

Mode of determining extent of fault, employed by Lieutenant Fisher, R. N.

One mode by which the extent of a defect in an electric cable may be roughly determined is given by Lieutenant (now Commander) Fisher, R. N., in his work entitled "A Short Treatise on Electricity," as follows:

"Depolarize the main and earth wires by connecting them, thus neutralizing the free electricity. After some minutes, test the depolarization by again making contact between earth, galvanometer, and main wire; if no movement of the needle takes place, the neutralization is complete. Attach earth wire to test-battery, and with the other pole of test-battery make contact with main wire (counting 'one') and then immediately remove it. Now the earth and main wires are slightly polarized, so see if the 'return current' can be obtained by attaching them to the galvanometer. If the needle moves now, it indicates a large fault; for the wires were not connected with the test-battery for much more than a second. If the needle does not deflect, repeat the operation; leaving the wires this time a little longer in the closed circuit, and so on until the return current is obtained.

"It will be obvious, from what has been said, that the longer the test-battery is in the circuit before the 'return current' is obtained, the smaller will be the fault."

The current called the "return current," obtained in this case, is due to the polarization of the exposed metallic conductor of the electric cable; and when a minutely small surface of metal is thus exposed, the momentary circulation of the current does not produce sufficient polarity to establish such a current as would deflect the needle of the galvanometer.

It must be borne in mind that, with the platinum-wire fuse, a very considerable defect in the insulation of the cable, between the fuse and the firing-battery, (as much as 24 inches of bare conductor, see page 88,) does not prevent the charge being fired by the application of additional battery cells; while a very small defect ($\frac{1}{16}$ of an inch for example) in the same position would be fatal to the tension-fuse, which could not be fired under such circumstances without a very large increase of battery power. The discovery of the extent of a defect in the insulation is a matter of considerable importance at all times, but especially when a tension-fuse is employed. A small defect in insulation beyond the fuse would not be of much importance if a platinum-wire fuse were used, but with a tension-fuse a minute defect in such a position would make a sufficient earth connection to fire the fuse, if the firing-battery were put in circuit. With a platinum-wire fuse and circuit-breaking system, a very large defect in the insulation of the electric cable would probably stop the power of signaling by means of the shutter apparatus, but would not prevent the charge being fired. With a tension-fuse and circuit-closing system, a very small defect in the insulation of the cable would not only prevent signaling by means of the shutter apparatus, but, if it existed between the firing-battery and fuse, would inevitably prevent the firing of the charge. Taking into consideration the relative practical working of the two systems, our present experience seems to indicate that a platinum-wire fuse, in combination with a circuit-breaking system, is most easily tested, and less liable to be rendered practically ineffective, than the tension-fuse combined with a circuit-closer. With the latter, too, the sea-cell is not so applicable for testing purposes, in consequence of the high electrical resistance of the fuse.

A defect of insulation not always fatal when a platinum-wire fuse is used. With a tension-fuse it is always a serious consideration.

When a defect has been found to exist in any part of the system, it should be taken up and repaired with the least possible delay, unless the presence of an enemy or some other imperative cause interfered to prevent it. With this object in view, arrangements are made to admit of raising the charge and circuit-closer (or circuit-breaker, as the case may be) with facility. Should a defect exist in the electric cable it should be under-run, and if it be a defect in insulation, its position may be discovered by keeping a test battery in connection with it during this process, and the moment the defect was lifted out of the water, its position would be indicated by a sudden reduction in the deflection of the galvanometer needle, as described in the tests of electric cables, page 246.

A defective charge or cable should be at once taken up.

Electrical instruments used in testing.

The instruments adapted for testing purposes are the reflecting electrometer, the reflecting, astatic, detector, and differential galvanometers, Wheatstone's bridge, resistance coils to 10,000 B. A. units, (or ohms,) the thermo-galvanometer, rheostat, and a few battery-cells of size adapted to the tests to be applied.

Reflecting electrometer.

The reflecting electrometer is a very delicate instrument, requires very careful handling, and can only be used by a practiced electrician. Its use must therefore be restricted to important stations and special tests of a delicate nature.

Reflecting galvanometer.

The reflecting galvanometer is also a very delicate instrument, adapted for fine tests of a delicate character; it suse may therefore also be restricted to important stations where delicate tests are required.

Astatic galvanometer.

The astatic galvanometer, though less delicate than the reflecting instrument, is very sensitive and is applicable to very fine and delicate tests. It may be made in a very compact and portable form, and should be supplied to all stations where submarine mines are used for defensive purposes.

Detector galvanometer.

The detector galvanometer is generally made with a vertical needle, and is used for all the rougher tests requisite for submarine mines. For this purpose it should be made as sensitive as possible, commensurate with small size and portable form. An insensitive detector galvanometer is of no use for the tests employed in connection with submarine mines. These instruments should be supplied to all stations.

Differential galvanometer.

The differential galvanometer is an extremely useful instrument for electrical purposes. The results obtained with it are very accurate, generally sufficiently so for all purposes connected with submarine mining operations. Two instruments of this nature have recently been devised, viz, Latimer Clark's, double shunt differential galvanometer, and the post-office pattern differential galvanometer, the latter designed by Mr. Becker, electrician to Messrs. Elliott Brothers. A diagram of the connections of Latimer Clark's instrument is given in Fig. 104, page 252. It is extremely portable and capable of being used in a great variety of combinations as described in Mr. Latimer Clark's very excellent hand-book on electrical measurements. The post-office pattern instrument is very similar in principle to Latimer Clark's. It differs in having only one shunt, and in being constructed with a suspended needle, instead of one working on a pivot. It is a more delicate instrument than the former, only inasmuch as the principle of suspension is a more delicate combination than that of a pivot, other details of construction being similar. It is not so portable as Latimer Clark's instrument, and cannot be used in a boat, or in any position where there is no steady foundation to put it on. A good differential galvanometer should be supplied to all where submarine mines are employed for defensive purposes.

Wheatstone's bridge or electrical balance.

The well-known application of the division of electrical currents for testing purposes, devised by Professor Sir Charles Wheatstone, and called "Wheatstone's bridge," is an extremely delicate apparatus for the measurement of electrial resistance in all cases into which the balancing process enters. In combination with the reflecting galvanometer, it is extensively used on all submarine lines of electric telegraph. The information afforded is similar in character, though more minutely accurate than that obtained with the differential galvanometer. Its employment may therefore be restricted to the more important stations and more delicate tests required for submarine mining purposes.

Resistance-coils.

Resistance-coils, capable of measuring up to 10,000 ohms, (B. A. units of electrical resistance,) should be supplied to all stations in which submarine mines form a part of the defense. Resistance-coils are necessary in most of the tests described, either in combination with the differential galvanometer or with Wheatstone's bridge and the reflecting galvanometer. They are made in two forms by Messrs. Elliott Brothers, either combined with Wheatstone's bridge, or in a smaller and more compact form, consisting of the resistance-coils alone without the bridge.

Thermo-galvanometer.

The use and construction of the thermo-galvanometer, as designed by Colonel E. W. Ward, R. E., is given in *The Course of Instruction in Military Engineering*, page 140, paragraph 302. This instrument should be supplied to all stations where the platinum wire fuse is used as the electrical igniting agent.

Rheostat.

An ordinary rheostat is an extremely convenient instrument for use with the thermo-galvanometer, and should be supplied with it to all stations.

Testing-batteries.

Testing-batteries generally consist of a few Daniell's or other similar cells, of small surface, and should be made in a portable form arranged in a wooden case. The nature of testing-batteries must be adapted to the nature of the tests to be applied. Where Abel's fuses are used, a current of small quantity and low electro-motive force must be applied, and Mr. Abel has designed a very compact form of sand battery with this object in view. In this battery, one or more cells may be rapidly introduced into the circuit, by the insertion of a contact-plug provided for the purpose.

Three or four testing-batteries, suited to the nature of the combination employed should form a portion of the equipment of every station where submarine mines are used.

Coils of instruments and apparatus must be suited to the nature of testing currents applied.

In all cases, the coils of the instrument and apparatus must be suited to the nature of the battery power used for testing and working purposes. Where a tension fuse is employed, fine coils, composed of a considerable length of insulated wire, are essential, so that the comparatively small currents, necessarily employed in testing, may produce a sufficient deflection of the galvanometer needle. On the other hand, when a platinum wire fuse and quantity-battery is used, coils composed of large and thick wires must be employed, because the current of a quantity-battery would destroy the coils of any instrument composed of fine wire, if passed through it for an instant.

Qualification of officers and men employed.

The officers, non-commissioned officers, and men employed in working any system of submarine mines must be thoroughly instructed in electricity, and further be well up in telegraphy, visual signaling, and in the use and management of boats and mooring apparatus. It has been found that the course of instruction necessary to qualify thoroughly for this service occupies a period of about six months.

Numbers and constitution of detachment.

A detachment for work with a system of submarine mines should consist of one officer and twenty thoroughly instructed non-commissioned officers and men. This may be considered as the unit, and one or more such detachments would be required according to the extent of the work to be performed. Five such detachments would form a company.

CHAPTER XIV.

CLEARING CHANNELS OF SUBMARINE MINES.

The best method of clearing a channel defended by submarine mines, though more a naval than a military question, is one concerning which a certain amount of knowledge is requisite for all engaged in the use of machines of this nature.

Use of passive obstructions combined with submarine mines.

Passive obstructions, in the shape of booms, nets, &c., would generally be used to check an enemy's operations against the mines, and to impede boats and small vessels in their approach toward them. In their project for the defense of Venice, in 1866, the Austrians proposed to place a light boom in advance of their outer group of mines with this object in view.

Mode of clearing channel by small boats followed by larger vessels.

The hostile removal of submarine mines implies the absence of guard-boats and of land defenses, or the inability of the latter to see the operation owing to the darkness or fog. Where electrical igniting apparatus is suspected, the banks of the river or roadstead would, if possible, be searched with a view to intercept the wires. The advanced booms and nets, if any, would be blown up, or, if secrecy be an object, cut, or turned by boats rowing round their shore ends. Lines of boats would then advance in couples, towing small hawsers between them weighted about the center, with a view to sweep the suspected waters for buoyant mines and circuit-closers, their own light draught giving them sufficient immunity. When a submarine mine or circuit-closer was thus caught, a signal would be made to other boats to avoid the locality, while the two boats concerned, crossing the ends of their hawser, would cautiously pull the mine up to the end of a long outrigger, (or davit,) and, carefully cutting the mooring rope, tow the mine into shallow water. Other lines of boats might follow, dragging small grapnels, in the hope of intercepting the wires of such ground mines as were unprovided with circuit-closers. The channel being thus partially cleared, small steam-vessels might advance in pairs, dragging between them large hawsers, weighted with chains and armed with grapnels; while pushing some sixty feet before each vessel a submerged framework, armed with hooks and nets, extending below the keel and beyond the broadsides, which might intercept and explode harmlessly the usual mechanical submarine mines. Even with very slow speed and every precaution great danger would be incurred for steam-vessels in the case of circuit-closers attached to ground mines, as the former might be dragged forward by the projecting frame and close the circuit when its mine was actually under the bottom of the ship. The breadth of channel so cleared should be carefully marked to prevent advancing vessels passing over unsearched ground. It is obvious that such operations could only be undertaken in undefended and unguarded waters. And it is worthy of remark that most of the United States vessels destroyed by submarine mines were lost while advancing in waters previously dragged or otherwise examined by boats. The introduction of electrical apparatus increases the difficulty of clearing channels, and too much precaution cannot be observed in navigating waters which are supposed to have been defended by submarine mines, even after they have been most carefully searched. If advanced booms or nets are not used by the defense, barges or rafts, with submerged frames to give deep draught, might be employed to drift over the suspected waters, with a view of exploding the mines by contact, should the conformation of the river or roadstead admit of it. If the tidal stream be very strong, light grapnels might be dragged over the bottom by these drifters, with a view of fouling the electrical cables or mooring ropes should the nature of the ground favor the proceeding. It is evident that a rough or rocky bottom, or the employment, by the defense, of a heavy chain laid across the channel in advance of the mines on hard ground might convert the grapnels into anchors, and thus defeat the primary object of exploding self-acting mechanical mines by contact. In many places, in the Medway for example, a heavy chain would soon sink into the mud, and become as far covered as to offer a small chance for catching the grapnel; under the same conditions, however, the electric cables would equally sink into the bottom and be less likely to be fouled.

Projecting frames or nets carried in advance of a vessel's bows.

In their operations against the confederates, the Federal fleets in many cases used projecting frames and nets, in front of the bows of the leading vessels, in which the submarine mines, arranged for mechanical ignition, were intended to be caught without danger to the ships. Notwithstanding this precaution several vessels were sunk and damaged. In many cases the charges were not fired at all, but this was due more to the failure of the igniting apparatus than to any special value attaching to the mode in which the machines themselves were caught; with the more efficient means we now possess for finding mechanical mines, combined with the vastly increased size of the charges proposed to be employed, it is probable that this mode of clearing a channel would be a far more dangerous and difficult operation; the mines would be fired with far greater certainty, and their radius of destructive effect would be so much increased as to necessitate a frame, extending to a much greater distance in front of a vessel than those used in the operations alluded to.

In the case of mines fired by electrical agency, the danger to a vessel using a projecting fender would be still greater if circuit-closers, in connection with ground mines, were to be attacked. In such a case the circuit-closer only would be caught by the fender, and the vessel would be more or less over the actual mine, when the collision, with its consequent explosion, would take place.

Fenders of this nature should, in all cases, be constructed to extend to as great a depth as possible below the water level, so as to catch mines and circuit-closers not only near the surface but to a considerable depth below it.

The course adopted by the Federal fleet, in searching channels for submarine mines, was first to send forward boats to drag for them and to follow the boats up with vessels fitted with fenders of the nature described. This system seems to be that best calculated to insure success.

Suggestion for the use of train mortars, fired simultaneously, in searching for mines.

The following mode of operation, which may or may not be capable of practical employment, is suggested for the consideration of naval and artillery authorities. It consists in simultaneously firing a couple of mortars, pointed in such a manner as to cause their shells to diverge from each other, by electricity, using very small charges of powder, only just sufficient to give a range of 400 or 500 feet; and having previously attached a chain to each of the shells, and another connecting the two shells together, the effect would be to cast the chains out and inclose a certain area. By hauling on the two extremities of these chains, any mine within that area would be caught and probably injured or destroyed. In certain parts of the world, at Bermuda for example, the sea water is so extremely clear that, in fine weather, such an object as a submarine mine would be easily distinguishable from a vessel's tops at a considerable distance and at a great depth; in such a case this mode of clearing a channel, by throwing out a chain attached to a couple of shells, might be successfully employed. Very clear water would be a favorable condition, as regards the search for submarine mines, whatever mode of proceeding may be employed.

In this, as in all operations of a similar nature, the same difficulties, as regards interruption caused by the fire of guns defending the system of mines, would still exist.

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To be effective it is probable that a specially fitted vessel and a special crew would be required. Such an operation would be comparatively easy if the mortars were fired from the shore or from a vessel anchored in a harbor in smooth water, but it must be borne in mind that, to be effective, it should be capable of being used in moderately rough water and from a vessel not necessarily at anchor.

Clearing a channel by submarine explosions.

Another method, which has suggested itself in the course of experiments carried on at the school of military engineering, Chatham, during the autumn of 1870, is to fire large charges of gun-cotton in positions which are supposed to be studded with submarine mines, with a view to destroying any charges which may be within the radius of explosive effect; to proceed, in point of fact, on the same principles which have been found effectual in attacking a land fortress defended by counter-mines. The experiments made last autumn demonstrated that a charge of 432 pounds of gun-cotton, fired under a head of between 40 and 50 feet of water, destroyed and rendered ineffective a series of mines placed in its vicinity, to a radial distance of at least 120 feet from the point of explosion. It would not be difficult nor tedious to carry on a series of explosions, of charges of 500 pounds of gun-cotton, with a little previous preparation. They might be easily maneuvered and fired from an ordinary steam-launch,. and two or three of these boats moving abreast, firing their charges, and gradually advancing over the ground thus made good, would in time clear a channel sufficiently wide to admit of the safe passage of the largest iron-clad. During such an operation these boats would, no doubt, be fired on by the guns covering the mines, and it would be absolutely necessary to cover them to the utmost extent, by the guns of the attacking force. The night or foggy weather would be the most favorable time for operations of this nature.

A slow speed to be employed by vessels searching a channel.

In whatever way a boat or vessel may be employed in searching for submarine mines, or whatever may be her size, it is of the utmost importance that she should move as slowly as possible—in fact, with the least possible speed, commensurate with efficient steerage-way. In moving it at a slow speed she would be less likely to explode a charge by contact, and would be more easily checked if found to be getting into danger.

The clearing of a channel defended by submarine mines, would, under any circumstances, be a tedious and dangerous operation, and the delay thus incurred could not fail to be of immense advantage to the defense, even if every ship and boat in the enemy's fleet escaped injury.

CHAPTER XV.

LOCOMOTIVE TORPEDOES.

We now come to the locomotive class of machines for producing submarine explosions, adapted for use in offensive warfare. These are more especially a naval arm, and to them the term torpedo is properly applicable. They may be divided into three classes :

Outrigger torpedoes.

1st. Those to which motion is given by a ship or boat to which they are attached, and from which they may be maneuvered.

Projectile torpedoes.

2d. Projectile torpedoes, or those possessing in themselves the power to move through the water, when once started, in any particular direction.

Drifting torpedoes.

And 3d. Drifting torpedoes, or those dependent for their motion on the tide or current of a stream. All three classes are applicable, generally, for the attack of vessels at anchor or in motion, booms or obstructions of any sort, ponton bridges, &c.; some forms may be most effectually used against stationary, and others against moving objects to be attacked.

To the first class belong those projected from a boat or ship by means of a spar or outrigger, as well as Harvey's towing torpedo, and all similar contrivances.

To the second class belong those propelled by compressed air, as Lupin and Whitehead's torpedo; those to which motion is given by means of a rocket composition, as suggested by Mr. Lancaster, the gun-maker, and Mr. Quick, engineer, royal navy, and all similarly propelled.

To the third or drifting class belong McEvoy's torpedo, Lewis's torpedo, and those of a similar nature.

The idea of attacking vessels by means of boats, either specially constructed for the purpose, or with the apparatus adapted to existing forms, appears to have originated with Fulton, in 1803; it was, however, considerably developed and brought into a practical working form during the civil war in America.

Special outrigger torpedo boats employed by the confederates.

The confederates made and used several special boats, some propelled by steam or by a screw propeller, worked by manual labor, to carry a torpedo attached to a spar or projection in front, to be exploded in contact, or nearly so, with the hull of the vessel to be attacked. The specially constructed boats were provided with water-tight compartments, and when these were filled the whole was so far submerged as to show very little above the surface of the water. The general results obtained with them were unsatisfactory; they were very dangerous to navigate in a sea, and one which had already sunk four times, drowning four crews, finally went down with a fifth crew in destroying the United States corvette, "Housatonic," off Charleston, South Carolina, on the night of the 17th of February, 1864. The corvette was sunk, but nothing was ever again heard of the torpedo-boat. This was the only successful attack out of five attempts made by the confederates with boats of this nature, and the results were so discouraging that they turned their attention to the use of ordinary ship's boats for this service.

Outrigger torpedoes fitted to ships and boats of ordinary construction.

The results as regards ship's boats carrying torpedoes on outriggers or spars, to be pushed out and fired in close proximity to a vessel's hull, were more satisfactory. Several steam-launches were adopted for service in this way by both Federals and confederates. Their general arrangements consisted of one or more long spars, to the extremities of each of which a torpedo was attached, carried in such a way as to be readily pushed out from the bow of the boat immediately before the absolute moment of attack, the charge being fired by the percussion of a self-acting mechanical fuse on the hull of the enemy's vessel, or by means of an arrangement fired by a trigger line; this latter combination was generally employed by the Federals. The confederate torpedo-boat "Squib," which attacked and so seriously damaged the United States frigate "Minnesota," lying at anchor in Newport News, at 2 a. m. on the morning of the 9th of April, 1864, was a steam launch fitted in this way. A very good account of this operation is given in Captain Harding Stewart's *Notes on Submarine Mines*. The torpedo-boat, with which Lieutenant Cushing, of the United States Navy, successfully attacked and destroyed the confederate ram "Albemarle," which was, at the time, alongside the wharf at Plymouth, eight miles above the mouth of the Roanoke River and carefully protected by a strong timber boom and other obstructions, was an ordinary man-of-war's steam-launch. A good account of this very daring enterprise, which was carried out at 3 a. m. on the 28th of October, 1864, is given in a book entitled *Submarine Warfare, Offensive and Defensive*, by Commander Barnes, United States Navy, page 142. In this latter work, at page 154, there is also a very good account of the United States torpedo-vessel

Results obtained more satisfactory.

"Spuyten Duyvil," of 200 tons, especially designed for use with an outrigger torpedo to be pushed out, below her water line, through a water-tight opening in her bow. This vessel is very completely fitted up, but no opportunity has hitherto occurred of trying her against an enemy's vessel. The construction and general arrangements of the "Spuyten Duyvil" were condemned by the committee on floating obstructions, as may be seen from the following extract from their report, page 138: "In the beginning of 1865, the plans of Mr. Wood's outrigger torpedo apparatus were offered to Her Majesty's government, but a careful examination confirmed the opinion originally entertained as to the too complicated nature of the machinery. The arrangement for giving lateral motion to the outrigger is obviously unnecessary, inasmuch as this may be accomplished by the use of the helm; it is also dangerous, because it renders the outrigger liable to get across the stem at high speeds, when the spar might snap, the torpedo being thus under the bottom. The separation of the torpedo from the outrigger before exploding, as proposed, would involve the danger to the operating ship of advancing within the sphere of its destructive action when the explosion takes place. The committee therefore fully concur in the opinion expressed by Rear-Admiral A. Cooper Key, C. B., then captain of Her Majesty's ship 'Excellent,' that this plan 'is not worth adoption, or even of trial with a view to adoption in our Navy.'" In addition to this vessel the United States possessed a number of steam-launches, each carrying one 12-pounder boat howitzer, and a crew of 15 men, fitted for outrigger torpedo service, the torpedoes being carried on spars resting on crutches, and ready to be run out and fired at short notice. Six low free-board monitors were also similarly fitted.

Spuyten Duyvil, construction disapproved by committee on floating obstructions.

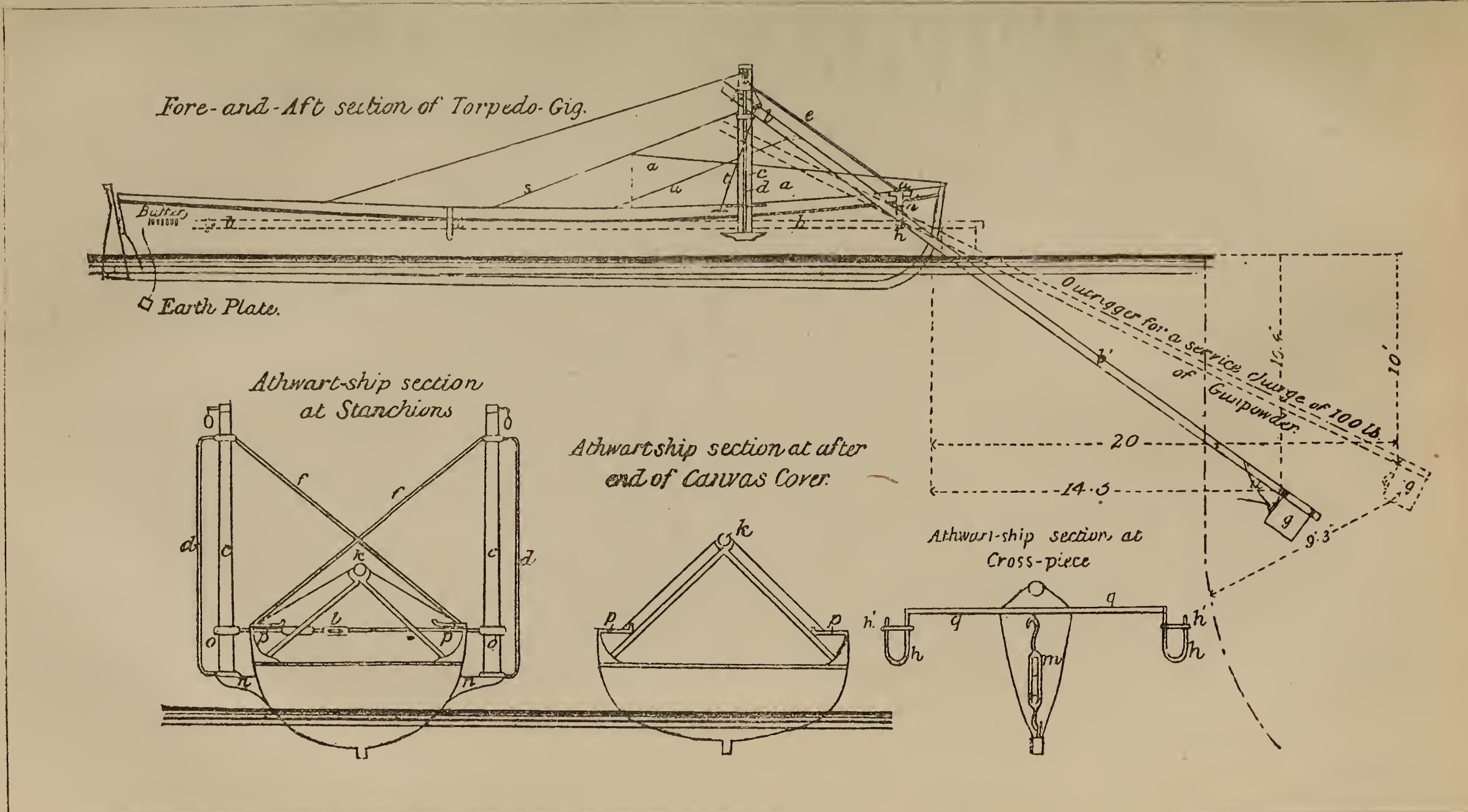
No attempt has been made in this country to fit up any special vessel, such as the "Spuyten Duyvil," for offensive torpedo service, our naval authorities being, it is understood, of opinion that such operations as the attack of a vessel by a torpedo-boat would be similar in character to the cutting out of a ship at anchor in an enemy's harbor, which was so successfully performed during the French wars in former times; they therefore propose to adopt boats and small vessels, of classes already existing in the Royal Navy, for this service. The following description, extracted from a book entitled "*A Short Course of Electricity*," by Lieutenant (now Commander) Fisher, R. N., late instructor in electricity and torpedoes on board Her Majesty's ship "Excellent," gives a good idea of the arrangements proposed as most suitable for the purpose required.

Fittings of Excellent's steam-launch for torpedo service.

"A general description will be given of the manner in which a steam-launch and gig are fitted in Her Majesty's ship "Excellent" for torpedo purposes, as shown in Fig. 109, both giving most successful results.

"The fore part of the boat is covered over with a canopy, which is spread over a fore-and-aft pole, resting on two wooden crutches, and is tightly laced down to a foot-board that extends round the fore part of the boat, just inside the gunwale, to allow the crew to work outside when required. At about two feet abaft the stem a projecting cross-piece is secured to both gunwales, having at either end an iron crutch, in which rests the outer part of the torpedo-pole when not in use, and which serves as a fulcrum for the pole when rigged out; a pin across the crutch prevents any chance of the pole being lifted out of it. An upright, similar to a rocket stanchion, ships into a step on either side of the boat, outside of the gunwale, and is secured to it by iron clamps; these stanchions, which are about six feet in length, have attached to, and projecting from, their exterior sides, an iron rod, the torpedo-pole working between the iron rod and the stanchion, so that when the heel of the torpedo-pole is triced up to the head of the stanchion, (thus rigging it out and at the same time submerging its outer extremity,) the pole is confined between them, and thus any lateral movement is prevented.

"The rigging-out rope of the torpedo-pole is led from the stern-sheets through a small block at the head of the stanchion, and made fast to the pole about a foot from the heel. A back rope is secured to the heel, for the purpose of easing out the pole, and of rigging it in again when required. When the poles are rigged in, their heels rest on crutches on the outside of the after part of the boat. The height of the stanchion, its distance from the fulcrum-crutch, and the length of the pole, depend on the depth to which the torpedo is required to be submerged and on its charge; but appended are the dimensions of the "Excellent's" torpedo-gig and fittings, constructed to admit of 50 pounds of gunpowder, submerged nine feet, being fired with perfect safety to the boat and its crew. Such a charge so placed, we know from experiment, would inflict irreparable damage on any ship as at present constructed, if exploded in contact with her bottom; and as it is probable that the horizontal section of its ellipsoid of destruction at the depth of nine feet would not be less than a circle of five feet radius, great mischief would doubtless be caused by it even when not exploded in perfect contact, but within the assumed five-feet limit.


Fore-and-Aft section of Torpedo-Gig.
Earth Plate.
Outrigger for a service charge of 100 lb. of Gunpowder.
20
14·5
15·4
10
9·3
Athwart-ship section at Stanchions
Athwartship section at after end of Canvas Cover.
Athwart-ship section at Cross-piece

"The 'Excellent's' steam-launch, fitted up in a similar manner, carried a torpedo charged with 100 pounds of fine-grained powder, the only exceptions to the torpedo gig arrangements being that it was submerged to a depth of 10 feet, and the torpedo when in position was 25 feet (instead of 17½ feet) from the stem, in the direction of the pole. No water was shipped on the explosion being effected, nor was there the slightest inconvenience of any sort experienced.

Dimensions of torpedo gig and fittings.

Length of boat	30 feet.
Beam	5½ feet.
Length of canopy	10¾ feet.
Distance of cross-piece from stem	2 feet.
Length of poles	28 feet.
Thickness of butt-end of poles	4½ inches.
Length of stanchion	6 feet.
Distance from stanchion to the cross-piece in stem	5 feet.
Distance from after crutch to stanchion	10¾ feet.

"Each stanchion is supported by two ⅝-inch iron stays, one going to the opposite gunwale and the other supporting it in a fore-and-aft direction."

Rear-Admiral A. Cooper Key, C. B., F. R. S., then director general of naval ordnance, remarked upon the above apparatus and experiments: "That it would be rarely advisable to risk a boat's crew for the purpose of using a charge of 40 pounds, which must be placed in *actual contact* with the bottom of the ship it is intended to destroy. The uncertainty attending such an attempt must lead to failures. I consider that 100 pounds of gunpowder, or its equivalent in gun-cotton, *is the least charge* that should be used."

The use of such service-charges would involve a greater strength in the apparatus and longer poles.

Description of fitments.

Fig. 109 is copied from the *Report of the Committee on Floating Obstructions* in the following description as extracted from it: (*a*) shows the canvas covering, (*b*) the outrigger rigged in, (*c*) a stanchion, (*d*) the guide rod, (*e*) the fore-and-aft stays of iron, (*f*) the stays athwart-ships, (*g*) the torpedo for 40 pounds of gunpowder or 10 pounds of gun-cotton; (*g'*) the torpedo for 100 pounds of gunpowder, and 25 pounds of gun-cotton; the dotted lines show the arrangement of boom recommended by the committee on floating obstructions, the firm lines the form adapted for a charge of 40 pounds of powder only, (*h*) the foremost crutch, (*h'*) the pin to retain the outrigger in the crutch, (*i*) the after crutch, (*k*) the fore-and-aft mooring pole, (*l*) the securing screw of the stanchion, (*m*) the securing screw of the cross-piece, (*n*) the step for the stanchion, (*o*) the securing clamp for the stanchion, (*p*) the foot-board, (*q*) the cross-piece, (*r*) the topping-lift, (*s*) the inhaul, (*t*) the outhaul, (*u*) the conducting wire.

"Only one outrigger should be placed in position for action at a time, otherwise the first explosion might injure the other torpedo.

"It would be necessary to impart increased strength to these fittings to enable them to withstand the explosion of serviceable charges of 100 pounds and upward of gunpowder. In an experiment of this description material injury was sustained by the apparatus.

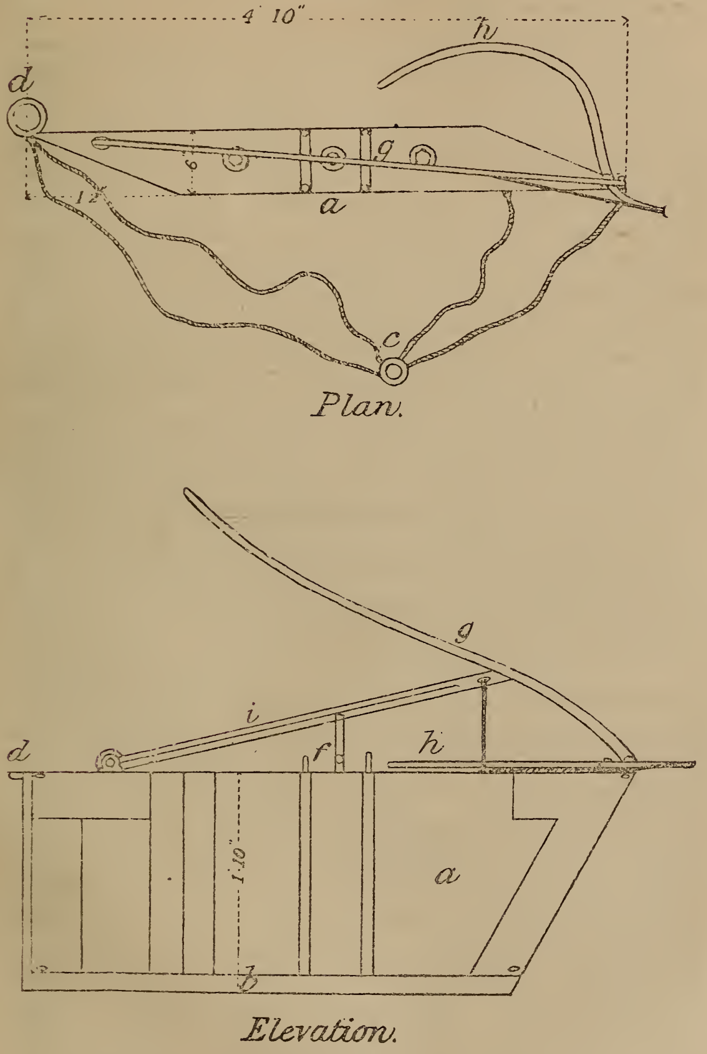
"The dotted line thus — - ——- - — - — represents the computed area of principal destruction of 100 pounds of gunpowder at the depth of greatest effect."

Outrigger torpedoes are applicable for the attack of booms, ponton-bridges, vessels at anchor or moving very slowly, and similar objects.

Harvey's sea torpedo; description.

Harvey's sea torpedo also belongs to the first class of weapons, being maneuvered from a ship in motion. It is a joint invention of Captain John Harvey and Commander Frederick Harvey, R. N., and consists of a case (*a*) of No. 18 B. W. G. sheet-copper, of the form shown in Fig. 110. This case may be made of any size; the dimensions, as shown in the figure, are those calculated to contain a charge of 76 pounds of gun-cotton, or an equal bulk of other explosive. This charge would be sufficient to sink any vessel if fired in contact with her hull, and is of convenient size to work with facility from a ship's deck. The form adopted is similar to the machine called an "otter," used by poachers for fishing purposes, and its mode of propulsion through the water is identical therewith. Outside the sheet-copper, which forms the internal water-tight portion of the apparatus, is a thick wooden casing strengthened with iron plates, to preserve the former from injury. To the bottom of this wooden casing is attached a keel of iron, (*b*,) with a leaden covering on the lower side, to keep the apparatus upright while floating in the water. The weight of iron used is regulated by the speed of the vessel from which the torpedo is to be maneuvered, and it should be sufficiently great to sink the whole apparatus when complete with charge, &c. This capacity to be submerged at will is essential to the proper maneuvering of the apparatus, and, when the towing line is cut away, its effect is to sink the whole to the bottom, and thus prevent chance of injury to a friendly vessel. Lines are arranged, as shown at (*c*,) to enable the torpedo to be towed at an angle diverging about 45° from the direction of the course of the vessel from which it is worked. The towing line is composed of several strands of galvanized steel wires over a hemp core, forming a $1\frac{1}{4}$-inch wire rope. The towing line passes through a ring in connection with the guiding ropes (*c*,) thence through another ring (*d*) on the stern of

Fig. 110.



the apparatus, and is connected with a buoy, arranged to prevent the torpedo sinking too deeply for subsequent work during any temporary slackening of the towing line. A knot on the towing line prevents the buoy being drawn too closely up to the torpedo, but being beyond the ring (*d*,) directly the towing line is cut at any point, the latter slips through, and the torpedo itself is disengaged and sinks.

Nature of explosive used.

The charge of gun-cotton or other explosive is contained in two compartments within the sheet-copper case which is divided in the middle. A loading hole, 1½ inches in diameter, to be closed by a water-tight screw plug, is provided for each compartment.

Mode of firing.

The charge is arranged to be fired by means of a metal bolt (*f*) in connection with a sulphuric acid fuse. When the bolt is forced down it breaks a glass vessel containing sulphuric acid, which, falling on a chemical mixture, produces heat and fires the priming of the fuse, which in its turn ignites the charge. The priming charge is contained in a vertical copper cylinder, placed in the center of the torpedo, and only divided from the two sections of the charge by the thin metal of which the cylinder is composed. The fuse piece, with firing-bolts, &c., complete, is carried separate from the charge, and only screwed into it just before the torpedo is launched overboard for the attack of a vessel. The firing-bolt is provided with a safety-key, passing through a hole in the former, and till it is removed the bolt cannot be pressed down and the charge cannot be fired; this key is drawn out by means of a line attached to it and veered out from the ship simultaneously with the tow-line. The firing-bolt may be arranged to explode the fuse on any given pressure being applied; for this purpose a pressure of about 60 pounds has been found to be convenient. The pressure required to withdraw the safety-key should be arranged at about 30 pounds. Pivoted on the bow of the torpedo are two levers (*g*) and (*h*,) one (*g*) passing vertically over it toward the rear, the other (*h*) on the side of the apparatus which is most likely to come in contact with the vessel to be attacked, always on the opposite side to the directing lines (*c*.) The lever (*g*) is arranged over the head of the firing-bolt; on coming in contact with the bilge of a vessel, it would be pressed down, carrying with it the lever (*i*) and the firing-bolt, which would break the glass capsule containing the sulphuric acid, and thus fire the fuse and consequently explode the charge. The lever (*h*) performs the same office when acted on by side pressure against a vessel; when pushed in toward a topedo, it draws in a lanyard in connecwith the lever (*i*) and pulls this latter down, acting on the firing-bolt with the same result as before.

Different forms of torpedo required for each side of ship.

Different forms of torpedo are employed for each side of the vessel, the lever (*h*) being always so arranged as to be on that side of that apparatus which, when floating in the water, is away from the ship from which it is maneuvered, the tow-lines being on the side nearest to the vessel.

Mode of maneuvering.

In order to maneuver torpedoes of this nature, the ship should be provided with a couple of drums, with brakes attached, on either quarter. One of these drums carries the tow-line, the other the safety-key line, which are veered out uniformly together; they should be of such dimensions as to hold a length of 240 fathoms of each. To attack a vessel the proper torpedo is launched overboard by its towing-line and gradually veered out to any distance required, usually about 150 yards, the vessel being kept in motion during the whole process. The brake is then put on, which has the effect of bringing the torpedo to the surface and carrying it along in a line parallel to the ship's course and diverging from her quarter at an angle of 45 degrees, and at any distance from 150 yards upward, that may be required. A reserve of about 150 yards of line is kept on the drum for future use. The torpedo is visible from the deck of the vessel using it during the whole of this operation, and its approach toward the vessel to be attacked may be readily watched. As it approaches its object the safety-key is withdrawn by means of the line provided for the purpose, the brake is relaxed, and, the pressure on the towing-line being thus removed, the torpedo sinks for a moment, the brake is again applied just at the time when it is supposed the torpedo is under the vessel to be attacked, it rises in consequence of the pressure thus applied to the towing-line, comes in contact with the bilge, one or both levers are forced down and act on the firing-bolt, and the charge is fired.

Electrical mode of ignition.

Commander Harvey has applied Captain McEvoy's circuit-closer for firing his torpedo by electricity; he seems, however, to prefer mechanical ignition on contact, in consequence of the danger of fracture or injury to be apprehended in veering out the insulated conducting wire, which must be made in the center of the towing-line and consequently be subjected to a considerable strain. He is of opinion, moreover, that electrical ignition would not, under any circumstances, be so certain in its action as mechanical action.

Most useful application.

Experiments with this form of torpedo have been carried on by the government at Portsmouth and Plymouth, and it was maneuvered with great success. To render it thoroughly efficient, however, in rough water and in the open sea, much skill and practice are necessary. This apparatus is adapted for the attack of vessels at anchor or in motion, but it is in the latter service, either in a rough sea or smooth water, that its peculiar advantages are most apparent. It has been approved by our naval authorities, and is about to be issued to some of Her Majesty's ships.

High speed essential in maneuvering Harvey's sea torpedo.

In order to maneuver this torpedo to advantage, Commander Harvey prefers a high speed. He is of opinion that it cannot act well at a less speed than six knots an hour. This fact has an important bearing in limiting its use, especially at night and in narrow waters.

The following observations, on the subject of outrigger torpedoes, are extracted from the *Report of the Committee on Floating Obstructions*, published in 1868:

Outrigger torpedoes.

"The success which appears to have attended the use of torpedoes as a means of attack by the Americans, led the committee, at an early stage of their labors, to devote considerable attention to the plans which were submitted for their consideration by Captain H. H. Doty and others, for projecting torpedoes from the bows of small steam-vessels by means of outrigger fittings.

"The plans suggested for the arrangement of outrigger torpedo steam-ships, among which the most efficient appears to be that proposed by Captain Doty, all involve the application of special machinery and fittings for the vessel, of more or less complicated and costly character, and it appeared to the committee, upon a careful consideration of the subject, that the objects for which the various mechanical appliances were designed could be sufficiently attained by easily extemporized devices of a comparatively very simple nature, readily adaptable to the many varieties of small vessels propelled by steam which are now constantly employed in all ports and rivers frequented by shipping.

Fittings suggested by the committee.

"In March, 1865, the committee submitted to the secretary of state for war, plans for applying extemporized outrigger fittings to small steam-vessels, and since that time they have endeavored to ascertain experimentally, with the assistance of the captain of Her Majesty's ship "Excellent," at Portsmouth, whether any obstacles presented themselves to the rapid application and ready manipulation of such outrigger fittings. Another object of their experiments has been to ascertain whether a torpedo containing a charge of gunpowder or gun-cotton, calculated to produce seriously destructive effects when exploded in close proximity to a ship's bottom, could be fired from a small vessel such as a steam-launch, if attached to the end of an outrigger spar, without risk of injury to the attacking vessel and her crew. The conclusions which the committee believe they are warranted in drawing from these experiments are as follows:

"(1.) One hundred pounds of gunpowder, inclosed in a sufficiently strong case for the proper development of its destructive action, can be manipulated with sufficient ease when attached to the end of a spar projected 25 feet from the bows of a steam-launch, and fitted with the gear described at page 151 and Plate XXXVIII, page 144.

"(2.) A charge of 25 pounds of compressed gun-cotton, which may be relied upon to produce a destructive effect equal to that of 100 pounds of powder, furnishes a considerably lighter and less bulky torpedo than the latter, and is therefore decidedly the most convenient for boat service.

"(3.) Either of the above charges may be exploded from a steam-launch, with safety to its crew and engine, if submerged at a depth of 10 feet below the surface, and fired at a horizontal distance of 20 feet from the launch. For this purpose the outrigger spar should project about 23 feet from the vessel.

"Some experiments are still needed for the purpose of determining whether, when the torpedo has been lowered and the outrigger spar fixed at the proper angle, the launch may be navigated over a moderate distance of water without difficulty.

Fittings for gigs and whale-boats suggested by Captain Hood.

"Captain A. W. A. Hood, R. N., of Her Majesty's ship "Excellent," has instituted some additional instructive experiments for the purpose of ascertaining whether much smaller craft, such, for example, as gigs or whale-boats, can be safely and effectively applied as outrigger torpedo boats, and the conclusion to which he has been led is, that charges exceeding 40 pounds of powder, submerged at a depth of 10 feet, cannot be exploded with safety from a 30 feet gig at a horizontal distance of 14 feet.

Size of charge for service.

"Though a 40-pounds charge, exploded at such a depth of immersion, might prove effective if in absolute contact with a ship, yet the committee are of opinion that the uncertainty which would attend the attempt to secure such con tact in the various contingencies of actual service must inevitably lead to failures, as it repeatedly did in the American experience. For this reason they consider that 100 pounds of gunpowder, or its equivalent in gun-cotton, is the least charge that should be employed. The explosion of such serviceable charges within a horizontal distance of 14 feet from the operating boat was never contemplated by the committee, but it is evident that these charges may be exploded with safety from any ship of war's boat capable of projecting a torpedo, at the extremity of an outrigger, to a horizontal distance of not less than 20 feet.

Rigging-out apparatus.

"Captain Hood has devised a very convenient arrangement for handling outriggers in small boats, which has the advantage of enabling a second torpedo to be brought very readily into action. Though no explosions have been made with 100-pound charges attached to this apparatus from boats smaller than a launch, the committee have reason to believe that it can be easily adapted for employment with such torpedoes, projected by outriggers of suitable length, from most of the boats carried by ships of war. In determining, therefore, the class of boat to which the outrigger apparatus should be fitted, it will only be necessary to select that which is best adapted for this service by its ability to carry the outrigger with ease, its speed and handiness, and by such other qualities as may be most suitable to the particular time and place of attack, whether it be by day or night, in a harbor or river, or in the open sea.

Simplicity in manipulation essential.

"The implements and manipulations connected with the explosion of outrigger torpedoes need only be of the most simple kind. Many plans have come to the notice of the committee for exploding this class of torpedoes by mechanical agency; thus it has been proposed to apply friction tubes to their explosion, a method of firing which embraces several elements of uncertainty; various mechanical arrangements, (some of which appear to have been used by the Americans,) to be fitted into the heads of the torpedoes, and to explode upon collision with the ship's side, have also been suggested, that of Mr. C. A. McEvoy being decidedly the best of this class of contrivances, but the committee consider that any mechanical arrangement for explosion by a blow must involve elements of danger or uncertainty: either the torpedo is liable to accidental explosion from a blow or fall in the course of the manipulation to be performed after the "exploder" has been fixed into it, or the latter must be provided with a safety-guard—the removal of which at the last moment may be neglected; moreover, the employment of such an arrangement would necessarily limit the direction from which a ship could be attacked with a prospect of success.

Simplicity in voltaic arrangements essential.

"The great simplicity to which the voltaic arrangements, required for boat service, have been reduced by the experiments conducted at Woolwich during last year under Mr. Abel's direction, has placed beyond doubt the advisability of exploding outrigger torpedoes exclusively by electrical agency. The simple pile battery, which is readily constructed and put into working order by seamen after a very brief instruction, is prepared from materials everywhere at hand, has no special fittings whatever, remains in continuous working order for at least 24 hours, and may be used in open boats in any weather. A small length of covered wire is all that is specially required in addition to this battery and the electric fuses for exploding the torpedoes, and even the coated wire and fuses, suitable for this simple boat equipment, may be extemporized on board ship. The only operation to be performed by the man in charge of the boat battery, in order to explode the torpedo upon receipt of the word of command, is to touch a metal plate on the battery with the end of the conducting-wire which he holds in his hand; but if it be desired to render the firing of the torpedo quite independent of any operator, and also to insure its explosion at the instant of its collision with the ship's side, it should be fitted with the electrical percussion-fuse, devised for that purpose by Mr. Abel. This fuse, which is perfectly harmless unless placed in an electric circuit, may be fitted to the torpedoes either in the boat or previously to their being placed on board. Just before the torpedo is lowered into the water, or before the outrigger is projected from the bows, one end of a conducting-wire is screwed into the fuse; as the boat approaches the vessel to be attacked, the other end of this conducting-wire is attached to the battery, (which is already connected to earth,) and the torpedo is then ready to be fired by collision with the ship.

"The committee entertain a strong opinion that the simple system of applying torpedoes by means of outriggers referred to in the preceding paragraphs, if carried out by men well trained in the management of the outrigger boat and its fittings, under cover of the night, is likely to prove a most formidable means of attack.

Experiments to test apparatus.

"It was deemed proper, however, to submit to actual experiment an expedient of this kind, suitable for the use of boats of ships of war; and on the 15th of May, 1866, a trial was made by the officers of Her Majesty's ship "Excellent," in concert with the committee. A small spar was inclined over the stem of the launch, so that the charge at its extremity was at the horizontal distance of 23 feet from the boat, and 6 feet below the surface of the water. The charge was inclosed in a ⅛-inch wrought-iron case, and consisted of 9 pounds 10 ounces of gun-cotton, which is equivalent to about 40 pounds of gunpowder. The boat was placed only 6 to 8 feet from, and holding the charge nearly in contact with the bow of the "America" frigate; ignition was effected by electricity. The explosion tore away 15 feet of the ship's outer planking, laying bare 11 timbers, starting back an iron knee and an inner plank, and showing daylight through the bottom, the oblique thickness of which at that spot was 30 inches. The launch, however, did not suffer in the least; the outrigger was broken 6 feet from the charge, where an iron rod, bearing the torpedo, had been lashed, but the three or four turns of spun-yarn, employed as a slight lashing to retain the spar in position, remained undisturbed, showing that no strain had been experienced by the boat.

"To test the probable effect on the operating vessel more thoroughly, a second experiment was made, in which the launch was placed with the outrigger at right angles to and the charge in contact with the sunken "America," so that the boat might receive the full shock of the recoil due to the explosion. The charge consisted of 74 pounds of gunpowder inclosed in a strengthened barricoe, ignition being effected by a friction tube. The horizontal distance of the charge from the boat was 19 feet 8½ inches, and its depth below the surface was increased to 11 feet. The explosion did not in any way affect the boat, or the lashings and guys of the outrigger, but the outer end of the spar was broken off at a weak point about 8 feet from the charge.

"On the 4th April, 1867, a further experiment was made against the sunken frigate "America," with a launch fitted with an outrigger torpedo. The only special fitting made for the boat was a movable iron crutch on the stem-head, to receive a spar 6 inches in diameter and of 30 feet in length. The inner end of the spar had an iron hoop with three eyes for small heel-tackles; the outer end had hooped on it a 4-foot rod of round iron, 1½ inches in diameter, to which the torpedo was attached; when required for use the crutch was fastened on the stem, and the outrigger launched through it, leaving 6 or 8 feet of the spar inboard. The outrigger was inclined at such an angle as submerged the torpedo about 10 feet beneath the surface, and 13 feet 9 inches to 17 feet 6 inches horizontally from the boat at the water-line, and was confined in this position by three small heel-tackles inboard, and externally by a martingale. Charges of 50 pounds and 100 pounds of gunpowder, and 21 pounds of compressed gun-cotton, which is equivalent to about 80 pounds of gunpowder, were employed; these were confined in wrought-iron cases ¼-inch thick, and were exploded by electricity. The boat was in each case secured in position with the outrigger at right angles with and a few feet from the bottom of the sunken ship. At each explosion the spar was broken off at a weak point, some 6 to 13½ feet from the outer end, but when the torpedo was projected to a suitable distance from the stem, no injury whatever was sustained by the boat or its fittings, and only a small quantity of water was shipped. On the 20th of December, 1867, these results were confirmed by the explosion of a 100-pound charge immersed 10 feet, and projected by an outrigger in a line with the keel, from the side of the bow of a steam-launch, to a horizontal distance of 23 feet 10 inches from the stem at the water-line; no injury whatever being sustained by the boat or the machinery.

"To determine the limits of the destructive results to be anticipated from similar charges exploded at increased depths of immersion, two 100-pound gunpowder torpedoes were, in July, 1868, fired from outriggers projected from a launch to a depth of 20 feet, at a horizontal distance from the stem at the water-line of 22 feet 4 inches and 17 feet 6 inches respectively. In neither case was the launch injured, though sufficient water fell in-board from the column thrown up by the nearer explosion to have swamped the boat, had not the fore part been protected by a sloping canvas cover which extended to 15 feet abaft the stem. The depth of greatest effect of 100-pound charges is estimated to be less than 15 feet, and the lateral destructive action of a serious nature to be anticipated is computed to extend over an area of 9¼ feet radius; but it is supposed that a minor destructive effort may extend beyond that distance sufficient to do injury to boats. These experiments tend to confirm the previous estimations of the limited extent of the destructive area, while they show that the falling water must also be taken into consideration in determining the maximum distance at which torpedoes can be exploded from open boats with safety to the operators.

Results of explosion of 100 pounds of powder at various depths and distances.

"With a view to the application of outrigger torpedoes to the smaller boats of ships of war, a series of experiments were conducted with a 27-foot whale-boat, and a 30-foot gig, fitted with outriggers projecting from the broad part of their bows. These side outriggers were found very convenient for carrying and handling torpedoes in light boats, the weight being thrown further aft, and the outriggers being manipulated, without any movement of the crew, by persons in the stern sheets. A canvass awning was stretched over the fore part of the boat to deflect any falling water raised by the explosion. The ignition was in all cases effected by electricity. The length of the outriggers employed in these experiments did not admit of the explosion of the torpedo at a greater horizontal distance than 15 feet 1¼ inches, which, with an immersion of 9 feet, was found inade-

Sizes of boats most suitable for outrigger torpedo service.

quate to the safety of the boat and crew with a greater charge than 40 pounds of gunpowder. Though this charge would suffice for the destruction of a ship of war, if exploded in absolute contact, the difficulties of insuring this in actual service, would render it inexpedient to risk undecided results by the employment of such a doubtful charge. If four-oared gigs cannot be fitted to carry outriggers capable of projecting 100-pound torpedoes to a horizontal distance of 20 feet, their application to torpedo service must be very limited. The means, however, devised for carrying side outriggers in gigs, are equally applicable to galleys and cutters, and there is no reason why these boats should not project serviceable charges to safe distances.

"These experiments show that outrigger torpedo appliances, to project destructive charges, can be employed in any ordinary ship's boat capable of carrying a spar of sufficient length, with perfect safety to the boat and crew.

"A series of torpedo-boat experiments was therefore conducted by the officers of Her Majesty's ship "Excellent," at the suggestion of the committee. By these it was demonstrated that 100 pounds of gunpowder and 21 pounds of gun-cotton can be exploded with perfect safety to the boat and crew, from the extremity of an outrigger projected from the bow, at such an angle that when the charge is immersed 10 feet beneath the surface its horizontal distance from the stem at the water-line shall be 20 feet. A charge of 40 pounds of gunpowder, immersed 10½ feet, was also exploded with safety from a four-oared gig with the crew embarked, at the horizontal distance of 14 feet; but a 50-pound charge immersed 9 feet, and exploded at a horizontal distance of 15 feet 1¼ inches from a whale-boat, swamped the boat. These distances were much less than were at any time contemplated by the committee as calculated to secure immunity to the operating vessel, while the uncertainty of securing, in actual warfare, the absolute contact essential to the destruction of an enemy's ship by the explosion of such small charges must preclude their employment on service.

"The committee are of opinion that outriggers sufficiently long to project 100-pound charges to a horizontal distance of 20 feet may be carried in boats of much smaller capacity than launches; but whether fittings can be applied to four-oared gigs, by which they can do so, is yet a matter for experiment. The best means of projecting outriggers from steamships of various sizes, and of maintaining them in position at different speeds, and their influence on the steering capabilities of the vessels, are problems which have yet to be submitted to experimental investigation."

As regards the second class, or projectile torpedoes, one of the most promising is that invented by Messrs. Lupin and Whitehead. A considerable amount of secrecy has been observed with reference to this machine, but the following, as far as can be ascertained, is a description of it: *Lupin and Whitehead's fish torpedo.*

It is fusiform in shape, and is provided with projections resembling fins and some kind of rudder, by means of which it may be set to run in any particular direction, and at the same time the depth at which it is to move below the surface of the water is regulated. The fins also serve to guide it in passing out of the tube through which it is discharged into the sea. Motive-power is given by means of compressed air, which is made to turn a four-bladed screw propeller. The speed obtained is about eight and a half knots an hour. Direction is given to the torpedo by means of an iron tube fitted into a vessel in such a position as to discharge it at a considerable depth below the surface of the water. The tube constructed in Her Majesty's ship Oberon, for experiments tried with this torpedo last autumn at Sheerness, was 2 feet in diameter, 28 feet long, and directed horizontally through the bow; its outer extremity was covered by a metal cap. The tube was divided into two portions, and was provided with two vertical sluices to keep the water out. *Construction.*

The rear sluices having been opened, the torpedo is passed into the tube on rollers; the rear sluice is then closed, the front one opened, and the cap covering the outer extremity of the tube having been removed, the torpedo is expelled from the ship by means of a piston; during this process the fins serve to prevent any turning motion by bearing upon four rails, the upper and under ones being provided with friction rollers placed within the tube to serve as guides for this purpose. As it passes out a tripper catches against a stud in the tube and puts in action the propelling power. Direction is given, or, in other words, aim is taken by moving the ship herself as required. *Mode of projecting torpedo.*

The charge, which may be of gunpowder, gun-cotton, or any other explosive, is carried in a chamber in the head of the torpedo, and ignition is effected by means of a percussion fuse. *Position of charge.*

Numerous experiments were tried during the autumn of 1870 with torpedoes of this nature without an explosive charge, to ascertain their capacity to move at given depths below, and in a given direction through the water, and these *Experiments to test the use of torpedo.*

having proved fairly successful, an experiment with a loaded torpedo was decided on and carried out at Sheerness on the 8th of October, 1870. The charge used on this occasion was 67 pounds of gun-cotton; the torpedo was discharged from a distance of about 150 yards at an old hulk called the Aigle, moored at the mouth of the Medway; the hulk was struck and sank immediately. The explosion threw up a column of spray and smoke mixed with coal-dust to a height of about 70 feet. The spray was perfectly distinct from the smoke and coal-dust, and proceeded from the water disturbed outside the vessel's hull; the smoke and coal-dust being probably due to the explosion acting inwards, through the vessel's side, and the column of gas driven through the interior of the ship. The two sections of the column, viz, the white spray and black smoke and coal-dust were entirely distinct from each other and not mingled in any way.

Effect of explosion.

The damage done by this explosion consisted of a clear hole on the side struck, (the starboard side,) 26 feet long and 9 feet in depth, and extending down to the keel; about 4 feet of the planking above this hole was broken and the copper more or less torn off for a length of about 40 feet. Inside the hulk half the main deck, up to the mizen hatchway, was carried away, and the remainder much torn and injured. On the upper deck the planks round the hole, left by the removal of the mizen-mast were displaced and forced upwards for a distance of about 12 feet. The planking on the port side of the vessel was blown outward for a length of 16 feet, and to a depth of 2 feet, while it was shaken for a further distance, and the copper more or less stripped over an area extending considerably beyond the space mentioned. In considering the extent of damage done, it must be borne in mind that the Aigle was an old wooden ship, probably somewhat rotten, and it is scarcely likely that this amount of damage would have occurred had the same torpedo been exploded against the side of a ship so strongly built as a modern iron-clad. This is, however, a question for the consideration of naval architects.

Fish torpedo fired from boat.

A small torpedo of the same class, 14 feet long, 14 inches in diameter, and carrying a charge of 18 pounds of glyoxaline, was subsequently fired from an apparatus suspended beneath a boat which was placed at a distance of about 150 yards from the Aigle, and directed at some netting arranged to protect the vessel against an attack of this nature. The torpedo was fired by contact with the netting, but did no apparent injury to the ship. The netting was hung about 16 feet clear of the vessel's side.

This torpedo must necessarily start with a low velocity, and even at its best, as at present arranged, does not attain a speed of more than eight miles an hour, which would render it very liable to disturbance from the effects of currents. This, combined with the extreme care and the amount of trouble which seemed to be necessary in taking aim from a distance of only 150 yards, in perfectly smooth water, in the experiment above described, seems to indicate that there would be a considerable amount of uncertainty in direction at the distance of 800 yards at sea, at which the inventors claim that it is practically effective. Destruction would no doubt result from striking a ship with this or any other torpedo; but the great difficulty would seem to be experienced in attempting to hit a ship, with this or any other known projectile torpedo, at a serviceable distance with any approach to certainty. Conflicting influence of currents, &c.

Mr. Lancaster, the gun-maker, made a proposition to the Government some years ago, to propel a torpedo through the water, by means of rocket composition carried in the body of the apparatus. His ideas, however, were not approved, and consequently were never worked out. More recently Mr. Quick, engineer of the royal navy, has brought forward a similar proposition, and an experiment has been recommended by the royal engineer committee to test its value. This experiment has not yet been carried out. Torpedoes propelled by rocket composition.

Mr. Quick's idea seems to be similar to that of Messrs. Lupin and Whitehead, the chief difference being in the propelling agent, rocket composition, suggested in the former, instead of compressed air, as in the latter case.

Should efficient projectile torpedoes be devised they might be used against ships at anchor, or perhaps moving slowly, also for the destruction of obstructions extending to any considerable depth below the surface of the water. They do not seem applicable to the attack of ponton-bridges or booms as the chance of striking such objects would be comparatively small, unless the power of regulating the depth at which they would move below the surface is capable of being very nicely adjusted. Their direction with such a comparatively low velocity as can be attained, is so easily disturbed by currents and other conflicting causes, that they would seem applicable only to the attack of objects presenting a considerable breadth of front, and the chance of hitting a ship in motion, at a distance of even one or two hundred yards, would appear to be extremely small. Use of projectile torpedoes.

Drifting torpedoes.

Among the various devices suggested at different times for the third class or drifting torpedoes, the most promising seem to be those designed by Captain McEvoy, of the late confederate torpedo service, and by Lieutenant J. F. Lewis, R. E.

McEvoy's drifting torpedo.

The following description of McEvoy's self-acting drifting torpedo, is extracted from the *report of the committee on floating obstructions*, published in 1868:

Construction.

"The torpedo case is to be suspended from a float, and permitted to drift down upon an enemy's floating bridge in a river, or against a vessel at anchor, but specially suitable for the former purpose.

"On the top of the exterior, protected by iron bars, is a sensitive percussion fuse, with a hammer retained at full cock by a lever, which is acted upon by the threads of a screw. To this screw is attached a many-bladed screw propellor of sheet tin, balanced by a fan or rudder blade on the opposite extremity, the whole pivoting round the percussion fuse, and occupying little space.

Mode of action.

"So long as the torpedo continues to drift, the apparatus on its top will be unaffected by the current, but as soon as the motion of the torpedo is interrupted, the current running past will act on the fan or rudder blade and turn the screw propeller to the current, when a given number of turns will liberate the hammer and cause explosion."

Fig. 111 shows the general design of the apparatus; A is the sensitive fuse, B the hammer, retained at full cock by pressure against the catch K, which works in the threads of the screw; C is the fan to turn the screw propeller, pivoted round the fuse A to the current when the torpedo ceases to drift; D is the screw propeller of sheet tin, to be revolved by the current when the torpedo fouls anything and ceases to drift; this action would disengage the catch K and allow the hammer to fall and ignite the sensitive fuse A; E E are circular guards to protect the igniting apparatus, F F iron slings, G the suspension rod, and H the surface buoy. This figure is copied from the *report of the committee on floating obstructions*:

Lewis's drifting torpedo.

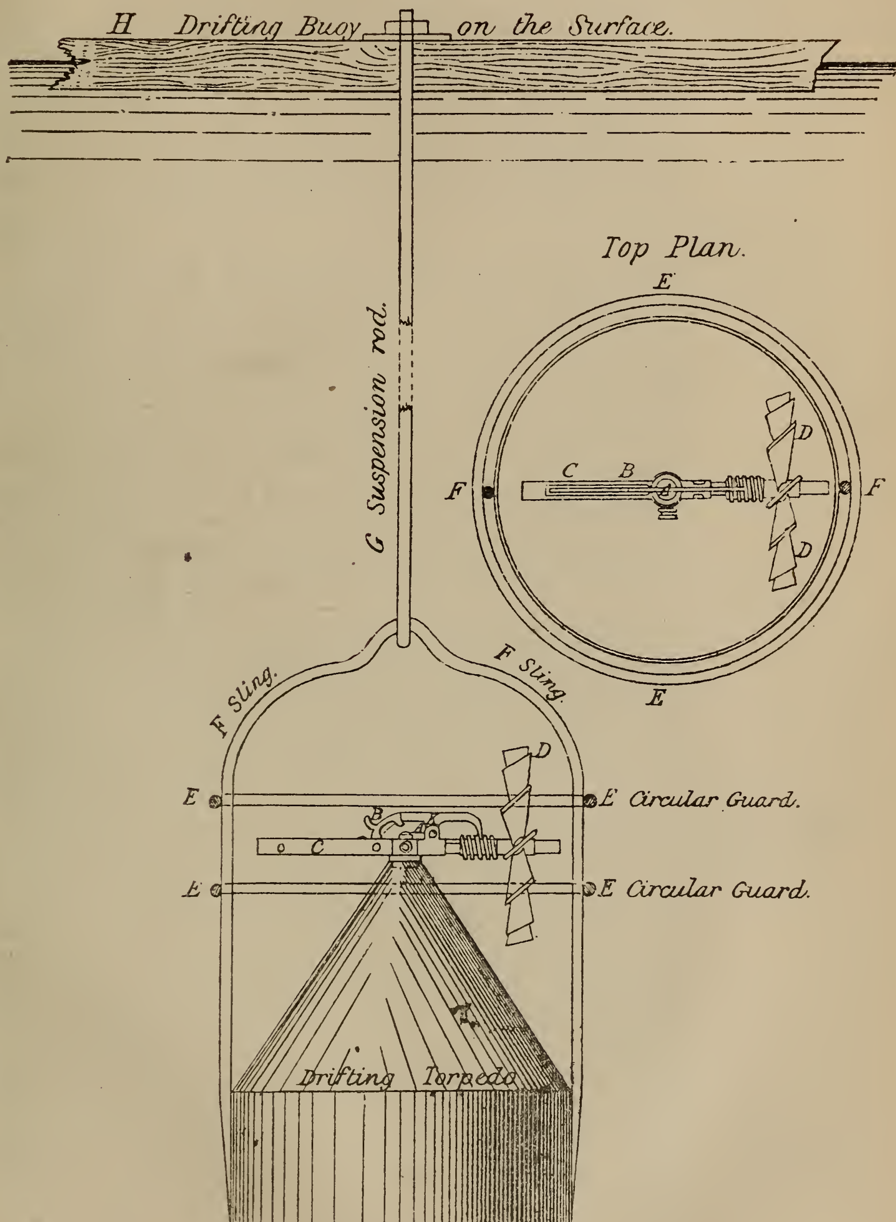
The following description of Lieutenant Lewis's self-acting drifting torpedo, is extracted from the *report of the committee on floating obstructions:*

"This is a contrivance for projecting drifting torpedoes under booms or other floating obstructions employed for the defense of ships at anchor.

Construction.

"The torpedo consists of a cubical box capable of containing 55 pounds of powder, and furnished with five detonating fuses in one of its sides.

Fig. 111.


H Drifting Buoy on the Surface.
G Suspension rod.
Top Plan.
E
C
B
D
D
F
F
E
F Sling.
F Sling.
D
E
E Circular Guard.
B
C
E
E Circular Guard.
Drifting Torpedo

"This torpedo is attached to one side of a beam, and within six inches of one extremity—the beam being 20 feet long and 7 inches square. To the opposite side of the same end of the beam a 60-pound iron weight, resting in a shoe, is attached by a long iron rod which reaches to the other extremity of the beam, and is there connected to a bell-crank lever and spring, a pressure on which detaches the weight. A chain 18 feet long connects the weight loosely with the upper end of the beam, and another chain, 9 feet 6 inches long, connects it with a point more than two feet below the center of the beam. The whole arrangement floats nearly vertically with the top of the beam, just above the surface of the water.

Mode of action.

"When the apparatus drifts against the boom or other obstruction, the spring or lever at the upper extremity is pressed down, thus raising the long iron rod and releasing the weight, which, falling, becomes suspended by the two chains, throwing the beam into an inclined position. The weight of this mass of iron and the chain suspending it are suddenly brought to bear on the top of the beam, dragging it under water and clear of the floating obstructions, at the same time the lower end, released from the weight, rises and the whole apparatus is carried forward by the current against the side of the vessel, on striking which the torpedo explodes."

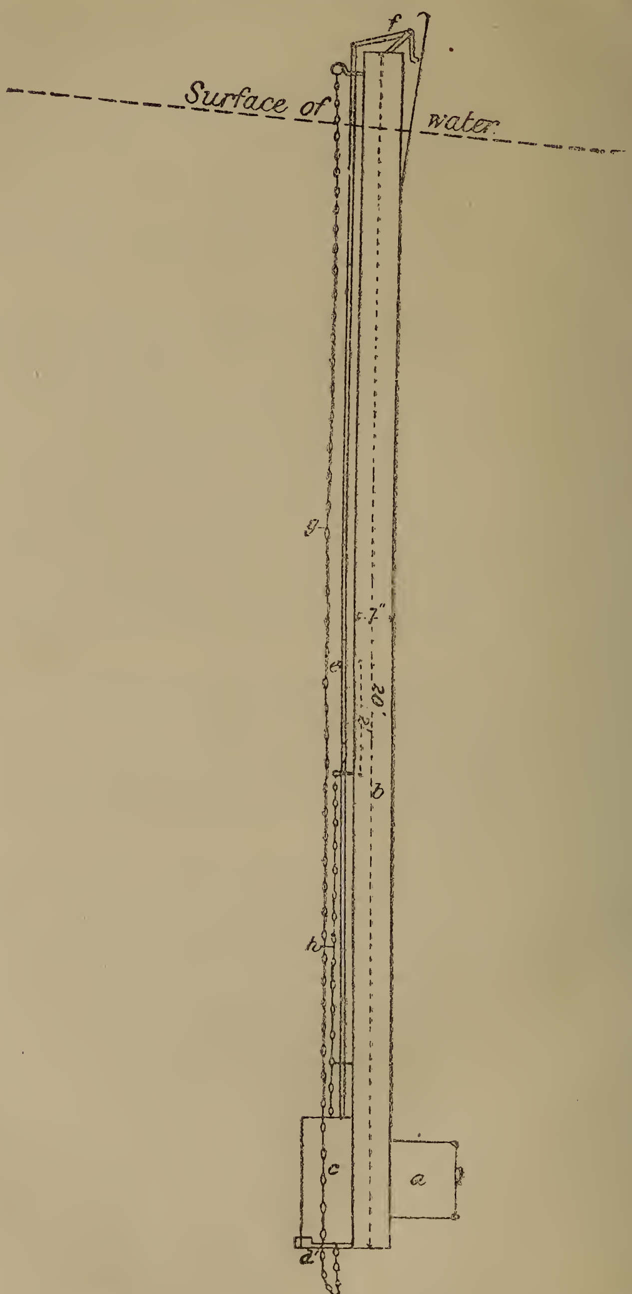
Fig. 112 shows the general form of the apparatus; (*a*) is the box containing the charge; (*b*) the beam to which it is attached; (*c*) the 60-pound weight resting on the shoe (*d;*) (*e*) is the iron rod connecting it to the bell-crank lever and spring (*f;*) (*g*) and (*h*) are the two chains connecting the weight to the beam.

Nature of operations to which drifting torpedoes are applicable.

Machines of this nature might be used for the attack of ponton-bridges, booms, and obstructions generally; those exhibiting a broad face being the most likely to be injured by them. Being dependent on the force and direction of currents, it would be necessary to study both carefully before proceeding to undertake any operation involving their use, and in a tide-way it should be borne in mind that if carried in one direction, toward an enemy for example, by the flood tide they would, unless expended, return toward their friends with the ebb. The two forms described are not very expensive or difficult of construction; if to be used, therefore, it would seem desirable to employ very large numbers, as, from their nature, it is probable that a large proportion would prove ineffective. The consternation and confusion described in Commander Barnes's book on *Submarine War-*

fare, as having occurred among the British ships in the Delaware on the 7th of January, 1778, when a number of

Fig. 112.



kegs, filled with powder and arranged to be fired on contact by a simple gunlock, were drifted down to attack them, shows how much may be done with extremely rough means. An attack by drifting torpedoes in large numbers is therefore quite applicable to certain cases, and may be successfully employed.

CHAPTER XVI.

APPROVED FORMS OF APPARATUS.

A considerable advance has been made, since the first of these papers was written in January, 1869, in determining the nature of the explosive, size and construction of cases, form of fuse, nature and dimensions of voltaic batteries, forms of electrical cables, and other similar details, and it is proposed to describe briefly what, at the present moment, may be taken as most appropriate for submarine mining purposes.

Explosive gun-cotton.

The explosive should be compressed gun-cotton, fired with a detonating fuse; where gun-cotton is not procurable, gunpowder fired, if possible, with a detonating fuse may be used.

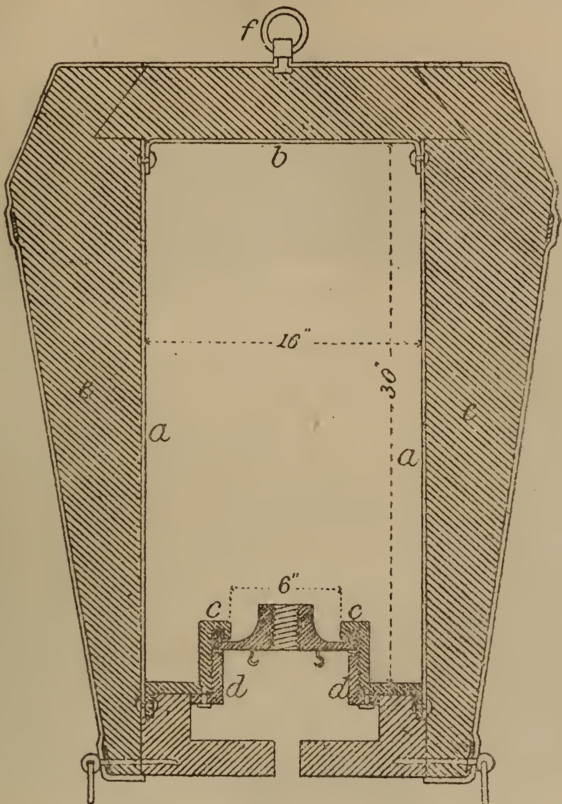
Cases.

The cases should be of wrought iron, with a cast-iron loading-hole, which also serves to receive the fuse or circuit-closer. Cases to contain charges of the following sizes are recommended, viz: 100 pounds, 250 pounds, 500 pounds, and 1,000 pounds.

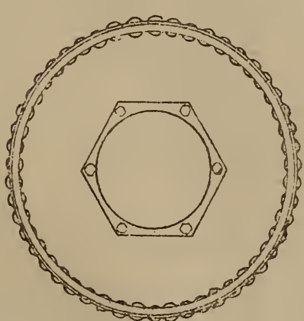
One hundred pound case, construction and dimensions.

The general design and dimensions of the 100-pound case are shown in section in Fig. 113. It consists of a wrought-iron cylinder (*a*) of No. 12 B. W. G. iron plate, riveted; the upper end (*b*) to be dished and of the same thickness of metal; (*c*) is the mouth-piece, riveted directly to the cylindrical iron plate of the body; this opening is circular, 6 inches in diameter, and serves as a loading-hole and for the introduction of a circuit-closer of Mathieson's form, which is arranged to be placed within the case; (*d*) is a screw-piece to keep everything water-tight, as described in page 96, Fig. 33; (*e*) is a wooden jacket of fir, conical in form, to protect the iron cylinder from injury when subjected to blows from friendly passing ships. The wood of which the jacket is composed should be well seasoned, thoroughly saturated in tar, and subsequently painted to keep the water as much as possible from entering into its pores after submersion, so that the buoyancy of the wooden jacket may increase the flotation. The case is intended essentially for a contact charge, and a maximum of buoyancy is absolutely necessary. The wooden jacket is bound together by iron bands and provided with a ring (*f*) at the top, from which to suspend the case for mooring purposes. The whole of the iron work of the case should be painted two coats, and tested up to a pressure of 10 pounds on the square inch, gradually increasing from within. The calculated weight of this case, complete with circuit closer and charge, is

Fig. 113.



Section.



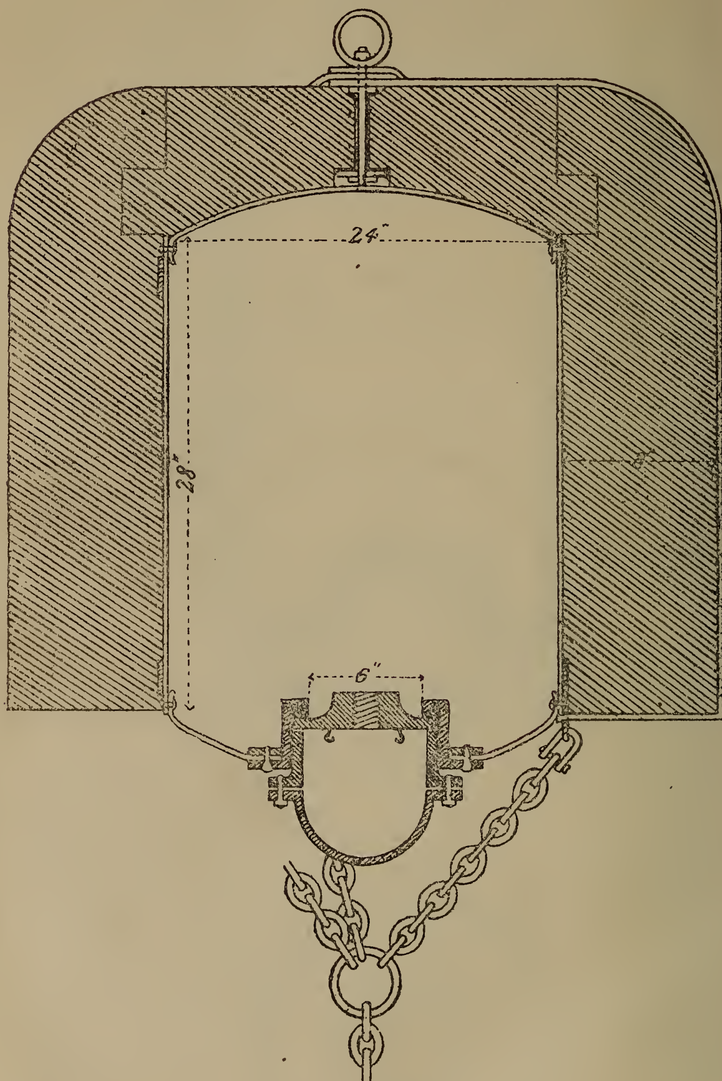
Bottom Plan.

about 470 pounds, and its available buoyancy, that is to say, actual power of flotation, about 140 pounds.

Two hundred and fifty pound case, construction and dimensions.

The general design and dimensions of the 250-pound case are shown in section in Fig. 114. The body consists of $\frac{3}{16}$-inch best boiler-plate iron, riveted, with dished ends. The size and construction of the mouth-piece is similar to that

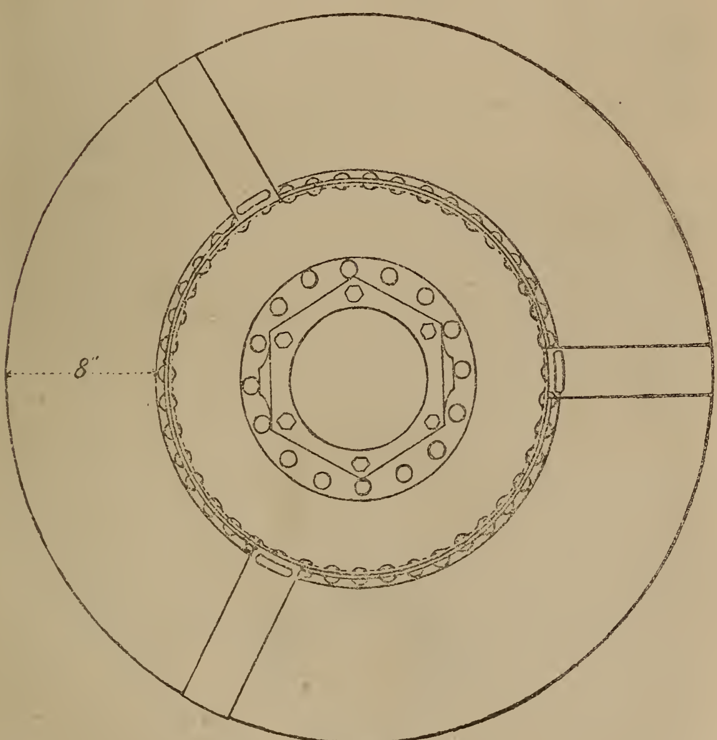
Fig. 114.



Section.

of the 100-pound case, so that the fuses, &c., may be interchangeable. The whole of the iron work should be painted two coats, and tested to a pressure of 30 pounds on the square inch, gradually increasing from within. The mooring chains are attached by eyes to wrought-iron bands shrunk on and screwed to the body by coupling screws, as shown in the figure. The charge of 250 pounds renders it applicable for the destruction of a vessel without absolute contact; it may, however, be necessary, in certain cases, to employ it as a contact mine, and when used as such, a wooden jacket, as shown in the figure, must be added to protect the case from injury by collision with friendly vessels. Its calculated weight, complete with charge, and without the wooden jacket, is about 520 pounds, and its available buoyancy, (actual power of flotation,) is about 80 pounds. Fig. 115 shows a plan of the bottom of this case, including the wooden jacket.

Fig. 115.



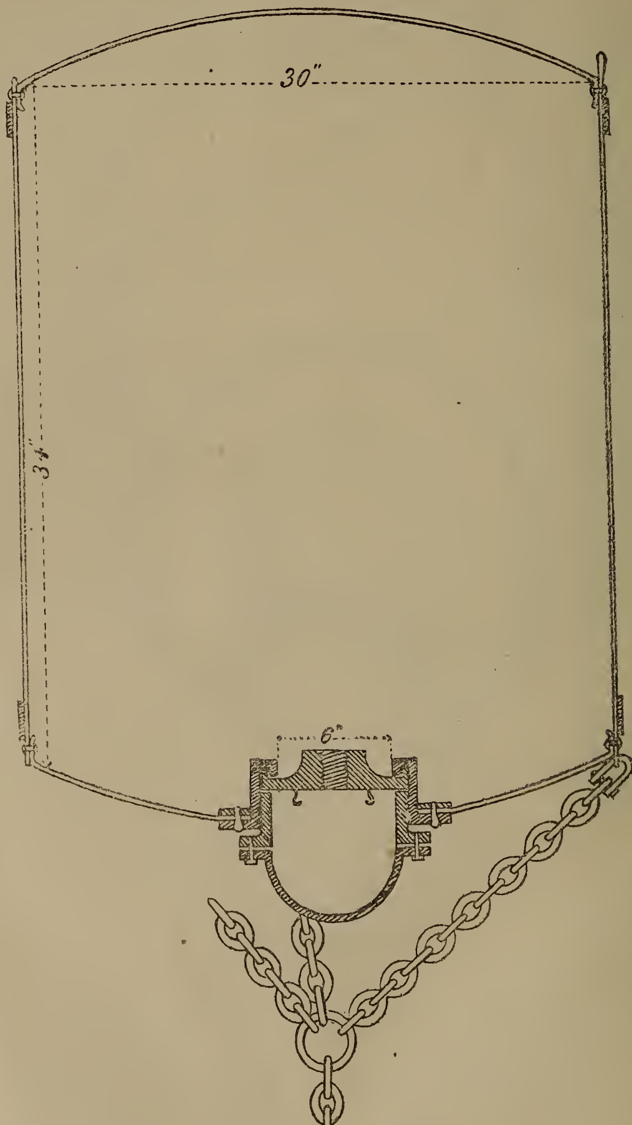
Bottom Plan.

In order, therefore, to convert this into a buoyant mine, additional flotation must be given by the attachment of buoyant bodies thereto. The amount of flotation to be added would involve conditions, dependent on the length of mooring cable necessary and the nature of the current in which the mine is to be placed. The wooden jacket adds to a certain extent to the buoyancy, but it must be borne in mind that, even with every precaution, the wood becomes more or less saturated after submersion for any considerable time, and only half the buoyancy due to this outer casing should, on this account, be included in calculating for flotation to be given under any particular circumstances.

Five hundred pound case, construction and dimensions.

The general design and dimensions of the 500-pound case are shown in section in Fig. 116. The body is formed of $\frac{1}{4}$-

Fig. 116.



inch best iron boiler-plate. The ends are dished, an the mouth-piece and arrangement for the attachment of the moorings are precisely similar in form to that of the 250-pound case. The whole of the iron-work should be painted two coats; the case should be tested to a pressure of 40 pounds on the square inch, gradually increasing from within. The calculated weight of the case, with charge complete, is about 1,000 pounds; this exceeds the total buoyancy by about 190 pounds; it has, therefore, no floating power, and if required to be floated up from the bottom the necessary buoyancy must be attached.

One thousand pound case, construction and dimensions.

No definite pattern of case to contain a charge of 1,000 pounds has yet been made; it should, however, be similar in form to the 500-pound case, and be composed of ½-inch best iron boiler-plate, and of such cubic space as to contain the requisite charge, viz, 2 feet 9 inches by 3 feet 4 inches, not including the dish of the ends. The mouth-piece should be the same as before, in order that the fuse-pieces may be interchangeable; the attachments for the moorings should be similar to those of the 500-pound case, but of proportionately larger dimensions.

Above dimensions calculated for compressed gun-cotton.

The dimensions of all these cases are calculated for compressed gun-cotton, and their thickness is not sufficient to develop the maximum explosive force of gunpowder; if, therefore, this latter explosive be used, detonating fuses and several centers of ignition must be employed. The cubic space occupied by a given charge of gunpowder is slightly less than that required for an equal weight of compressed gun-cotton; for practical purposes, however, the cases described may be taken as the same for both.

Mooring apparatus, mushroom anchor.

The best special mooring apparatus for general purposes seems to be the mushroom sinker, somewhat similar to that shown in Fig. 20, and described in pages 72 and 73. Its weight would depend upon the buoyancy to be overcome, and would generally be from five hundred-weight, upward. Ordinary mooring-chains and hemp cables may generally be employed in connecting the charges or circuit-closers with the sinkers. Where there is any tendency to twist, a wire cable is the best to counteract it. Any considerable amount of twisting must be checked, as it is liable to entangle the moorings and to rub and injure the electric cables. The strength of the chains or cables employed must depend upon the amount of buoyancy possessed by the mine or circuit-closer. The cable connected with the circuit-closer would also frequently be subjected to a severe strain if caught by the paddles, screws, &c., of a friendly vessel passing over the mine. For this reason stronger cables, both electric and mooring, must be provided at that point.

Abel's torpedo primer.

For mechanical ignition Abel's torpedo primer, described at page 88, and shown in Figs. 26 and 27, may be used.

Platinum wire fuse.

For electrical ignition a platinum wire fuse, primed with fulminate of mercury, somewhat similar to that shown in Fig. 51, page 133, seems most suitable.

Mr. Abel is now engaged in experiments with a new form of tension-fuse for submarine mining purposes, but as yet it is impossible to decide whether it will eventually supersede the platinum wire fuse or not.

Electric cables.

The electric cables which seem best suited for submarine mining-service, are the following:

Single cable.

The single cable, to consist of a strand of four No. 20 B. W. G. copper wires tinned, insulated with vulcanized India rubber to a diameter of $\frac{24}{100}$ inch, over which a layer of felt is wound; the whole is then submitted to a temperature of about 300° F. to consolidate the di-electric. Over the core thus formed a covering of tarred hemp should be wound on spirally, followed by 8 No. 13 galvanized iron wires, each wire separately covered with tarred hemp. The whole to be finally covered with two coatings of hemp and composition, (consisting of tar and some bituminous substance,) wound on with a short twist in opposite directions. The external diameter of the whole would be about $\frac{7}{8}$ inch. The weight of this cable would be about 20½ cwt. per nautical mile.

Multiple cable.

The multiple cable, to consist of seven single cores, as above described, formed into a strand. The whole covered with tarred hemp, laid on spirally, subsequently with 16 No. 9 B. W. G. galvanized iron wires, (each wire separately covered with tarred tape,) laid on spirally over the hemp covering. The whole finally covered with a layer of hemp and composition laid on with a short twist. The diameter of a multiple cable, constructed in this way, would be about 1¼ inches and its weight 5 tons per nautical mile. Either Hooper's or Gray's patent di-electric is very suitable for this service. They are both combinations of vulcanized India rubber, which forms a very flexible covering to the copper conductor, and may be stored either wet or dry. It must, however, be kept always wet or always dry, as any alternation of these conditions would tend to rot the hemp covering and di-electric. Should it be necessary to store an electric cable insulated with gutta-percha, it must be kept under water. When so treated it may be preserved in a sound state for a considerable length of time. Dry air has a very deleterious effect upon gutta-percha, causing it to become brittle and crack when bent after exposure to its influence for a comparatively short time. When gutta-percha cables, therefore, are to be stored, tanks must be provided for their reception.

Firing-battery, Walker's.

The voltaic battery temporarily adopted is Walker's, (zinc and carbon plates in diluted sulphuric acid.) The zinc element consists of a plate 7½ inches by 4½ inches, amalgamated with mercury, the carbon pole being formed of a pair of plates each 6½ inches by 4½ inches, connected together to form one element. The dimensions of the outer cell are 5 inches by 2½ inches and 7 inches deep. The greater depth of the zinc plate brings its lower extremity to the bottom of the outer cell, in which a small quantity of mercury is placed to keep the zinc amalgamated. The graphite plates do not reach down so far as to touch the mercury. The slipper generally used in this form of battery to hold the mercury may thus be dispensed with. They should be arranged in a wooden frame, so that the battery-plates may be lifted out of the liquid when not in use. This may be readily done by means of a small chain, or rope and pulley. They need only to be lifted a very short distance, just clear of the diluted acid, and not absolutely out of the cell. This will prevent the chance of damage to the plates which was found to occur when they were lifted to any great height, by striking against the edges of the cells when subsequently lowered.

Le Clanché battery.

Experiments are now being made with a large form of Le Clanché battery, to ascertain whether it is not better than Walker's for submarine mining purposes. The Le Clanché battery is no doubt preferable to Walker's in many important respects; its constancy, for example, is greatly superior, but till the experiments are completed no definite opinion can be given.

Dynamo-electrical machine.

For firing at will, when it is desirable to dispense with battery power, the dynamo-electrical machine seems to be the best form of instrument for submarine mining purposes. The size adopted as the field-service pattern for the engineer equipment, seems to be a very convenient form of instrument for this work. Its weight complete, with carrying case and straps, is 28 pounds.

Telescopic firing-key.

For firing by intersection at long distances, telescopic keys, somewhat similar to that described at page 194, Fig. 82, would be required. The radius of the arc on which the firing-contacts are to be fixed, should be increased to a minimum of 36 inches, and the eye-piece of the telescope should be placed farther back, so as to be easily seen through when the hand is employed in moving the apparatus round in following a ship. A pair of improved instruments of this nature are now being made for the trial of this system.

Mathieson's circuit-closer and breaker.

When a platinum wire fuse is used, a circuit-closer or breaker of Mathieson's form, as described at page 209, Fig. 87, seems to be the most generally useful instrument of this class. When simple contact mines are used the instrument may be connected as a circuit-closer. When the mines are arranged with a detached circuit-breaker to be fired by the contact of a ship, with an alternative mode of ignition by intersection, the apparatus should be connected as a circuit-breaker. An improvement has recently been introduced into this instrument, which consists in reducing the number of supporting pillars and springs, with their corresponding connections, to three instead of four, as shown in Fig. 87. The reason why this instrument is so well adapted for use with the platinum wire fuse is, that the springs produce a slight prolongation of the contacts when the apparatus is used as a circuit-closer, and this gives an almost inappreciably prolonged interval for the circulation of the battery-current which is desirable to produce the heating power necessary to fuse the fine platinum wire forming the fuse.

Abel's circuit-closer.

Experiments are now being carried on with Abel's circuit-closer, somewhat modified on that described at page 202, Fig. 85, with a view to test its capabilities as compared with Mathieson's circuit-closer and breaker. It is probable that, with a tension fuse, either may be used, and no definite decision can be made till the experiments are completed. With the platinum wire fuse, however, Mathieson's apparatus is preferable to Abel's, as the latter is at present constructed for the reasons already given.

Shutter signaling and firing apparatus.

The form of shutter-signaling apparatus, which seems best adapted for submarine mining purposes, is that described at page 232, Fig. 97, in which the contacts are made by means of mercury-cups in place of the springs which were first used. Further experiments, however, are required with this form of instrument before it is possible to decide definitely whether it is the best suited for the purpose, or even whether it may be found convenient to use an apparatus of the shutter form at all.

THE END.

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NOTES

ON

TORPEDOES, OFFENSIVE AND DEFENSIVE.

BY

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