SUBMARINE BLASTING

IN

BOSTON HARBOR, MASS.

FOSTER.

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#6418

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REMOVAL OF TOWER AND CORWIN ROCKS.

BY

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WITH ILLUSTRATIONS.

NEW YORK:
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY STREET AND 27 WARREN STREET.

1869.

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REMOVAL OF TOWER AND CORWIN ROCKS,

IN THE

NARROWS OF THE ENTRANCE TO BOSTON HARBOR, MASS.,

BY DRILLING AND BLASTING.

THESE rocks were situated (see Plate 1) in the main ship-channel, between the Great Brewster Spit light and Fort Warren, nearly in a southwest direction from the light; the first being distant from it one hundred yards, and the latter two hundred yards.

The sailing course laid down on the charts passed directly between these rocks, and vessels had therefore only about 120 feet space on each side in which to avoid collision with them, which rendered the navigation quite dangerous for heavy vessels.

This danger was increased by the risk of mistaking in thick weather the large Navy Yard chimney for the Bunker Hill monument, upon which the true course, passing through Nix's Mate, was directed. The course through Nix's Mate and the Navy Yard chimney led directly over Corwin Rock. Being nearly in the same direction, one course might very readily be mistaken for the other in thick weather, at the distance of these rocks.

The depth upon Tower Rock at mean low water, was 18½ feet (Plate 1). It was 50 feet in length and 26 feet in breadth, and contained above the level of 23 feet below mean low water, 63 cubic yards. Corwin Rock had only 16 feet of water upon it at mean low water, was 110 feet in length by 80 feet in breadth, and contained above the 23 feet level, 600 cubic yards.

The two rocks were ridges of the same general ledge which extends beneath the channel, running in a north-east and south-west direction.

An examination of Corwin Rock by divers, disclosed the ragged and ridged character of its surface, and the presence of a considerable quantity of sheet lead and copper in its crevices; also bolts, chains, pieces of planks from vessels' bottoms, pieces of a keel, an anchor, etc. The sheet lead was of a very old manufacture, and both it and the copper retained the crumpled form given them by the sharp edges of the rock when they were stripped off. Everything indicated that a great number of vessels must have struck upon this rock in times past, of which number the old frigate "Constitution" was one. The last one known to have struck it was the "China," of the Cunard Line.

CHARACTER OF THE ROCK.

The rock was an argillaceous slate of hard compact texture and irregular stratification, some portions being much twisted and bent, forming every variety of conchoidal surface.

The weight of a cubic foot of the rock varied from 155 to 180 pounds, giving a mean of 165 pounds, the same as granite.

The rock operated very disadvantageously in blasting. It did not "seam" well. The rifts rarely extended beyond the immediate effects of the charges. The craters and size of the fragments thrown out were small, and, generally, the effect of blasts was much less than in granite.

The presence in the rock of crystals of sulphuret of iron, or "iron pyrites," retarded much the operation of drilling, as they were so hard as to break or cut a piece out of the cutting-edge of the drill whenever it struck them.

The circumstances, therefore, were regarded as less favorable for blasting and removing than in the majority of cases of submarine rocks.

ESTIMATED COST AND CONTRACT.

The cost of removal of these rocks to the depth of 23 feet at maen low water, as estimated by the Board of Harbor Commissioners of the State of Massachusetts, was $20,000, and this amount was assigned to this particular work by the Engineer Department, from the general appropriation, approved March 2d, 1867, for improvement of Boston Harbor.

Proposals were advertised for, in June, 1867, but no one could be found to undertake the work by contract for the sum available—the only bid received being for $44,000. It was therefore decided to execute it by day's work.

A contract was accordingly made with Mr. George W. Townsend, Sub-Marine Diver, of Boston, by which, for the sum of $90 per working day, he was to furnish a working vessel of 70 tons, fitted for the purpose, with steam engine, boiler, boom derrick, and capstan to work by steam; the services of a captain and crew of six men, two submarine divers with their armor, air-pump and hose complete, a patent submarine drilling machine, mooring lines, buoys, and materials of every description, including powder, cartridges, and fuses.

The contract was amended in October, 1867, by increasing the amount to be paid per diem to $100.00 for every day's work of 9 hours during the winter season; in addition to which, powder, cartridges, and fuses were supplied by the Government. In March, 1868, the amount per diem was again reduced to $85.00 per working day, at which price the work was prosecuted to completion, the contractor furnishing all the labor and materials required, with the exception of powder, cartridges, and fuses, which, being variable quantities, were paid for separately.

The amount available becoming exhausted, further sums, amounting to $15,000 in all, were assigned to the work by the Chief Engineer, making the total amount assigned, $36,423.32.

COMMENCEMENT OF THE WORK.—"TOWER ROCK."

"Tower Rock," being the smaller of the two, was selected as the one to be first removed. Its horizontal dimensions being only 50 by 26 feet, it was estimated that one large central charge surrounded by five or six others, all in large and deep drill-holes, would be able to rend the rock into pieces.

The working vessel, the sloop "Hamilton" of 70 tons, was moored over this rock on the 30th of July, 1867, and the new submarine drilling machine, invented by Mr. Townsend, the contractor, expressly for this work, was placed in position and tried.

Several imperfections were found at the first trial, which prevented its efficient working. While these were being remedied, a trial was made of surface blasts placed in and around the rock in the positions most favorable for their action. These proved to be entirely without effect. No seams or breaks were made by them in the smooth surface of the rock.

The submarine drilling machine being soon perfected, was put in operation, and successfully worked.

The central and surrounding holes were drilled to depths varying from two to eight feet, each hole being 3½ inches in diameter. These were well charged with blasting powder, tamped with sand, and fired. In some holes the charges produced no visible effect, the tamping being blown out like the charge from a cannon. In others a crater was formed, but with a radius only about one-half the line of least resistance. The holes that were intact were then deepened, and new ones drilled. These were charged with Dupont's Sporting Powder. The result was much better, but not what was desired. The pressure of the body of water, from 23 to 33 feet in depth, seemed to diminish largely the ordinary explosive effect of gunpowder upon rock, as seen in blasts in the open air.

Trial was then made of the Patent Safety Blasting Powder, manufactured by the Oriental Powder Company, of Boston—the proportions having been so modified as to increase its strength, for our especial use. This produced the desired effect. The rock was rent in pieces; and by drilling additional holes and continuing large charges of this powder, the rock was finally reduced to the required depth.

To smooth off its upper surface, and break down the sharp projecting points, large surface charges of sporting powder were employed. These accomplished the result to a limited extent, but not completely. A large 15-inch shell was then placed in a crevice near the centre of the rock and fired. Its explosion swept the rock completely, breaking down and levelling the projecting points.

The work upon this rock was finished on the 29th of September, 1867, eight weeks after its commencement. In that time 80 tons of stone had been blasted out, hoisted up, and deposited on shore, attaining the required depth of 23 feet at mean low water. About 70 tons of small fragments were suffered to remain on the bottom around the rock, where they had been thrown by the blasts, and where they could do no harm.

The cost per ton of the quantity hoisted up and deposited on shore was $64.93, no account being taken of the equal quantity blown, in small fragments, into deep water.

PROGRESS OF THE WORK.—"CORWIN ROCK."

"Tower Rock" being entirely removed to the required depth, the moorings of the working vessel were at once removed to "Corwin Rock," and work commenced upon it on the first of October, 1867.

This rock was found to be much more difficult to blast, on account of its extremely tortuous lamination, its great toughness, and the presence of a greater number of iron pyrites.

Surface blasts were also tried upon this rock, at the outset, in hopes that by being placed in the most favorable positions between the sharp ridges of the rock, they might break them down.

These, however, as upon Tower Rock, entirely failed of any noticeable effect, even when they contained four and five hundred pounds of the best sporting powder. The drilling machine was therefore called into requisition, as before, and used continuously to the completion of the work.

On account of the extent of this rock, a different plan of operations for its removal was adopted. One side of the rock most favorable for blasting was selected, and a row of holes drilled parallel to the edge, and at a distance from it equal to the depth of the holes, which was taken to extend one foot below the required level, 23 feet at mean low water. After blasting out these holes, a new line of holes was drilled parallel to the former line, or to the "face" left by the blasts, and these also blasted out; then a third line, and so on, progressing regularly across the rock, continually blasting it off in parallel blocks, extending downward a little below the depth required.

The advantages of this mode of operating were that it enabled the blasts to act laterally, in which direction they were the most powerful; and the rock was left, after each series of blasts, with a nearly vertical side, or "face," in which the presence of seams could be more readily detected, and the character of the strata observed, so that the most favorable positions for the next blasts, to produce the greatest effect, could be selected.

Sometimes the craters, following the strata, ran under, or left an overhanging "face," in which case a large charge placed under its projecting edge (see Fig. 10, Plate 5) usually had the effect to throw off the overhanging portion, and sometimes to dislodge large masses.

After the rock had been in this way blasted entirely across, and to the general depth required, a careful survey was made, the soundings being taken in lines from five to ten feet apart, and at right angles to each other, and the lower end of the sounding-pole being placed by the diver alternately upon the highest and lowest points. This survey showed that although more than the required depth had been generally attained, yet many points projected above this level, distances varying from two to fourteen inches.

To remove these, large surface charges were again tried, but with the same ineffective result. Their only effect was to pile up the sand and small fragments of stone into irregular winrows on the surface of the rock. Small holes had, therefore, to be drilled at each of these points to blast them off. This occupied much more time than could reasonably have been expected ; so that it was not until two months' labor had been expended that all the points were finally reduced to the required level.

It is now apparent that it would have been an economy of time and money, if, from the commencement, the drill holes had been sunk to a general level two or three feet below the required level, instead of one foot below, as was estimated to be sufficient at starting. More stone would have been taken out, it is true, and also the upper surface of the rock would have been left irregular and angular, instead of comparatively smooth as now ; but the time and expense would have been less.

The work on "Corwin Rock" was continued during the few days of winter of 1867–8, resumed fully in the following spring, and completed on the 15th day of December, 1868, the total working time occupied in its removal being 290½ days. During this time 1,192 tons of stone, by weight, were blasted out, hoisted up, and deposited on shore. About 164 tons of small fragments were left on the bottom around the rock where they could do no harm. The total cost of removal was $31,228.61, making an average cost of $26.20 per ton of 2,000 pounds, or $58.36 per cubic yard for the quantity actually removed and deposited on shore. Taking 600 cubic yards, the cubical contents above the 23-feet level, calculated before the work was begun, the cost per cubic yard of the work, as estimated, becomes $52.05. The difference between the actual and estimated cost per cubic yard is due to the greater quantity actually removed to obtain the required level at all points, making the mean actual depth nearly one foot below that level ; and also to the quantity of small fragments blown into deep water, and not included in the amount of stone hoisted up, weighed, and deposited on shore.

DESCRIPTION OF THE SUBMARINE DRILLING MACHINE USED, AND ITS MODE OF OPERATION.

This machine (Plate 2) consists generally of a drill, a drill-stand or guide, a clutch or hoister, and an adjustable connection with the motive power, situated on the deck of the working vessel.

The *Drill* (Plate 3) is a churn drill, about 16 feet in length, 1¾ inches in diameter, and weighing about 125 pounds. It cuts by the force due its weight, which may be made greater or less, as the rock to be drilled is softer or harder.

The *Drill Head* (Fig. 11, Plate 4), or *Cutter*, is about 14 inches in length, and is attached to the lower end of the drill-shaft by a socket and pin. The *cutting edge* is made similar to the form of the letter S, as this is found to stand better and work truer than any other form. They may be made to cut any sized hole from two to six inches. The cutters used on Tower and Corwin rocks drilled a hole 3½ inches in diameter.

The *Drill Stand* (Plates 3 and 4) consists of two parallel plates connected by uprights, to serve as guides to the drill-shaft, the lower plate being supported by three legs, made adjustable in length to fit the uneven surface of rocks. It is made of iron, and heavy enough to resist an ordinary current. The one in use on Tower and Corwin rocks weighed 850 pounds, and maintained its stability perfectly against a four-knot current. To resist stronger currents its weight must be increased, and, in addition, guys attached to the upper plate, and to iron pins driven into holes drilled in the rock, by the diver, with a hand-drill, may be used if necessary.

The *Clutch* (Plate 4, Fig. 9), or *Hoister*, is a bar of iron, with an oblique slot through it, through which passes the drill-shaft. When the clutch is raised, the sharp, bevelled edges of this slot gripe the drill-shaft and raise it. One end of the clutch is forked to run upon a spiral guide, so as to turn the drill as it is raised. The other end is weighted, so as to bring the clutch rapidly back to its first position after its gripe upon the drill-shaft has become disengaged by a trip-pin, on the spiral guide, against which the fork of the clutch strikes in its ascent.

The *spiral guide*, which regulates the turn of the drill, is made adjustable in inclination, so that greater or less turn may be given, for any fixed elevation or "hoist." The trip-pin is also made adjustable in position upon the spiral guide, so as to regulate the "hoist," or fall of the drill, to suit the degree of hardness of the rock. It is usual to give as great "hoist" as the cutting edge of the drill will stand without breaking.

Attached to the clutch is a chain which passes through a hole in the upper plate, and is attached at its upper end to a ballasted block, *C* (Plate 2). Through this block a line passes, one end of which is attached to the crank-pin of a steam-engine situated on the deck of the working vessel, and the other end to a cleat upon the rail of the vessel.

TO OPERATE THE DRILL.

The working vessel having been moored over the rock by means of mooring-lines attached to buoys placed about 150 feet from each quarter of the vessel (Plate 2), the diver, arrayed in his submarine armor, descends and selects the exact position for the blast, and then signals, by a certain number of pulls upon his signal line, to have the drill and stand lowered to him. This being quickly done by means of the steam derrick, he guides the drill-stand to its place, and finally fixes it in position by means of its adjustable legs. He then signals to haul up and make taught the drill lines attached to the motive power on deck; and this being done, he signals to commence drilling.

The crank-plate of the engine being thrown into gear, the engine being in motion, the end of the drill line attached to the crank-pin is raised, which raises the ballasted block, the drill chain, and the clutch, which latter gripes and raises the drill, turning as it rises, until the forked end of the clutch strikes against the trip-pin, when, the drill chain still hoisting, the grip of the clutch is disengaged, and the drill falls straight, cutting the rock by the force due to gravity.

The crank-plate continuing its revolution, the drill line and chain is lowered, permitting the clutch to descend to its first position, ready to gripe and raise the drill again.

The revolutions continuing, the drill is raised and let fall, making a cut at each revolution of the crank-plate; and in this manner the drilling proceeds. Usually the drill makes from 60 to 80 blows per minute.

As soon as the diver sees the drill in perfect operation, he either busies himself with any other work that he may have to perform, upon the bottom, or he comes to the surface of the water, and supporting himself upon the ladder attached to the side of the vessel for his use, waits for some necessity of his diving again.

Sometimes the drill works uninterruptedly till the hole is drilled to the depth desired. At other times its working requires the constant attendance of the diver, either in replacing drill-heads broken by contact with hard crystals, or in regulating the "turn" or "hoist" of the drill, or in clearing the holes of cuttings, or "spooning out," as it is termed; or rectifying the direction of the drill by adjusting the legs or guys.

To afford an indication above water, of the motion of the drill below, and thus to obviate the necessity of the diver going down for this purpose, an iron rod is fitted into a square socket on the upper end of the drill-shaft, and to the upper end of this rod a wooden pole, extending above water, is attached. (Figs. 10 and 12, Plate 4.) This pole being held by an attendant standing upon a movable staging, *g* (Plate 2), rigged out from the side of the vessel, indicates clearly to him the motion of the drill, and also enables him with his hand to prevent the drill falling repeatedly into the same cut, or "bouncing back," as it is termed.

In rough weather the staging and index pole cannot be used. At such times the motion of the drill line is the only indication, above water, of the working of the drill.

Frequent descents of the diver are then necessary. The tendency of the drill to "bounce back" is then prevented by a ratchet and paul (Fig.

2, Plate 4) placed on the upper guide plate, and operated by a vertical groove in the drill-shaft, and a pin on the ratchet.

It was found that the drill could be worked in a rapid current as well as in slack water. This will enable the operation of drilling and blasting to be conducted in an extremely rapid tidal current, by a proper division of time and labor, so that the principal work of the divers in inserting charges for blasting, slinging stone, etc., may be done near the periods of slack water, while the drilling may be advantageously continued during the period of rapid flow. Upon Corwin Rock the current had a velocity of four miles an hour, which did not interfere in the least with the work of the divers at any stage of the tide.

In a rapid current the stoppage of the drill for the purpose of "spooning out" the hole becomes unnecessary, as the motion of the drill works up the powdered cuttings to the mouth of the hole, whence they are sucked out and carried off by the current, in a dark stream like the smoke from the stack of a locomotive.

In a sluggish current, or during slack water, the hose of the air-pump was sometimes introduced, and air forced into the hole, creating a current of water extending to the bottom, which by this means was cleared of cuttings more thoroughly than by the most careful "spooning out."

To attach this arrangement permanently to the drill, it is proposed to have a small hole along the axis of the drill-shaft, with outlets on each face of the cutter, and a hose attached by a swivel to the upper end of the shaft, through which air or water is to be forced to the bottom of the hole, by which means the drill may be kept constantly clear.

CHARGING THE HOLE, FIRING, ETC.

As soon as the hole is drilled to the required depth, the drill is stopped, the drill line is detached from the crank-pin, and unrove from the ballasted block; the diver then descends, fastens the derrick chain, which is lowered to him for the purpose, to the drill-stand, and then signals to hoist away, upon which the whole machine is quickly hoisted on deck.

After an examination of the hole and clearing away any cuttings remaining in the bottom, the diver comes to the surface, and taking in his hand the charge, contained in a water-tight cartridge (Plate No. 5)—usually of india-rubber, carefully prepared with its fulminating exploders inside, its mouth hermetically closed, and insulated wires extending to, but not yet connected with, the electric battery on deck—descends and inserts it into the drill-hole, carefully pressing it to the bottom with a rod.

The tamping (Figs. 1 and 2, Plate 5), if any is used, is then inserted above the cartridge, and the diver comes up.

The working vessel is then quickly hauled, by the mooring-lines, to a safe distance, the capstans worked by the steam-engine being used for the purpose ; the wires are then attached to the battery ; a few turns are given to its crank to generate electricity; the operator asks, "All ready?" and being answered "All ready" by the diver, pulls the connection knob, when a shock, followed instantly by a second shock, and the upheaval of the water, announces the explosion of the charge.

The working vessel is then hauled back to her position by steam, as before, and as soon as the water becomes sufficiently cleared of the dark, muddy matter with which it is filled by the blast, to enable the diver to see in it, he descends and examines the result.

If the blast has been effective, and thrown out a crater from the rock, he signals for the stone chains to be lowered to him ; which being done, he proceeds to sling the large pieces of broken rock, one after the other, as they are hoisted up by steam and deposited on deck. All the pieces large enough to sling being thus removed, he signals for the tub and shovel, and upon their being lowered to him, proceeds to shovel into the tub the small fragments, and to have them hoisted up and piled on deck, until the surface of the rock is sufficiently cleared to place the drill for a new hole and another blast.

This operation is repeated, and the work thus progresses steadily.

After some experience, such facility was attained in drilling and blasting as to enable the work to be continued in a rough sea, and during all stages of the tide.

To accomplish this the slot in the clutch is made of such an oblique form as to permit the clutch to run up the drill-shaft, after tripping, a sufficient distance to accommodate its motion to the upward heave of the vessel in a *swell of the sea.*

The peculiar adjustable connection between the drill and the motive power is also so arranged as to afford the means for *compensating for the rise and fall of the tide*, by simply letting out or taking in the line attached to the cleat on the rail of the vessel (Plate 2). In addition, this arrangement also enables the vessel when threatened by a collision, or a sudden storm, by casting off this line, to detach itself entirely from the drill, and haul out of danger.

After the danger is past, the working vessel can readily haul back again, pick up the drill line, and at once resume work. This last facility was found to be of much value, since from the position of the rocks in the middle and narrowest part of the channel, the collisions with passing vessels were frequent, especially during the prevalence of light winds and strong currents. The drill was repeatedly knocked from its position on the rock by the keel of passing vessels. Its simple construction, however, enabled a blacksmith to repair all damages in a few hours.

To reduce the chances of collision with passing vessels, the lower ends of the supports of the upper plate were made hinged (Figs. 6 and 7, Plate 4), so that the whole upper part of the frame could be turned over, thus reducing its height to about 4 feet. This was a great advantage whenever it became necessary to leave the frame standing by itself upon the rock, as was usually the case at night when the working vessel sought its anchorage under the lee of Lovell's Island.

During the day a red flag was always displayed, in a conspicuous position, on board the working vessel, to notify masters of vessels of the character of the operations in which she was engaged, as described in a published notice, and to warn them to avoid a collision.

POWDER USED.

The powder used in the drill holes at first, as previously stated, was common blasting powder. This proving too weak to rend the rock, Dupont's best sporting powder was tried, in charges from 6 to 20 pounds, with better, but not satisfactory results.

It at once became evident that a stronger blasting compound must be obtained.

Trial was then made of the Patent Safety Blasting Powder, manufactured by the Oriental Powder Company, of Boston. Its composition, as manufactured for general use, is:

Chloride of Potash	50	parts.
Kutch or Gambia	50	"
	100	"

This gave results nearly twice as great as the sporting powder. A charge of it placed in a drill-hole from 3 to 8 feet deep, could almost invariably rend the rock, and throw out a crater more or less extended.

Trial was also made of a powder made from the proportions furnished by Dr. Charles T. Jackson, State Assayer of Massachusetts, as follows:

Chlorate of Potassa	490
Yellow Prussiate of Potash	280
Powdered Loaf Sugar	230
	1,000

This gave equal results to the chloride powder above, but as there was no manufacturer of this powder for general use, the other was employed, and, by especial agreement, made much stronger than usual, to attain the greatest possible blasting effect.

The proportions used were:

Chloride of Potash	80	parts.
Gambia	20	"
	100	"

The price paid for this was $15 per box of 20 pounds.

An effort was made to obtain nitro-glycerine, at first, but unsuccessfully, as none could at that time be procured nearer than New York, and even then with considerable difficulty attending its purchase and transportation. Subsequently the chloride powder, in its increased strength, proving entirely satisfactory in its results, it was no longer necessary for the progress of the work to get a stronger explosive. It did not therefore seem proper, with a just regard for the safety of the divers, to add to the ordinary risks of their avocation, the additional danger usually attending the use of this highly explosive compound.

As it was, no accident from the use of powder occurred during the whole work, although large quantities were at times kept on board the working vessel. As a general thing, however, the powder was kept stored for safety in a small house on shore, near by, where the cartridges were filled and thence brought off in a boat when needed.

For blasting in seams, or under projecting faces, where large charges were required, the best sporting powder was used, as it was found to be more effective under those circumstances than the Patent Safety Blasting Powder. It was only in the drill-holes, or when confined, that the latter exhibited its superior strength.

It was found that surface blasting was generally without effect, even when from 300 to 500 lbs. of the best sporting powder was used in a single charge. It was only when the charge could be inserted into a seam made by previous blasts, or placed under a projection, that it produced any effect.

The cost and quantity of powder used is given in the following table:

50lbs. white powder	@ $2 00	$100 00
6 cases patent do.	@ 13 50	81 00
6 do. do. do.	@ 15 00	93 00
57 do. do. do.	@ 15 00	855 00
548 kegs sporting and gun powder	@ 6.50	3,562 00
		$4,691 00

CARTRIDGES.

Of these, numerous varieties were tried, in the search for one that combined all the requisites of impermeability to water, lightness, incompressibility, and cheapness.

Lightness or buoyancy of material was required in order that the fragments of the cartridges, after an ineffective blast, might float out of the hole, and not remain in to choke it, and prevent the introduction of a new charge.

Incompressibility was requisite to prevent the powder from becoming caked from the pressure of the heavy column of water, in which state the ignition from the fuses or exploders was slow and incomplete.

Cheapness was a desideratum, but not a controlling one. The absolute requisite was that the cartridges should be water-tight.

Trial was first made of *tin canisters*. These were water-tight, incompressible when braced inside, and cheap; but when used in drill-holes (Fig. 5, Plate 5), they had the defect described above, of the exploded tin canister choking the hole and preventing a new charge being pushed to the bottom. This caused their abandonment as cartridges for drill-holes. They were always used, however, to contain the charges for large blasts in crevices, large seams, or under projecting "faces." They were of the usual form (seen in Figs. 9 and 11, Plate 5), and were mostly braced crosswise on the inside, to prevent being collapsed by the pressure of the water. For seams, the canisters were made flat and thin, as seen in Fig. 12, Plate 5, and were also braced in the interior.

Trial was next made of *india-rubber cartridges* (Figs. 3 and 4, Plate 5) of a cylindrical form, for drill-holes. These answered very well—better, upon the whole, than any other kind. They possessed the indispensable requisite of being perfectly water-tight, and of leaving after the blast no debris to fill the bottom of the hole. They also, being elastic, easily yielded to any irregularities of the hole, so as to be readily pushed to the bottom. The mouth was easily made water-tight by being tightly wrapped around the electric wire with twine, and then covered with a water-tight compound.

They had, however, the defect of being compressible, so that, at the depth of thirty feet below the surface, the powder in them became caked almost as hard as a stone. The cost was also greater than for any other kind, being from 37½ to 75 cents each.

The india-rubber cartridges, to contain charges to be placed in seams in the rock, were made long, wide, and flat, and were stitched like a life-preserver, in vertical, parallel rows, not extending quite to the bottom or top (Figs. 13 and 14, Plate 5). They answered well, as they readily adapted themselves to the irregular forms and cavities of seams. The principal difficulty was in filling them with powder, on account of the small tubes formed by the stitching.

Wooden cylinders, made of successive wrappings of thin wood cuttings, such as are used in covering walls instead of paper (see Figs. 7 and 8, Plate 5), were next tried. In some, the wooden sheets were wrapped with the fibres longitudinal, in others transverse, in others diagonal. The bottoms and tops were also of wood, turned to fit tightly, and covered with water-tight composition. These cylinders were incompressible, also buoyant, so that the fragments, after a blast, floated out of the hole. The cost was also small, being about 20 cents each. But they were not water-tight. The pressure of from 23 to 35 feet of water forced so much moisture through the pores as always to dampen and frequently to thoroughly wet the powder, so that it would not explode. This was the case, although to a less extent, even when the cylinders were wrapped with paper steeped in coal tar, paraffine, and other water-proof substances.

Thick paper cylinders (Fig. 6, Plate 5), covered with water-tight substances, were next tried. These were buoyant, cheap, and nearly incompressible, but in a majority of cases they proved not to be water-tight. The pressure of water caused the coatings to crack.

Iron cylinders cast very thin were proposed, but not tried, as their fragments would be likely to jam in the hole after a false blast, and prevent getting a new charge down to the bottom. They might also jam in an angular hole. A similar difficulty was experienced in the use of some gun-metal cylinders, cast like the cup of the Minnie ball, that were tried over the charges, for tamping.

Glass cylinders or long bottles were also proposed, but not tried, as the divers objected to their use on account of the broken glass which would mix with the fragments of stone, being likely to cut their hands in handling the stone, and also to cut through their submarine dress while working upon their knees, in which position most of the work about the drill and in shovelling up the small pieces of stone, had to be done. A single small cut in a diver's dress would let in water enough to soon fill his armor.

We were therefore forced to continue the use of the india-rubber cartridge, notwithstanding its cost and compressibility. The latter defect was obviated to a certain extent by the diver constantly manipulating the filled cartridge with his hands from the time he went under water until he placed it in the hole ready for blasting, after which he came directly up, and the charge was fired without loss of time. In addition, several exploders were used in each of the larger charges (Fig. 3, Plate 5), so as to give several points of ignition to insure complete combustion.

MEANS FOR EXPLODING THE CHARGES.

Within each charge was placed one or more exploders or fuses, containing fulminating powder, placed between and around the slightly separated ends of two fine copper wires (Fig. 1, Plate 6). The spark produced by the passage of the electric current between these two wire ends explodes the fulminate, and thus ignites the whole charge. The wires in these exploders are connected with two other wires in an insulating coating of gutta-percha, which extend above water and to the portable electric battery on the deck of the working vessel. Sometimes these wires were in separate insulating coverings, as in Fig. 6, Plate 6, and at others both in the same covering, as in Fig. 5.

Great pains were always taken to make the mouths of the cartridges, where these connecting wires entered the charge, hermetically tight, by means of a tight-fitting cork or wrapping of twine, over which a thick coating of a water-tight compound of melted india-rubber, lard, and rosin, was carefully pressed and moulded. All this was done on the deck of the vessel, before the charge was taken below by the diver.

The conducting wires may be either iron, steel, or copper, the latter being preferred for its superior conducting power. Two were usually employed, as stated above; but at one time, when a very large charge was to be fired, it became necessary to use the whole length of the wire, in order to enable the sloop to lie at a safe distance. In this case a short portion of the second wire from the cartridge was left to project into the water, while a similar portion of wire connected with one pole of the electric battery, was suffered to hang over the side of the vessel into the water. When the poles of the battery were connected, as usual, to fire the charge, the explosion took place instantly, the return current passing through the water from the end of the wire projecting from the cartridge to the end hanging overboard, precisely as though connected by wires.

The exploders for small charges were single (Fig. 1, Plate 6); for larger ones they were double or treble, and for very large charges a large number, as many as fifty in some cases, were attached together, forming a string (Figs. 2 and 4, Plate 6). For such a string the exploders were made of a more sensitive fulminate, expressly prepared for the purpose by their manufacturers, Messrs. Moore & Smith, No. 62 Sudbury street, Boston, by whom the conducting wires and the friction battery were also made.

The *Friction Battery* is of a simple construction, as seen in Figs. 1–7, Plate 7.

It is only about one foot square by two inches in thickness, and is portable, light, and convenient for use. Although so small, it contains all the necessary parts of such a battery—a friction-wheel, Leyden jar, and connecting poles—all contained in an insulated covering. Its simplicity, lightness, and compactness recommends it for service in the field to fire temporary mines, fougasses, etc., or on the coast to fire the torpedoes used against shipping, or in forts to fire the heavy guns.

To fire a charge with it, the connecting wires from the exploders in the charge are first attached to the two knobs of the instrument; a few turns are then given to the handle to generate the electricity; then, every thing being "ready," the order to "fire" is given, when the knob to connect the poles is pulled by the operator, and the explosion takes place instantly.

No exploder missed fire during the whole course of the work upon Tower and Corwin rocks.

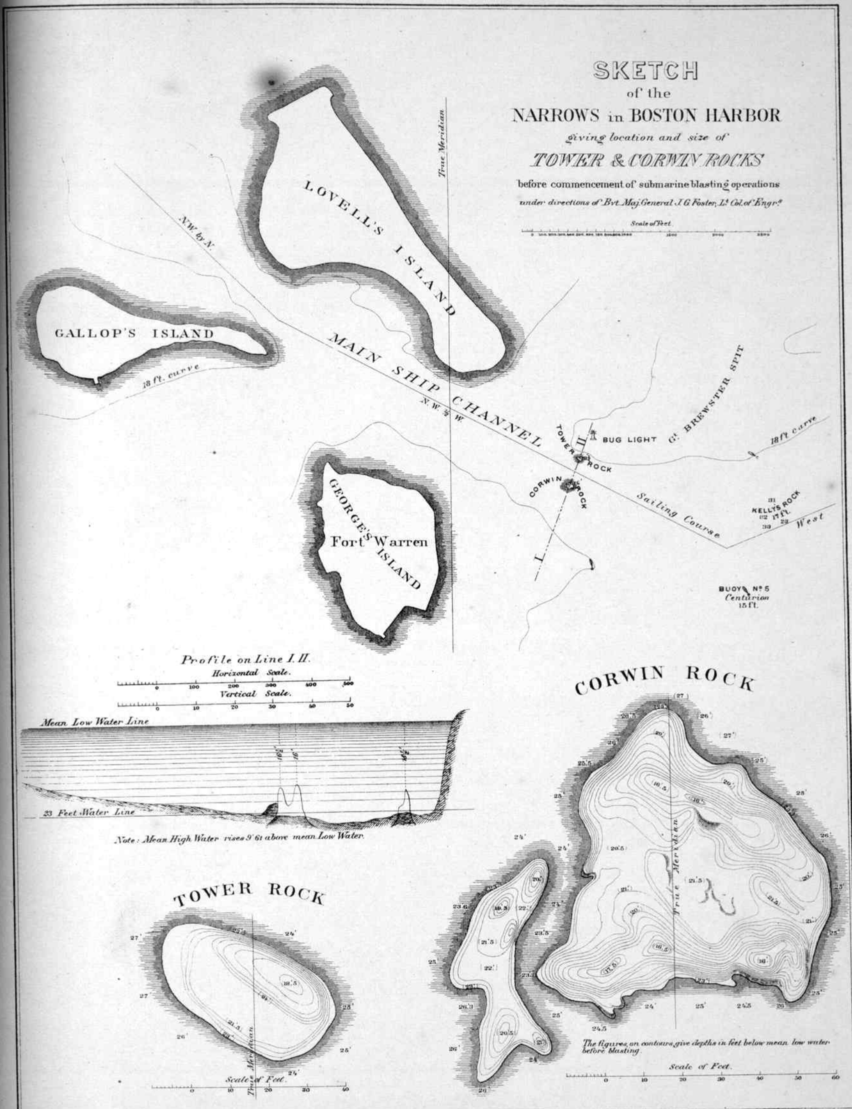
The friction battery requires to be taken in pieces about once in a month, to clean the friction-plate and its compartment of the loose powder and dust, and to renew the "mosaic gold" or sulphuret of tin, upon the spring friction rubbers. It should, when not in use, be kept in a warm, dry place.

TAMPING.

At first, common sharp sand, mixed with fine gravel, was used; but it was found that, at the depth of the charges, 23 feet at low and 33 feet at high water, the sand became so buoyant as to be deprived of the compactness necessary in tamping to produce effect. Metal tamping was then tried. Of these the Lewis form (Fig. 1, Plate 5) was always effective, but had the disadvantage of being introduced with difficulty.

A gun-metal cylinder (Fig. 2, Plate 5), with one end closed except a small orifice for the electric wires, was then tried with success. The upper part of the cartridge fitted into the cup of this tamper, and both were lowered into the hole together. In firing, the cup expanded like that of the Minnie ball, causing the outside of the cylinder to adhere by friction to the sides of the drill-hole.

Generally the best results in blasting were obtained by first exploding in the drill-holes successive small charges, without tamping, until seams were started in various directions, and then using a heavy charge of patent powder, with a good tamping, like the gun-metal cylinder, so as to dislodge, if not to hoist out, all the masses of rock that had become disconnected by the seams.



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SUBMARINE DRILLING MACHINE

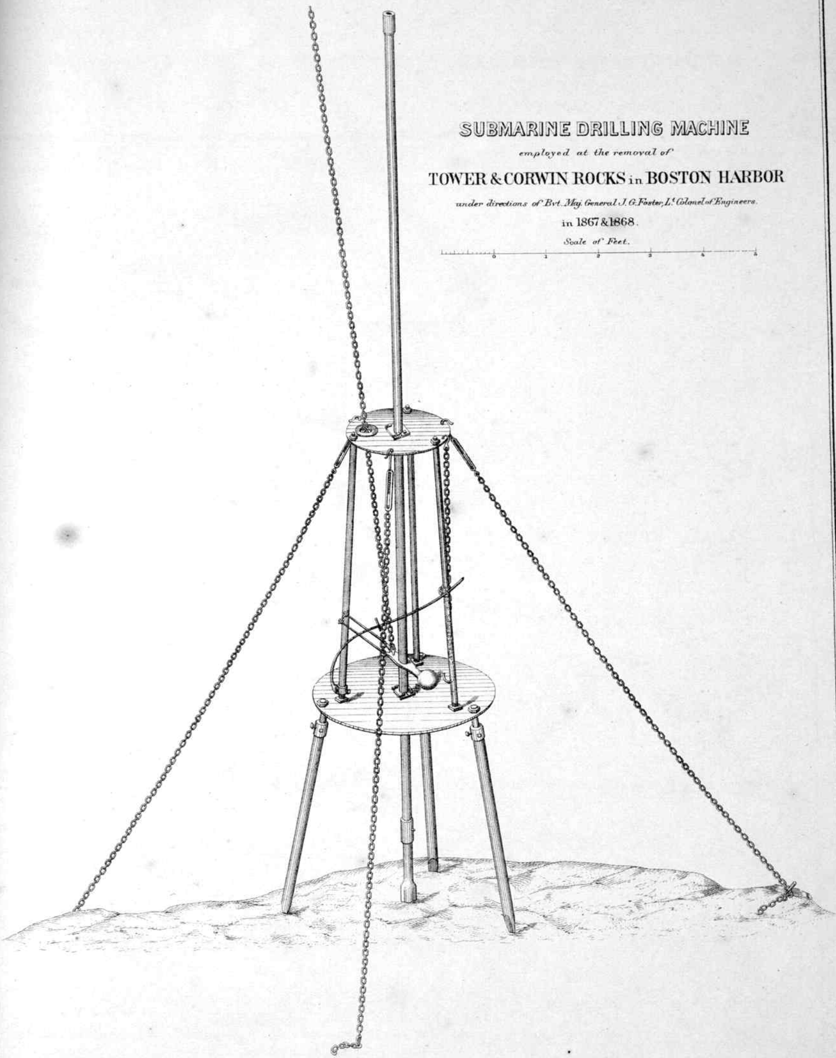
employed at the removal of

TOWER & CORWIN ROCKS in BOSTON HARBOR

under directions of Bvt. Maj. General J. G. Foster, Lt. Colonel of Engineers.

in 1867 & 1868.

Scale of Feet.



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DETAILS OF DRILLING MACHINE

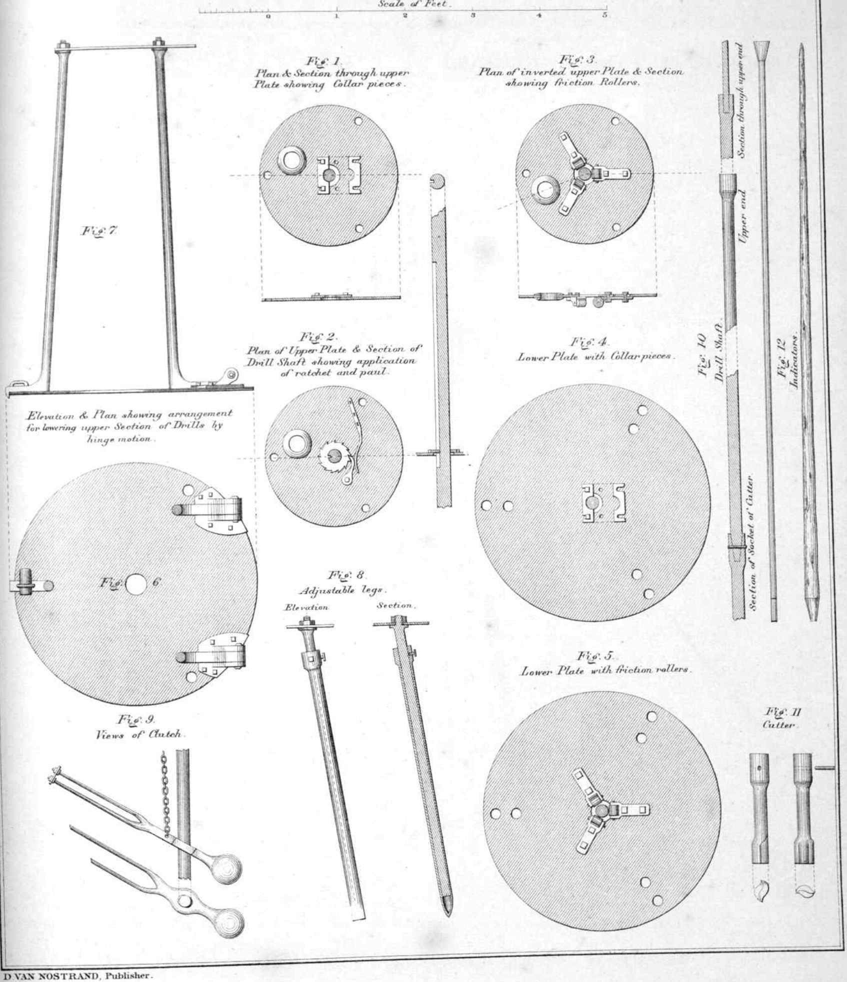
employed at the removal of

TOWER & CORWIN ROCKS in BOSTON HARBOR

under directions of Bvt. Maj. General J. G. Foster, Lt. Colonel of Engineers.

in 1867 & 1868.

Scale of Feet.



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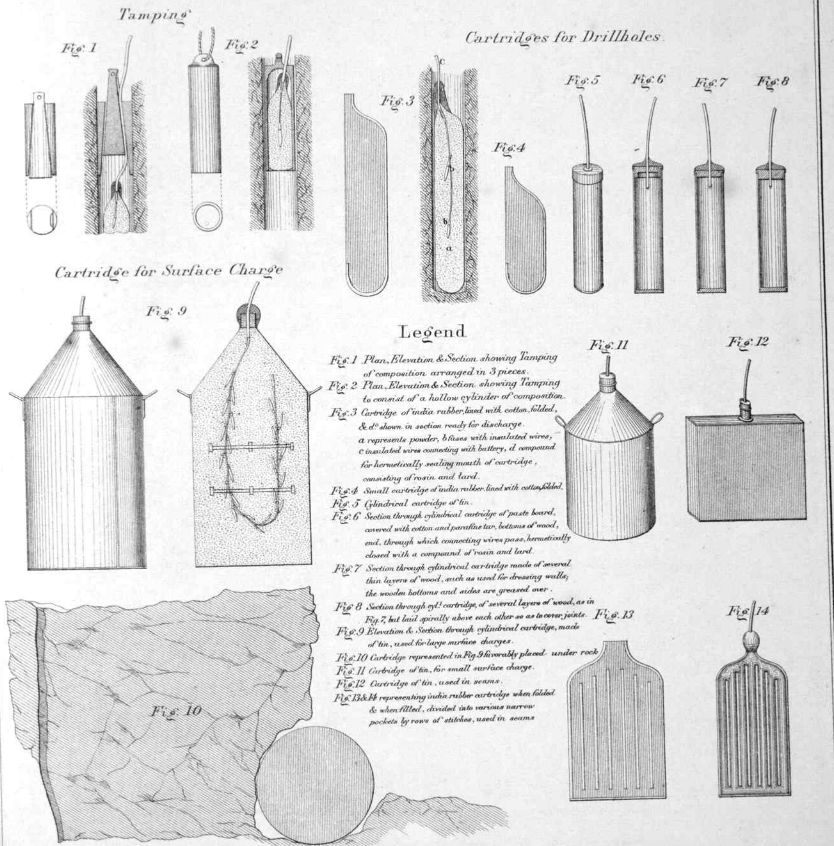
CARTRIDGES & TAMPING
used at the
SUBMARINE BLASTINGS on TOWER & CORWIN ROCKS in BOSTON HARBOR.

under directions of Bvt. Maj. General J. G. Foster, Lt. Colonel of Engineers.

in 1867 & 1868.

Scale of Inches.



Legend

Fig. 1 Plan, Elevation & Section showing Tamping of composition arranged in 3 pieces.
Fig. 2 Plan, Elevation & Section showing Tamping to consist of a hollow cylinder of composition.
Fig. 3 Cartridge of india rubber, lined with cotton, folded, & do. shown in section ready for discharge. a represents powder, b fuses with insulated wires, c insulated wires connecting with battery, d compound for hermetically sealing mouth of cartridge, consisting of rosin and lard.
Fig. 4 Small cartridge of india rubber, lined with cotton, folded.
Fig. 5 Cylindrical cartridge of tin.
Fig. 6 Section through cylindrical cartridge of paste board, covered with cotton and paraffine tar, bottoms of wood, end, through which connecting wires pass, hermetically closed with a compound of rosin and lard.
Fig. 7 Section through cylindrical cartridge made of several thin layers of wood, such as used for dressing walls; the wooden bottoms and sides are greased over.
Fig. 8 Section through cyl. cartridge, of several layers of wood, as in Fig. 7, but laid spirally above each other so as to cover joints.
Fig. 9 Elevation & Section through cylindrical cartridge, made of tin, used for large surface charges.
Fig. 10 Cartridge represented in Fig. 9 favorably placed under rock.
Fig. 11 Cartridge of tin, for small surface charge.
Fig. 12 Cartridge of tin, used in seams.
Fig. 13 & 14 representing india rubber cartridge when folded & when filled, divided into various narrow pockets by rows of stitches, used in seams.

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FUSES & INSULATED WIRES

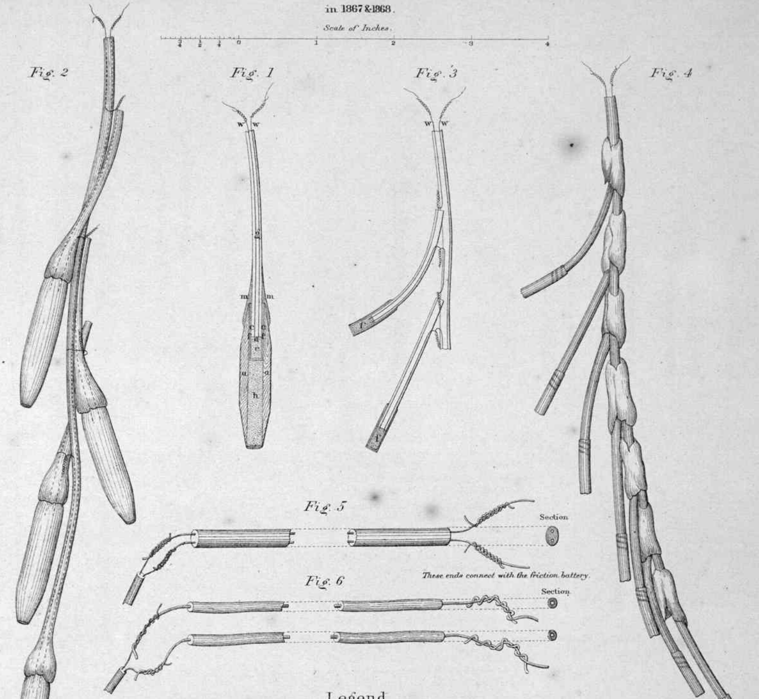
used in connection with a portable friction battery

at the

SUBMARINE BLASTINGS on TOWER & CORWIN ROCKS in BOSTON HARBOR.

under directions of Bvt. Maj. General J. G. Foster, Lt. Colonel of Engineers.

in 1867 & 1868.



Legend

Fig. 1 Section through single fuse, or patent exploder, of best quality. a hollow cylinder of soft wood greased on side and closed at end with parafine tar; W. W copper wires insulated by gutta percha (g); c tin foil enclosing ends of insulated wires and the strong fulminate d and common fulminate e; f, coating of grease on the outside of the tin foil; h, sporting or patent powder; m, coating of gutta percha and a compound of rosin and lard.

Fig. 2 String of fuses of best quality, used with large charges showing arrangement of insulated wires to form circuit.

Fig. 3 Section through patent fuses of inferior quality; W. W. copper wires insulated by gutta percha; f, fulminate tightly enclosed with tin foil greased on the outside.

Fig. 4 String of fuses of inferior quality, as in Fig. 3, having wire joints covered with gutta percha and compound of rosin and lard.

Fig. 5 Double wires, insulated by gutta percha, used for connecting poles of battery with fuse in charge, best answering for practical purposes.

Fig. 6 Two single wires, insulated by gutta percha, for connecting battery with fuse.

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PORTABLE FRICTION BATTERY

used at the removal of

TOWER & CORWIN ROCKS in BOSTON HARBOR,

under directions of Brt. Maj. General J. G. Foster, Lt. Colonel of Engineers

in 1867 & 1868

Scale of Inches

Fig. 1

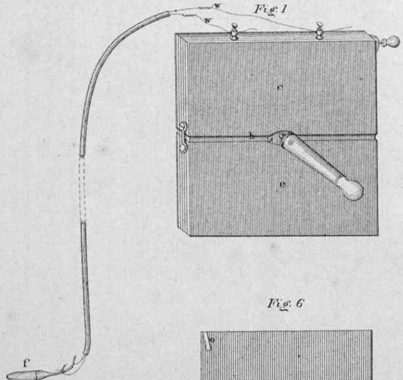


Fig. 2

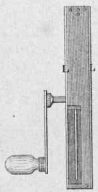


Fig. 3

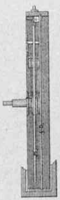


Fig. 4

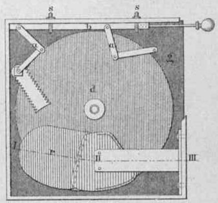


Fig. 5

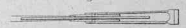
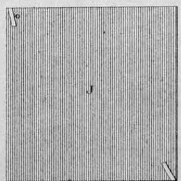


Fig. 6



Legend

Fig. 1 Perspective view of battery, with box covers c & e fastened, showing connection by insulated wires W, W, with fuse f.

Fig. 2 End view of battery, the box covers c & e, the india rubber tightening band h, and the spring rubbers r, r being removed.

Fig. 3 End view of battery, box covers, cover sides L, and end, spring rubbers r, r, and Leyden jar J being removed.

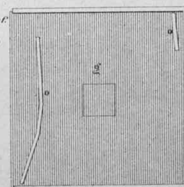
Fig. 4 Front view of battery, box covers, cover sides and end, and Leyden jar J being removed, showing revolving disk d passing through spring rubbers r, r, communicating arms a, a and bar b with knob attachment, and communicating screws s, s.

Fig. 5 Section through spring rubbers r, r and revolving disk d, on line I, II, III.

Fig. 6 Leyden jar, consisting of several thin plates of vulcanized india rubber, wrapped up in soft rubber, and connected by tin foil (o) with each other and the back plate g; or rather with the axle heads (brass) of the communicating arms and bar resting therein.

Fig. 7 Back plate g with strips of tin foil (o) over axle heads.

Fig. 7



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