Feb. 9, 1932. J. K. M. HARRISON 1,844,575

MINE

Filed Nov. 11, 1919 3 Sheets-Sheet 1

FIG. III.

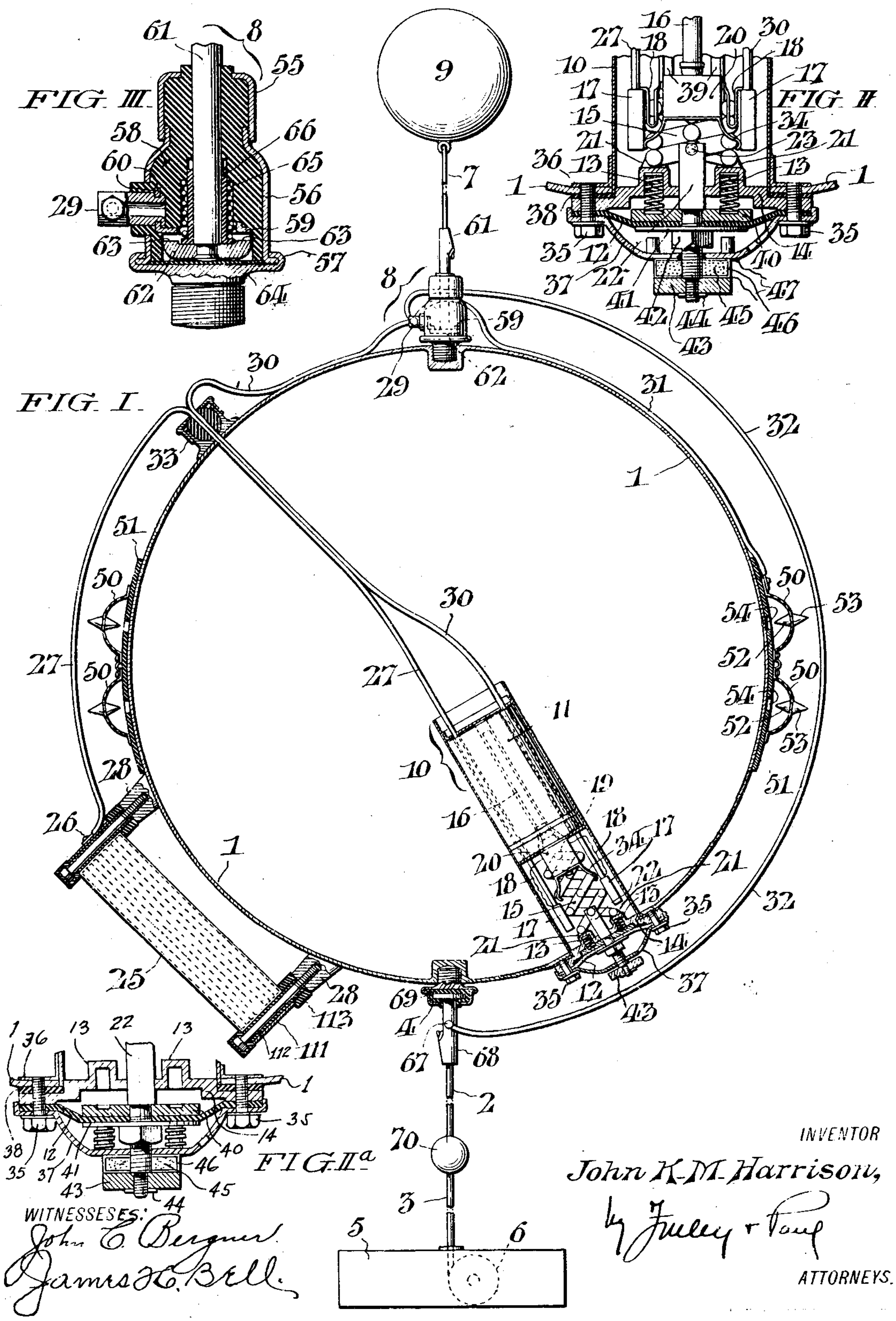

FIG. II.

FIG. I.

FIG. II^a.

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MINE

Filed Nov. 11, 1919 3 Sheets-Sheet 2

FIG-X.

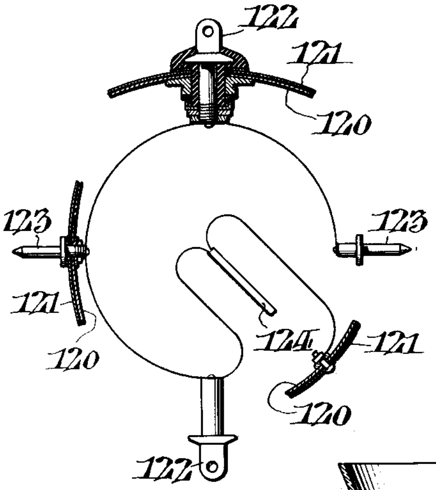


FIG-XI.

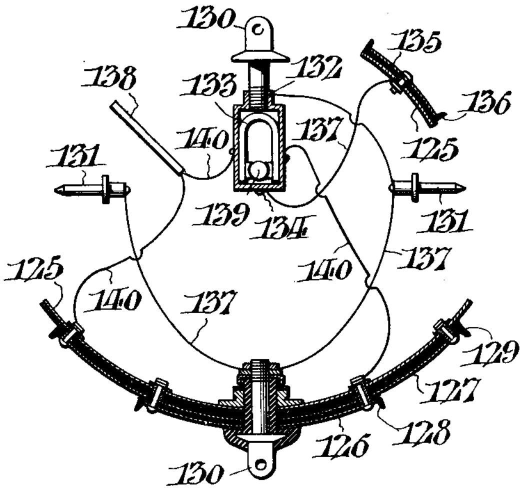


FIG-IV.

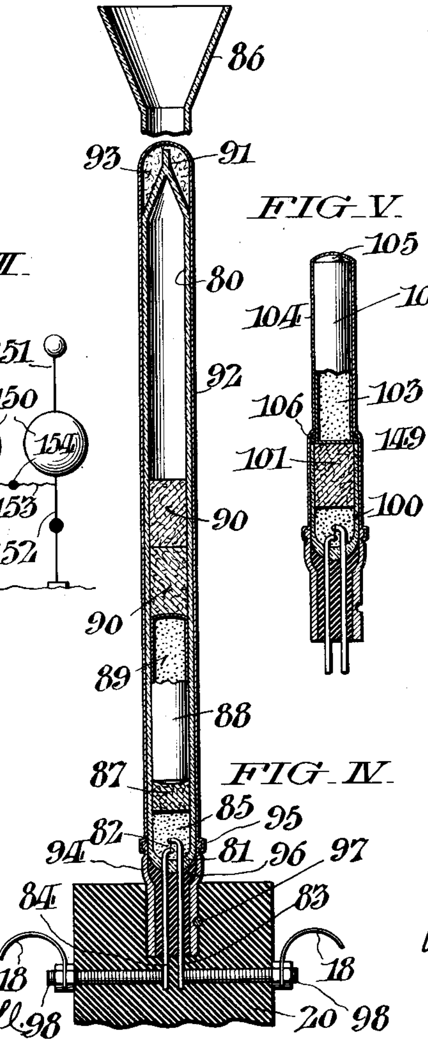


FIG-V.

FIG-XIII.

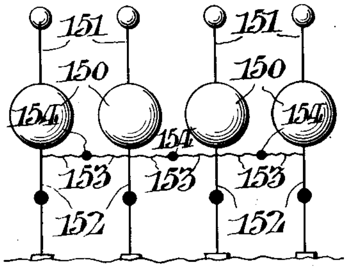
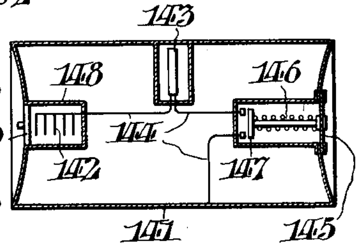


FIG-XII.



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MINE

Filed Nov. 11, 1919 3 Sheets-Sheet 3

FIG. VI.

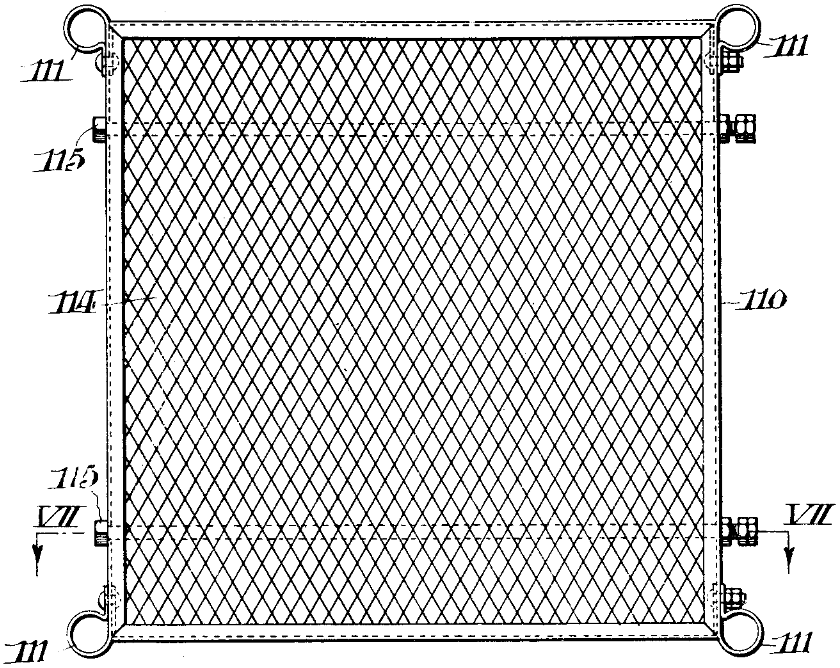


FIG. VII.

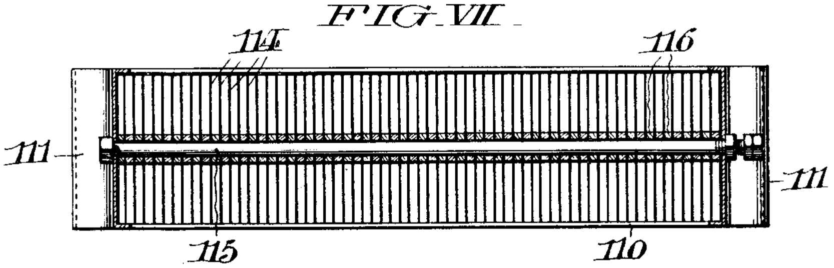


FIG. VIII.

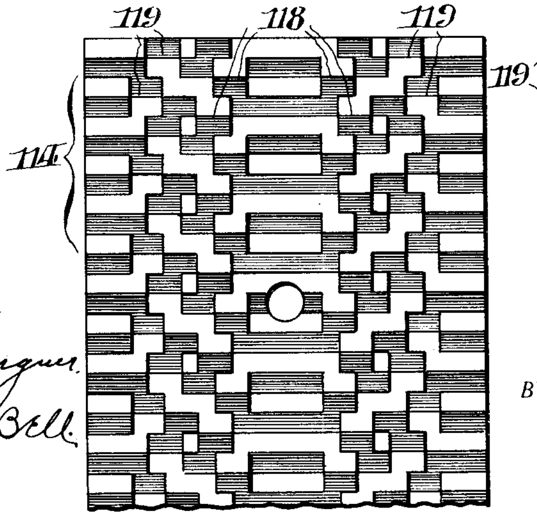
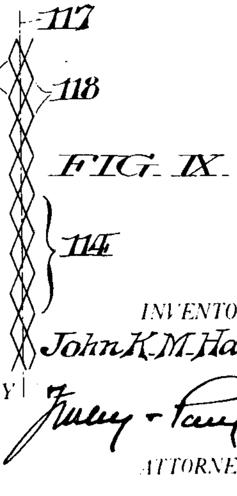


FIG. IX.



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UNITED STATES PATENT OFFICE

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MINE

Application filed November 11, 1919. Serial No. 337,220.

My invention relates to mines and the like, and particularly to mines of the marine type,—whether submerged or floating at the surface of the water. The invention is especially concerned with the supply of energy or power in connection with the setting off or firing of such mines; but it also involves a number of features of operation, construction, and arrangement that serve to increase the effectiveness of mines in various other ways. Amongst the main objects of the invention are certainty and reliability of action; durability and freedom from deterioration or derangement in service or in storage; structural simplicity and facility and economy of manufacture; immunity as against counter-measures of the enemy; and an extended zone of actuation. Various other advantages obtainable through the invention will become apparent from the description hereinafter of the best embodiment at present known to me, while its scope and essentials will be indicated in my claims. Certain features hereinafter described are, indeed, applicable to other uses than mine firing, as will readily be seen.

Some words of general explanation may advantageously precede the description of particular forms of apparatus.

If regarded broadly as a process, the firing of a mine includes every operation that intervenes between the occurrence of the condition under which the mine is intended to function and the letting go of the charge finally relied on to produce the desired effect on the object of attack. The process, therefore, divides itself into two parts: on the one hand, the total actual exploding, and on the other, the total precedent action, which brings about the exploding,—including the initial actuation or response of the mine organization to the condition of attack.

I have used the expression "total actual exploding" for the reason that in present practice this part of the mine firing process quite commonly comprises a succession of explosions rather than just one single explosion. While the number of theoretically or actually distinct explosions employed may vary considerably according to the requirements to be fulfilled, a procedure wherein three main stages are recognizable may be described as typical of current practice. In such a procedure, an initial explosion is produced in a device comprising a small amount of highly sensitive material, usually called a "detonator"; the energy developed or released by this initial explosion serves to explode or detonate a larger amount of material termed a "booster" charge; and this booster explosion in turn sets off or detonates the main mine charge. This is the commonest type of mine exploding, and the one I prefer to employ,—though it is to be understood that in its broader aspects my invention has no relation to the type of exploding process.

Now just as this exploding part of the firing process commonly involves a plurality of stages, so the antecedent action which brings about the initial explosion may itself involve a succession of more or less distinct operations or releases of energy,—such as the functioning of a plurality of relays, for example.

In all cases there is required a source of energy and an agency to which such energy is applied to produce initial explosion. This agency—whether a "detonator" within the limits of technical definition, or of some other type—may appropriately be designated as the "mine-firing means". To the parts of the mine organization involved in bringing into action or operating the mine-firing means in response to the conditions of attack, the term "firing gear" may conveniently be applied,—this team being, however, sufficiently elastic to include also the firing means when the context requires.

While various ways of providing the requisite energy have heretofore been proposed and tried, none of these has adequately met the needs of the case. For, in the first place, marine mines must often be located where an extrinsic source of energy (on shore or on an attendant vessel, for example) is out of the question; and, in the second place, while electricity is by far the most convenient form of energy for such purposes, yet all storage batteries, dry cells, or other such proposed sources of electricity as could in practice be incorporated in the mine organization or equipment proper deteriorate rapidly or become deranged under the conditions of service, or are liable to be put out of order or made to function prematurely by counter-mining or the like,—or are open to some other very serious objection. The provision of a satisfactory supply of electrical energy for operating electrical mine-firing gear is, therefore, a prime aim of my present invention.

I have found that the electrical energy or power required to operate the firing gear can be derived from the mine environment, by means of a galvanic special cell or "battery" device which I have invented. This galvanic cell may be used with sensitive detonators which I have invented capable of responding by explosion to the limited energy supplied by such "sea battery". Functioning on the galvanic couple principle with the sea-water about the mine as electrolyte, this battery device is not subject to deterioration or exhaustion like a storage battery, or dry cell, or any ordinary wet cell, so that it renders a mine organization or equipment in which it is incorporated a self-dependent unit,—independent of all extrinsic sources (save its immediate aqueous environment) and intrinsically complete in situ, as regards provision for power supply for operating its firing gear, when in the sea. In cases where electrical energy is required only at the moment of firing, the effective serviceability of a mine provided with it is limited only by the structural endurance of the mine. Such a sea-battery mine can be provided with actuating means automatically responsive to any conditions of attack desired, such as impact of a vessel to be attacked against the mine, contact of such vessel with a mine antenna or horn, sinking of a "depth charge" type of mine to the desired depth, etc. (Here and throughout my specification and claims, I have used the expression "conditions of attack" in reference to the circumstances under which the mine is intended to function and thus attack a vessel in suitable proximity to it,—without any regard whatever to whether the vessel in question happens to be friendly or otherwise to the party by whom the mine is employed. This usage is justified by the fact that marine mines are not customarily provided with any means of discriminating between vessels hostile and vessels friendly or neutral to the party employing the mines, but attack friend and foe indiscriminately when certain conditions of proximity or the like occur.) Not only, furthermore, can the battery device be made to afford and supply directly all the electrical energy or power required to operate electrical mine-firing means,—without supplementation from any such objectionable source as a dry cell, and without intervention of any other electrical source between battery device and explosive,—but it can be made to afford all the power required for operating mine firing means wherein *input* electricity (as distinguished from electricity from some internal source such as a dry cell included in the firing means) affords the sole energy ultimately applied to explosive material (specifically distinguishable as "straight" electrical firing means). Finally, while condition-responsive means of a type requiring internal energization to enable it to respond may be so energized from some other source even when associated with a sea-battery mine having electrical firing means, I have found that in general the energy for this purpose can be obtained from the same battery device that supplies energy for operating this firing means.

While I have herein referred to mines of the marine type and to sea-water as the electrolyte, and while I have set forth my invention with special reference to marine employment, it will be evident that the utility of a "sea-battery" mine in accordance with my invention extends to other bodies of water besides the ocean,—and, in fact, to any sufficiently aqueous environment wherein a suitable electrolyte is present.

I will now proceed to the description of specific forms of apparatus.

In the drawings, Fig. I is a somewhat diagrammatic sectional elevation of one form of mine organization embodying my invention, in its submerged condition, certain parts being broken away and others being slightly displaced from normal position.

Figs. II and II*a* are enlarged fragmentary sectional views of certain mechanism shown in Fig. I, in its condition prior to the mine's being put overboard. This view shows the mechanism in somewhat greater detail than does Fig. I, and includes certain additional parts.

Fig. II*a* is a fragmentary view to Fig. II showing a different arrangement of certain parts to secure a different action.

Fig. III is an enlarged sectional view of a circuit-breaking device shown in Fig. I, in somewhat greater detail.

Fig. IV shows a longitudinal section of a detonator of my invention.

Fig. V shows a similar section of a modified type of detonator.

Fig. VI is an enlarged detached front view of a battery device shown edgewise in Fig. I, slightly diagrammatic.

Fig. VII shows a section of the battery device at a plane corresponding to the line VII—VII, in Fig. VI.

Fig. VIII is a greatly enlarged fragmentary view of one of the plate elements of the battery device.

Fig. IX is a corresponding edge view of a plate element.

Fig. X is a diagrammatic view of a modified form of mine embodying my invention.

Fig. XI is a similar view of still another form of mine embodying my invention.

Fig. XII is a somewhat diagrammatic sectional view of a depth charge type of mine embodying my invention.

Fig. XIII is a diagrammatic view of a plurality of mines combined in a novel way invented by me.

The mine organization shown in Fig. I, comprises a spherical mine shell or case 1, of any suitable construction and material, intended to contain the main explosive charge. A cable comprising sections 2 and 3, with an insulating attachment 4, secures the mine to an anchor device 5, of any usual or preferred sort,—that shown having a cable reel mechanism 6, for supplying the necessary cable for varying depths of water. Another cable 7, whose attachment to the mine case 1, includes a circuit-breaking device 8, extends upward to a float 9, usually submerged somewhat.

In the lower portion of the mine shell 1, is an opening from whose edge extends inward a cylindrical casing 10, in which is mounted the metal can 11, containing the "booster" charge. Over this same opening is secured watertight a flexible rubber diaphragm 12, externally exposed to the hydrostatic pressure of the water about the mine, and urged outward against this pressure by helical compression springs 13, 13, acting against an abutment structure 14, secured in the aforesaid opening. The hydrostatic diaphragm 12, controls and operates a safety mechanism 15, whose function is to project the movable electrical firing means 16, into the "firing" position (as shown) with reference to the booster can 11, when the mine is in its desired submerged firing environment, and to withdraw it, when the mine is raised, to such an extent that its action would no longer detonate the booster and so explode the mine. The firing means 16, is accommodated in a tube extending from end to end of the booster can 11, and is connected between terminal blocks 17, 17, insulatively mounted in the casing 10, by means of flexible current leads 18, 18, which permit it to move freely as just described. As shown, the mechanism 15, consists of a lazy-tongs or Jacob's ladder pivoted at one end 19, to an insulating firing means holder carrier 20, and pivoted at its other end to lugs 21, 21, on the abutment structure 14. A short rod 22, attached to the diaphragm 12, extends inward through the abutment structure 14, and is suitably connected at 23, to one or both of the outermost lazy-tong members which are pivoted at 21, 21, as already described. Thus the lazy-tong extender mechanism 15, is operated by the diaphragm 12, under automatic control of the mine environment,—i. e., in response to the hydrostatic pressure,—and by suitable design and adjustment of the springs 13, 13, it can be made to function at any desired depth of submergence of the mine. This diaphragm extender mechanism 12, 15, renders the mine harmless in case it should break adrift and come to the surface of the water,—as required by the Hague Convention.

Coming, now, to the apparatus for operating the electrical firing means 16, I have here shown the sea battery device for supplying the required electrical energy as comprising a single pole element 25, of suitable material having a terminal 26, to which is attached a suitably insulated (and preferably armored) conductor cable 27. As shown, the pole element 25, is mounted on feet 28, spot-welded to the mine shell 1. On the circuit-breaker device 8, is mounted another terminal 29, having means for the attachment of a plurality of suitably insulated (and preferably armored) conductor cables 30, 31, 32. The conductor cables 27 and 30, enter the mine shell 1, through a rubber ball stuffing box 33, and pass through tubes (extending from end to end of the booster can 11,) to the contact blocks 17, 17, between which the firing means 16, is connected by the flexible leads 18, 18, as already described. The firing means 16, is, therefore, connected between the battery device 25, and the terminal 29, by a permanent metallic circuit, never interrupted or broken in the functioning of the mine organization prior to explosion.

As a safe-guard against accidental explosion additional to that afforded by the shifting of the firing means 16, there is mounted on the insulating holder carrier 20, a bridge piece 34, whose resilient ends wipe brush-wise against the conductive contact blocks 17, 17, almost as soon as the device 16, starts to move out of firing position, and vice-versa,—thus making and breaking a shunt across the firing device 16. The resistance of this shunt can be made a mere hundredth of that of the firing device 16, or even less. Such an arrangement renders firing at the proper time far more certain than would a make and break in the firing circuit itself; and since the actual shunt connection that must be relied on can be tested before the mine is charged with explosive, it affords just as good protection as would a firing make and break,—or even better, since the latter might be nullified by a broken part of the mechanism, or by an extraneous piece of metal accidentally getting into the casing 10.

In Fig. II, I have shown parts of the extender mechanism and the diaphragm mounting in somewhat greater detail than in Fig. I, and in their positions before the mine is put overboard instead of in their final positions after its submergence. As here shown, there are about the diaphragm opening in the mine shell 1, a number of stud-bolts

35, which not only take into the mine shell 1, but also into a flanged ring 36, fastened to the casing 10. These bolts 35, extend through and securely clamp in place the abutment member 14, the diaphragm 12, and a cover member 37,—a gasket 38, being interposed between the mine shell 1, and the abutment member 14, to make the joint watertight. This gasket 38, should be of the hardest material consistent with its function, in order to minimize its compression by counter-mining explosions and the consequent hammer effect of the parts upon the mine case 1. Angle-bar ways 39, serve to guide the carrier 20, and prevent the firing means 16, from binding or sticking in its tube in the booster can 11. The rod 22, that connects the extender mechanism 15, to the diaphragm 12, has a reduced threaded portion that extends through a pair of metal discs 40, 41, as well as through the diaphragm itself; and these discs are clamped upon the diaphragm 12, and against the resulting shoulder by a nut 42, that also limits outward movement of the diaphragm, by abutting against the cover member 37. The helical compression springs 13, 13, are seated in the hollow bases of the lugs 21, 21, and in recesses in the disc 40.

The rod 22, extends out and slides freely through the cover 37, and is again reduced and screw-threaded, and a disc or flange member 43, is screwed against the resulting shoulder and secured by a cotter pin 44. Between the flange member 43, and the subjacent outer surface of the cover 37, is an element 45, having the form of a washer, which, it will be seen, makes it practically impossible for hydrostatic pressure on the diaphragm 12, to operate the extender mechanism 15. This element 45, is to be made of material susceptible of gradual disintegration in the mine environment,—as, for example, soluble material like sodium chloride,—its function being to control and delay operation of the extender mechanism 15, after the mine is put overboard a sufficient time to allow the mine-layer to get out of its zone of danger. Until the mine is thus put in service, the soluble body 45, is protected by means of an enveloping cover 46, of waterproof material such as shellacked textile fabric or parchment, strings 47, 47, enabling the cover 45, to be quickly torn off at the proper time. It will be seen that this element 45, effectually locks the extender mechanism 15, in the position shown, with the firing means 16, so far withdrawn from the booster can 11, as to be incapable of detonating the booster charge. If it be desired to use the mine as a floating one rather than as a submerged one, it is only necessary to transpose the springs 13, 13, to a position between the member 40, and the cover 37, as indicated in Fig. II*a*, so that when the delay element 45, is gone the springs may take the place of the now deficient hydrostatic pressure as means for operating the extender mechanism 15. Under these latter conditions, the springs and disintegrating element together serve as means for operating the extender mechanism 15, under control of the mine enviroment,—as, in fact, do the hydrostatic diaphragm and the disintegrating element together when the mine is used submerged.

Coming, now, to the condition-responsive means for bringing the battery device 25, into action, it will be seen that the conductor cable 31, connects to the terminal 29 a plurality of interconnected hemispherical devices 50, of perforated sheet metal or wire gauze. These devices 50, are attached to a rubber belt 51, encircling the mine shell 1, and are thus insulated from said shell. At the center of each device 50, are secured internal and external metal contact cones or points 52, and 53, and beneath each internal cone 52, is an opening 54, in the belt 51. Any number of these contact structures 50, may be used, and they may be distributed over the exterior of the mine shell 1, in any desired manner.

If a vessel strikes a contact device 50, with any force, the impact will collapse the structure and force the inner cone point 52, against the mine shell 1, and so put the structure 50, in electrical connection with the shell and the shell in electrical connection with the battery pole 25. The effect of this will be to combine the mine shell 1, with the pole element 25, as the other pole element of a complete galvanic couple or "battery" with the seat water as electrolyte,—the materials of pole element 25, and mine shell 1, being so chosen in the galvanic scale of potential characteristics as to form a couple of sufficient potential difference. (For reasons which will hereinafter be set forth, the pole element 25, will usually be of copper or zinc, and the mine shell 1, of iron or steel, galvanized or ungalvanized, or even copper coated or sheathed.) The result will be that sufficient current will flow through the firing circuit 27, 30, 31, to operate the firing means 16, and set off the mine. If the vessel be a metal one, its mere contact with the outer contact point or horn 53, will combine its hull as pole element with the pole element 25, to form a complete galvanic couple or battery, with like result.

The perforations of the devices 50, allow free access of water to their interior and so prevent them from being collapsed and the mine exploded by countermining. These devices 50, may initially be filled with material soluble or otherwise subject to gradual dissipation in the water (as sodium chloride) which will prevent accidental premature staving in of the devices 50.

The conductor cable 30, being attached to the terminal 29, of the device 8, the upward-extending cable 7, is normally electrically connected to the firing circuit so as to serve as a contact antenna for combining with the pole element 25, the hull of any metal ship that comes against it,—just like the external contact point 53, of the device 50. This device 8, (Figs. I and III) has a metal casing comprising parts 55, 56, screwed together and a part 57, crimped upon a flange on the part 56, and screwed into a socket in the mine shell 1. In this casing is a chambered body 58, (Fig. III) of insulating material (such as bakelite) wherein is embedded, at the chamber bottom, an annular contact element 59, with an ear 60, for attachment of the terminal 29. The body 58, has a bore through which extends a member comprising a shank 61, to which the antenna 7, is attached and an enlarged contact head element 62, with engaging ridges 63. A disc 64, (of bakelite, for example) forms an insulating "floor" for the chamber, being held beneath the body 58.

Normally, float 9, holds up the antenna 7, under sufficient tension to keep the contact element 62, against the element 59, quite firmly and so maintain the electrical connection of the antenna to the terminal 29,—the swaying movement of the float by the waves grinding the sharp engaging ridges 63, against the element 59, so as to insure perfect contact. Should the float 9, become detached the tension would be relaxed and the antenna 7, would fall, and might (but for the circuit-breaking device 8) come against the mine shell 1, and set off the mine as described in reference to the internal horn 52, of the device 50. Relaxation of the antenna tension, however, would allow the contact elements 59 and 62, to separate automatically under the action of gravity, and so break the antenna circuit connection and protect the mine. Renewed tension on the antenna 7, (as by dragging along a submarine's hull, etc.) would restore the connection.

While the circuit-breaker 8, will function in this way under gravity alone, I prefer to reinforce gravity by means of a helical spring 65, (see Fig. III) surrounding the shank 61, and lying in an enlargement of the shank bore of the body 58,—thus, indeed, even insuring positive automatic separation of the contact elements 59 and 62, independently of gravity. In order to allow this spring 65, to be made of non-corrosive metal of extra resiliency without risk of destructive electrolytic action, I prefer to insulate it from the member 61, 62, by means of a flanged sleeve 66, of bakelite or other material. The spring 65, is, of course, effectually insulated from the contact element 59, by the relative arrangement of the parts.

The conductor cable 32, is attached to the terminal 67, of the insulating attachment 4, which puts the upper portion 2, of the anchor cable 2, 3, in electrical connection with the terminal 29, so as to allow this portion 2, to function as a downward-extending contact antenna,—just like the upward-extending antenna 7. As shown, the strain insulator 4, comprises a member 68, attached to the cable section 2, and having a head embedded in insulating material 69, (such as bakelite) in a two-part metal casing constructed and secured to the mine shell 1, like the circuit-breaker casing comprising the parts 56 and 57. A strain insulator 70, (such as is used in trolley wire systems, for example) is interposed between the upper and lower anchor cable portions or sections 2 and 3, in order to allow the latter to be made of lighter, stronger, or cheaper metal, such as steel.

It will be understood that in practice the conductor cables 27, 30, 31, and 32, will be snug and taut against the mine shell 1: in Fig. I, they are shown otherwise merely for the sake of clearness of illustration.

It will be apparent that the use of the downward extending antenna 2, doubles the mine's dangerous zone of actuation as compared with what it would be with only the upward extending antenna 7. This is of more consequence than it would seem at first blush, because submarines at present in existence can not stand submersion of much more than 200 feet, and are sure to be destroyed by explosion of a mine with the standard charge of 300 lbs. of trinitrotoluol as far away as 70 feet. When it is realized that the submarine's only good chance of passing a well guarded mine field or barrage is by travelling beneath the mines, it will be seen that the lower antenna 2, makes the chances of success vastly worse, and that an increase of the mine charge so as to bring the zone of certain destruction up to 100 or 110 feet would make a mine-field all but impassible. A field of mines with upper and lower antennæ in which the mines are all at a depth of submergence of, say, 100 feet is thus equivalent to a field of the same area with double the number of mines with upper antenna only, arranged in two layers or levels, of, say, 100 and 200 feet submergence.

So far as I am aware, electrical firing means heretofore known have required for their operation greater amounts of energy or power than are obtainable from a sea-battery device of admissible dimensions suited to the requirements of a marine mine. I have, therefore, devised electrical firing means capable of operation on energy input much lower than any hitherto known. While thus uniquely adapted to sea-battery mines, my new firing means has still other desirable properties, so that on all accounts it is well adapted for other exacting conditions of service. This feature of my invention is illustrated, in different forms of embodiment, in Figs. IV and

V. Both of these figures show "straight" electrical firing means of detonator type wherein the input electrical energy is transformed to act on the explosive in the form of heat, so that the devices may be concisely characterized as "electro-thermal" detonators.

The detonator shown in Fig. IV, comprises a glass tube 80, of about 0.30″ internal diameter and 5″ to 5½″ long when finished, closed and sealed by fusion at one end 81, and a short, fine heating wire or filament 82, preferably of platinum 0.001″ in diameter, mounted in the tube end 81, and extending lengthwise thereof substantially coincident with its center-line or axis. As shown, the current leads 83 and 84, enter the tube 80, endwise thereof through the seal at 81, and the lead 83, extends further inward than the lead 84, and is bent transversely of the tube so as to overlie said lead 84. The axial heating wire 82, is connected between the transverse end portion of the lead 83, and the end of the lead 84,—here also shown as bent transversely,—the length between joints being about 1.4 to 1.5, millimeters. The bridge wire 82, should be secured to the leads 83, and 84, by electrically welded or autogeneously fused joints, since such joints can be made more uniform and accurate than soldered ones. It is very important that the bridge-wire joints have the lowest possible thermal conductivity consistent with adequate electrical conductivity, and hence that the bridge-wire be embedded in the metal of the leads for no more of its length than can well be avoided in the welding operation. Neglect of this results in the requirement of an excessive amount of current to raise the bridge-wire to a sufficient temperature to effect detonation: indeed, it is so far controlling in the process of manufacture that the merits of the finished detonator can be accurately gauged in advance by determining the amount of current required to heat the bridge-wire 82, to bright redness in air and rejecting the tube if this is more than 40% of the desired final firing current. The electrical resistance through the bridge-wire 82, etc., should be about 0.5 ohm.

Since the tube 80, is ultimately to be evacuated, the current leads 83, 84, should be of such character that they can be sealed into glass so as to make a vacuum-tight joint. To this end, they may be of platinum; or of other metal having in the aggregate substantially the same coefficient of expansion as glass and a suitable surface; or of copper or other ordinary metal coated with an enamel which unites with both the metal and the glass—a wire of this latter type being known commercially under the name of "Dumet" wire. Their diameter should be about 0.03″, since it is desirable to minimize their electrical resistance. It will be understood, of course, that the problem of vacuum-tightness is by no means so difficult in this device as in the case of an incandescent lamp, where the range of temperature variation in service is much greater.

About the bridge wire 82, suitably sensitive detonating material 85, is to be packed in such manner as to come into intimate contact with it. The important point in regard to the "sensitiveness" of this material is, of course, that it should be of low flash point,—preferably not exceeding 136° C.—sensitiveness to shock being disadvantageous. It is also of great importance that the material employed have such thermal properties and be so packed that the transmission of heat therein beyond the zone of immediate contact with the bridge-wire 82, shall be minimized in order that the necessary detonating temperature may be attained immediately about the bridge-wire and detonation of the whole body of material ensue with a minimum heating current. Apparently, these properties depend on the materials having low specific heat and thermal conductivity, and being packed under as low pressure as consists with sufficient contact with the bridge-wire 82;—the poor thermal conductivity of a granular or powdered material with considerable voids is well understood. It will be observed that the axial arrangement of the bridge-wire and the overhang of the lead 83, serve to protect the delicate bridge-wire against rupture when the detonating material is introduced and packed around it.

As a detonating material, I prefer to use the diazobenzeneperchlorates, since these substances have relatively low flash points and are at the same time stable, non-hygroscopic, and not subject to rapid deterioration or chemical change. The special substances of this class with which I have obtained the best results are simple diazobenzeneperchlorate, paramethyldiazobenzeneperchlorate, and paranitrodiazobenzeneperchlorate, — commonly known as benzyte, paramet, and paranite. The last mentioned is, on the whole, distinctly superior to the others. About 0.15 gr. paranite should be used, and it should be packed under a pressure of about 3 lbs. per square inch.

In order that the highly sensitive material may be introduced into the tube 80, with minimum danger of detonation by impact or pressure, it is preferable that the tube should originally be formed with an integral funnel opening 86, thus avoiding the risk of inserting a separate funnel in the open end of the tube. To minimize risk of detonation in charging as well as to improve the action of the material, it should preferably be produced in a finely divided powdered state rather than in a flake or plate-like crystalline form.

The highly sensitive material 85, having been loaded into the tube 80, and packed down under suitable pressure, a tight-fitting pressed asbestos plug 87, is placed on top of it so as to hold it firmly. On top of this plug 87, is placed a copper capsule 88, containing a greater amount of less sensitive detonating material 89, highly compressed, such as 45 gr. fulminate of mercury, or 6½ grs. fulminate and 18 grs. of tetryl,—the sensitiveness here referred to being that to shock as well as that to heat. In the tetryl-fulminate combination, the more sensitive fulminate acts as a "booster" to receive the detonating impulse from the paranite and pass it on to the less sensitive but more powerful tetryl. If desired, the charge 85, may be augmented and the capsule 88, dispensed with. On top of the capsule 88, are placed a couple of tight-fitting compressed asbestos plugs 90, 90, to hold the capsule securely in place so that it can not shift. The completely charged tube 80, is now to be evacuated by means of a vacuum pump and sealed off by fusion in the usual manner at 91. The vacuum in the tube should be of the order of tungsten filament incandescent lamp practice,—from three to five microns, or even better. Of course, however, the tube 80, must not be heated during evacuation, as is done in evacuating incandescent lamps. If preferred, the tube may be filled with an inert gas such as CO_2 or argon instead of being evacuated.

The completed detonator tube 80, is enclosed in a round-ended tubular metal case 92, with an elastic cushion or pad 93, of glass—wool or the like in the closed end to protect the sealed tube-end 91, from shock. The open end of the metal tube 92, is secured to a stout metal base sleeve 94,—as by an enlarged end portion 95, fitting over a shoulder on said base and spun or snapped in. A body 96, of such elastic material as rubber fits inside the flanged end of the tube 92, and in the bore of the base 94, and serves to cushion and hold the glass tube 80, securely and protect the lead seals at 81, from breakage. The current leads 83, 84, extend through holes in this rubber packing and are thereby insulated and kept apart. The base 94, is here shown as fitting in a socket in the carrier block 20, and as held by a screw 97, which engages in a lateral notch in the base. The leads 83, 84, are engaged and connected to the flexible ones 18, 18, by the binding screws 98, 98.

The glass and asbestos which enclose the more sensitive finely divided detonating material are of importance in affording it an environment chemically inert and quite impervious, and also in affording a certain protection against heat. The hermetic sealing of the glass envelope or container protects the material from access of air and moisture: and the vacuum rarified air or other inert medium not only intensifies all these favorable conditions, and so greatly improves the keeping qualities of the detonator, but it stabilizes it as against shock and eliminates the air that must otherwise be heated up before it can be made to act. Not only is absence of air thus directly beneficial, but it also reduces the thermal conductivity of the detonating material. In practice, vacuum detonators constructed as described will fire on currents of 0.27 ampere or less under voltages of 0.135 volt; and they can be made so uniform that these figures will rarely be exceeded more than 10%. Such detonators withstand countermining remarkably well.

In Fig. V, I have shown a type of detonator which has many of the advantages of that shown in Fig. IV, though lacking its extremely low firing current characteristic and ultra-superior keeping qualities and insensibility to shock on account of the absence of vacuum. The vacuum feature being dispensed with, the glass tube 100, has merely to hold the electrical parts firmly in place and afford an inert environment for the detonating material which is loaded with very slight pressure about the bridge wire, so that this tube ends with the asbestos plug 101, that holds the sensitive detonating material in place. The copper capsule 102, of less sensitive detonating material 103, is contained in the reduced closed end of the tubular casing 104, a pad 105, of eiderdown wool being interposed. A rubber packing ring 106, about the end of the capsule 102, forms a yielding abutment for the open end of the glass tube 100. To compensate for the absence of vacuum, it is desirable that the flash-point of the more sensitive detonating material should not exceed 100° C. A detonator so constructed and loaded with paranite will fire on about 0.35 ampere under a voltage of 0.175 volt.

From the foregoing description of the firing gear which I prefer to employ, it will be evident that while the power and total energy required is relatively small,— much smaller, in fact, than for any other type of gear at present known to me,—it is still substantial. For not only must the requirements of the firing means itself be met, but other electrical resistance is to be overcome,—including that of the various antennæ, cables, leads, and joints which form the circuit, as well as the internal resistance of the "sea-battery" itself. This latter factor will, of course, vary according to the temperature of the water and a variety of other factors. The sea-battery must, in short afford substantial power.

Turning, therefore, to the battery device 25, it will be recalled that I have spoken of it as comprising a single pole element, and referred to copper and zinc (either alone or as coatings for iron or steel) as possible materials. The choice of materials for the pole element 25, is greatly limited by the consideration that all exposed parts of the mine equipment (i. e., parts that are outside the mine shell) normally in electrical connection with one another must be of the same potential characteristics (in order to avoid destructive electrolytic action amongst the parts, or even firing of the mine by such action), which practically means that they must be of the same material or have impervious exposed surfaces. On this account,—along with other reasons to be presently indicated, only copper,—or other cupreous metal and zinc or galvanized metal (using the term "galvanized" in a broad sense to indicate any zinc coating or sheathing sufficiently impervious), are available for pole element materials. (Ferrous metals such as iron and steel are no exceptions to this statement, because of the prevalence of these materials in ships' hulls.) Other metals that might seem available and highly desirable are subject to rapid wastage in sea-water, even when not in closed circuit, or tend to coat themselves with compounds whose insulating properties lower their potential characteristics very seriously. Very expensive metals such as gold and platinum, etc., are naturally out of the question, unless in very thin coatings that would be too liable to accidental puncture with resultant destruction of the parts by local electrolytic action.

As between zinc and copper, the former has the advantage of being kathode or negative pole in reference to ferrous metals, so that a pole element 25 with an active surface of zinc would not have its potential lowered by polarization,—which would occur on the hull of the ship attacked and so be of no practical effect on the current value, on account of the enormous exposed area. This advantage as regards polarization would, therefore, promise to allow a zinc pole element 25 to be of quite moderate surface area and weight; but the advantage is in practice more than offset (when iron, as in a ship's hull, is the other pole) by the tendency of zinc to coat itself with compounds whose insulating properties lower its potential characteristic as mentioned above,—at any rate, under certain conditions. This coating tendency is, of course, entirely different from polarization, —"polarization" being a phenomenon due to an envelope of minute bubbles of gas formed about the anode by decomposition of electrolyte and characteristic of the anode as such, independently of the particular material of which it may be composed.

Copper has the disadvantage that with reference to iron, zinc, and most metals it behaves as anode and so has its effective potential characteristic lowered by polarization. Even so, however, it is still greatly superior to coated zinc in connection with iron; and, in practice, some compensation will result from the depolarizing action of the movement of the sea-water. Copper has, moreover, an advantage which (so far as I am aware) is as unique amongst metals as it is unexpected in view of its known properties: with exposure to sea-water, its potential characteristic and current yield for a given area gradually improve some 20%. Whether this is due to a greenish salt that seems to form on the copper or to other causes, I can not say; but observation leaves no doubt as to the fact.

On all accounts, therefore, copper is at present the preferable material for the pole element 25. When it is used, this pole element should be so constructed as to have an exposed surface of from 10,000 to 11,000 square inches, in order to afford a safely adequate available firing current for the requirements of my vacuum detonator described above,—about 0.4 ampere at 0.2 volt, for example. Under these conditions, a mine shell 1, of usual 34 inch diameter with exposed steel surface will commonly afford ample firing current for the operation of the contact device 50, by a wooden ship; but if there be any doubt as to this, the matter can be put beyond peradventure by galvanizing, sherardizing, etc., of the mine shell 1, and all exposed parts normally in electrical connection with it—since the potential difference of zinc-copper exceeds that of iron-copper, even though the zinc be coated as mentioned above. This has the additional advantage of greatly prolonging the life of the whole mine outfit in sea-water.

To provide the pole element 25, with such a large amount of active surface condensed into the small space shown with a relatively small amount of metal, I prefer to employ foraminous metal interstitially exposed to the sea-water. In order to give the pole element such a foraminous or cellular structure, it may be built up in a particular way that I have invented and have illustrated in Figs. VI to IX. As will be seen from Fig. VI, the pole element 25, has, in this construction, a frame structure 110, (about 13½" square) formed of sheet metal strips with inturned edges (see Fig. VI) bolted together at their corners, the ends of opposite strips being curled back on themselves to form tubular sockets 111, adapted (see Fig. I) to fit over the flanged insulating sleeves 112, (of bakelite or the like) which co-act with insulating washers 113, (of similar material) to insulate the pole element from the feet 28, and so from the mine shell 1. In this frame structure 110, is a pack of superposed thin metal plates 114, slightly spaced apart (see Fig. VII) and held in place by bolt rods 115, extending through them from side to side of the frame, and also by engagement of their ends in the shallow channels formed by the inturned edges of the frame side plates. By making these plates 114, of 0.006" sheet copper corrugated as hereinafter described to space them apart and increase the interstitial surface an exposed area of 10,000 square inches or more can easily be obtained with plates only 3″ wide and about 13″ long, in a pack about 13″ thick. Washers 116, are preferably interposed between the plates to improve their electrical connection to the bolt rods 115, one of which forms the terminal 26, (see Fig. I).

While various modes of corrugation will answer the purpose more or less adequately, I prefer to employ such a one as is shown in Figs. VIII and IX. In Fig. VIII, all the short longitudinal lines between light and shaded areas (whether heavy shade lines or not) represent shearing of the metal, and all the transverse lines separating light and shaded areas represent bends in the metal. By a suitable die, the metal may be bent about 22° out of its original plane both up and down at the same time that it is sheared (being perhaps, also stretched somewhat) along lines extending transversely of the strip, as noted above, and lying both at the ends of the shear lines and at the middle of such lines. This is done in such a way that all the light areas lie in the same or parallel planes inclined upward toward the lower edge of the drawing, and all the shaded areas lie in the same or parallel planes inclined downward toward said lower edge. The result is (as will be seen from comparison of Figs. VIII and IX) that the sheet 114, has a single set of simple trough-like corrugations (of which the plane of the paper is the median plane, as indicated by the dot and dash line 117, of Fig. IX), interrupted or mutilated by two double chain-like sets 118 and 119, of additional corrugations superposed upon them at opposite sides of their median plane 117. It will further be seen that the crests of the main corrugations (as determined from Fig. VIII) form the base-line of the "super-crest" set 118, and that the hollows of the main corrugations form the base-line of the "infra-hollow set 119." From Fig. VIII, it will be seen that the halves of the double super-crest set 118, are symmetrically arranged with reference to the center of the plate 114, and that adjacent corrugations of each half are offset half their own with reference to one another, first to one side and then to the other in alternation, so that the set as a whole has a peculiar chain-like appearance. The like is true of the halves of the infra-hollow set 119, which lie outside of the halves of the super-crest set 118. In addition to "nesting" in such a way as to insure that when the plates 114, are assembled the crests of their main corrugations shall coincide,—thus in a manner spacing the plates apart,—the extra corrugations 118, and 119, result in zigzag cross openings or passages from top to bottom of the pack of plates and so permit freer circulation of the electrolyte. In addition, the interlocking of the extra corrugations 118 and 119, greatly stiffens the whole structure.

It will be understood, of course, that Figs. VI and VII, represent the plates 114, somewhat diagrammaticaly, since if they were drawn to correspond exactly to Figs. VIII and IX, the reduction of scale would render the interstices between the plates almost invisible. It will also be seeen from Fig. VI, that the aggregate of assembled plates 114, in effect constitute a compact cellular or honey-combed body of metal with very large exposed surface and provision for very free internal circulation of the electrolyte, stiff enough to stand impact with the water when thrown overboard from a mine-layer.

In Fig. X, I have illustrated diagrammatically the essential features of a mine organization wherein a single-pole element battery device corresponding to the device 25, of Fig. I, is embodied in the exterior surface of the mine shell 120, itself. In view of considerations of strength and cost on the one hand, and of those set forth in the discussion of materials for the battery device 25, on the other hand, it is best to make the mine shell 120, of iron or steel with a sheathing or coating 121, of copper, zinc or other suitable material. The mine shell 120, is provided with devices 122, 122, (suitably insulated therefrom) for the attachment and electrical connection of upper and lower contact antennæ corresponding to the antennæ 7 and 2, in Fig. I, and with similarly insulated contact point or stud devices 123, 123. The firing means 124, is connected in circuit between the devices 122, 122, 123, 123, on the one hand, and the mine shell sheathing 121, on the other hand, so that contact of a metal ship with either antenna or stud will cause its combination with the pole element 121, to form a complete galvanic battery and operate the firing device 124,—just as in the case of the mine organization of Fig. I.

As compared with the organization of Fig. I, that of Fig. X, has the advantage of simplicity and reduced number of parts. On the other hand, it has two chief disadvantages: First, that any accidental puncturing of the surface 121, will set up local electrolytic action which (with copper surface 121, and steel shell 140) will eventually puncture the shell and sink the mine; second, that contact of a vessel with the surface 121, in advance of contact with the devices 123, 123, etc., may short-circuit the firing means 124, and result in failure to fire.

It will be apparent that the condition-responsive means of Figs. I and X,—elements 2, 7, and 50, of Fig. I, organization, and 122, 122, 123, 123, of the Fig. X, organization,—are alike enabled to respond by energy derived from the same battery device 25, or 121, that supplies energy for operating the firing means 16, or 124,—since, in fact the same energy that enables the responsive means to respond operates the firing means. Or, to put the matter differently, it will be seen that in both organizations the responsive means as a whole includes the battery device pole element 25 or 121, and combines it—with the mine shell 1, in Fig. I, and with the vessel to be attached in both Fig. I and Fig. X,—to form a galvanic couple for bringing the battery device into action to operate the firing means 16 and 124.

In Fig. XI, I have illustrated diagrammatically the essential features of a mine organization wherein the relation of parts in the firing gear is different. As here shown, there is on the steel mine shell 125, a sea-battery device comprising plates 126 and 127, of suitable materials (such as copper or carbon and zinc) insulated from one another and from said shell by flange-edged rubber pads 128, and 129. The shell 125, is also provided with antenna-attachment devices 130, 130, (suitably insulated therefrom and from the plates 126 and 127, and corresponding to the devices 122, 122, of Fig. X), and with suitably insulated contact stud or horn devices 131, 131, corresponding to the devices 123, 123, of Fig. X. These devices 130, 130, 131, 131, are all connected to one control terminal 132, of a suitably encased standard Weston circuit-closing relay 133, whose other control terminal 134, is connected to a small copper plate 135, insulated from the mine shell 125, by a flange-edged rubber pad 136,—this control circuit being everywhere and comprehensively designated by the numeral 137. The firing means 138, is connected between the plates 126, and 127, through the circuit-closing device 139, of the relay 133,—this firing circuit being everywhere and comprehensively denoted by the reference numeral 140. It will be seen that the battery device 126, 127, is in itself a complete galvanic couple or battery for supplying energy to operate the firing means 138, whenever its firing circuit 140, is closed. The condition-responsive means here includes the plate 135, the control circuit 137, and the contact devices 131, 131, etc., by means of which the vessel to be attacked is combined with the plate 135, as pole element to form a complete galvanic couple which produces sufficient current to cause the relay 133, to close the firing circuit 140, and operate the firing means 138. Since the current in the control circuit 137, has only to operate the relay 133, the amount of energy or power required from the "control couple" including the pole element 135, is only nominal in comparison with the substantial amount which the battery device 126, 127, must afford to operate the firing means 138. In practice, of course, the pole elements 126, and 127, may be made to cover a larger proportion of the mine shell 125, than indicated in the diagrammatic showing of Fig. XI. The choice of materials for these pole elements is greater than in the mine organizations of Figs. I and X, because the contact devices 131, 131, etc., are not in electrical connection with them.

In Fig. XII, I have illustrated diagrammatically a depth-charge type of mine organization whose operation resembles that of the organization of Fig. I, when set off by impact of a wooden ship in combining mine shell 141, with a separate pole element 142, insulated therefrom to form a complete galvanic battery and operate the firing means 143, and resembles that of the organization of Fig. XI, in having wholly separate condition-responsive means for closing the firing circuit 144, and effecting the combination just set forth. The condition of attack being the sinking of the mine to a certain depth, the condition-responsive means comprises an elastic hydrostatic diaphragm 145, acting against a spring 146, to close a switch 147, in the firing circuit 144. As shown, the pole element 142, (shown as in the form of a number of plates connected together) is mounted in a chamber 148, provided with a safety cover 149. Since the pole element 142, is only exposed to the sea water for a short time, it may be made of magnesium, which has a high potential characteristic but disintegrates rapidly. The mine shell 141, may be of iron or steel, as usual.

In Fig. XIII, I have illustrated diagrammatically a new type of mine-barrage or field devised by me and comprising a plurality of mines 150, firing by combination of the vessel to be attacked in an electric circuit,—as in a galvanic-coupled circuit such as described above in connection with Figs. I, X and XI. As here shown, there are not only upper and lower antennæ 151 and 152, corresponding to the antennæ 2 and 7, of Fig. I, but also circuit-forming contact antennæ 153, strung from mine to mine—insulators 154, being preferably interposed between mines thus coupled to prevent firing of more than one mine by contact of a vessel with these string antennæ close to any one mine. As shown, these string antennæ are attached to the downward-extending antennæ 152, below the mines, to prevent firing of a mine by contact of a broken antennæ string with other parts.

It will be apparent that a single mine firing by combination of the vessel to be attacked in a galvanic-couple circuit will probably not operate against a vessel with exposed surface of the same metal as its own pole element that must be combined with the vessel, and that efforts may be made to attain similar immunity by charging the hull of a vessel with electricity sufficiently to give it just the same potential characteristics as such mine pole element. Through the latter expedient can hardly ever prove successful in practice because of the variations of potential that will be found over the surface of the hull, the former expedient is more promising. While both expedients might be thwarted by a mine having pole elements of widely different potential characteristics for combination with the vessel, such a mine would be highly dangerous to lay, and likely to be eventually "hoist with its own petard" by self-firing. In laying down a mine-field or barrage, however, it is an easy matter to make the field just as formidable as though composed of such "hermaphrodite" mines. This can be done by including in the field or barrage different mines with pole elements of different potential characteristics, so as to frustrate all efforts to assimilate the potential characteristic of a vessel to that of the pole elements,—whether by sheathing or charging. Such mines may either be coupled up with antenna strings as described above, or may be wholly separate and unconnected.

Having thus described my invention, I claim:

1. A marine mine equipment having firing gear requiring electric power in substantial amount for its operation; intrinsically complete in situ, as regards provision for power supply for said firing gear, when in the sea; and comprising, as source of such power supply, a battery device including an electrode attached to and insulated from the outside of said mine case having less displacement than the mine case and exposing to the water when planted a surface larger than the surface of the mine case using the water of the immediate environment as electrolyte.

2. In marine mine firing-gear having electrical firing means, a battery device as source of energy for operating such firing means having a pole element exposed to the sea water as electrolyte, said element having less displacement than the mine case and exposing a larger surface than that of the mine case, and means automatically responsive to conditions of attack for combining another pole element with that aforesaid to form a galvanic couple with the sea water as electrolyte and thereby cause operation of said firing means.

3. In marine mine firing-gear, the combination with the mine shell and an electrode having less displacement than the mine shell and exposing a larger surface than that of the mine shell, attached thereto and electrically insulated therefrom as pole elements of a galvanic couple, of means for combining said pole elements in closed circuit to complete the couple and cause firing of the mine, said means comprising a collapsible metal contact structure mounted on the exterior of the mine shell in electrical connection with said electrode and adapted, when collapsed, to come into external contact with the mine shell.

4. In electrical firing-gear for marine mines, the combination with a firing device movable into and out of firing position with reference to a charge, of a firing circuit including said device, and means controlled by movement of said device for automatically shunting it when out of firing position and opening the shunt when it comes into firing position.

5. In electrical firing-gear for marine mines, the combination of a firing circuit including a firing device, and means controlled by the mine environment for automatically shunting said device when the mine is out of its desired firing environment and opening the shunt when the mine comes into its desired firing environment.

6. In electrical firing-gear for marine mines, the combination of a firing circuit including a firing device, and means controlled by the mine environment for automatically shunting said device when the mine is out of its desired firing environment and opening the shunt when the mine comes into its desired firing environment, said means including an element exposed to said environment and suspectible of gradual disintegration thereby for delaying opening of said shunt under firing environment of the mine.

7. In firing-gear for marine mines, the combination with a firing device movable into and out of firing position with reference to the charge, of means controlled by the mine environment for automatically moving said device into firing position under the desired firing environment of the mine, and means including a delay-element exposed to said environment and susceptible of gradual disintegration thereby.

8. In firing-gear for marine mines, the combination with a firing device movable into and out of firing position with reference to the charge, of means controlled by the mine environment for automatically moving said device into firing position under the desired firing environment of the mine, said means including a delay-element exposed to said environment and susceptible of gradual disintegration thereby, and readily removable protecting cover means for preventing accidental premature disintegration of the delay element.

9. In firing-gear for floating marine mines, the combination of a firing device movable into and out of firing position with reference to a charge, automatic means constantly tending to move said device into firing position, and means for delaying movement of said device into firing position under the desired firing environment, said latter means including an element exposed to said environment and susceptible of gradual disintegration thereby so as to permit said automatic means to act.

10. A mine-barrage comprising a plurality of marine mines firing by combination of the vessel to be attacked in a galvanic-couple cir-

cuit and having pole elements for combination with such vessel exposed to the sea water as electrolyte, there being pole elements of different potential characteristics, so as to frustrate efforts to assimilate the potential characteristic of a vessel to that of the pole elements.

11. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the resistance of the electric circuit and of said detonator sufficient to explode said detonator by the energy alone created by the electrode, antenna and the contact of the hull in sea water as electrolyte.

12. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, the detonator adapted to explode by the electrical energy alone received from said circuit, and not requiring substantially more than .08 watt.

13. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, the detonator adapted to explode by the electrical energy alone received from said circuit with the internal resistance of said circuit approximately equal to the external resistance of said circuit.

14. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, said antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, said detonator adapted to explode by the electrical energy alone received from said circuit on currents at said detonator of not substantially more than .4 ampere under voltage of not substantially more than .2 volt.

15. A submarine mine comprising a mine case, two open electrical circuits, not connected, three electrodes attached to said mine case, insulated therefrom and from each other, and adapted to be constantly exposed to the sea water when said mine is planted, one circuit provided with two of said electrodes, each of said two electrodes consisting of elements of widely different electrical potential, an electrical conductor passing from each of said electrodes to the inside of the mine case, a detonator in said circuit within the mine, the second circuit provided with an antenna of metal of different electrical potential from the metal of a ship's hull, said antenna attached to the outside of and insulated from said mine case, and an electrode of the same metal as said antenna electrically connected thereto and attached to the outside of said mine case and insulated therefrom, an electrical conductor passing from the electrode of the second described circuit to an open relay within the mine, an electrical conductor passing from one of the electrodes in the first described circuit to said relay, the antenna and electrode connected thereto adapted on contact by a ferrous hull to form a galvanic couple to close said relay, the conductors leading from the electrodes of the first described circuit in electrical connection with the detonator when the relay is closed and said electrodes of the first described cir-

cuit when submerged capable alone of furnishing energy to explode the detonator.

16. A submarine mine comprising in combination, a mine case, an upper antenna insulated from said case provided with a float at its upper end and an anchor antenna of the same metal insulated from said mine case, a strain insulator between the lower extremity of said antenna and the anchor cable, the usual anchor casing attached to said cable, both antennæ of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, said antennæ electrically connected each with the other, said connection being of the same metal as said antennæ, an electrode of the same metal attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the mine case, the electrode and antennæ connected respectively to the leads of a detonator within the mine case, and adapted on contact by a ferrous metal hull of a ship with an antenna to furnish electrical energy through the electric circuit formed by said electrode, antennæ and hull with the sea water as an electrolyte, the detonator adapted to explode by the electrical energy alone received from said circuit, and not requiring substantially more than .08 watt.

17. A submarine mine comprising in combination, a mine case, an upper antenna from said case provided with a float at its upper end and an anchor antenna of the same metal insulated from said mine case, a strain insulator between the lower extremity of said antenna and the anchor cable, the usual anchor casing attached to said cable, both antennæ of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, said antennæ electrically connected each with the other, said connection being of the same metal as said antennæ, an electrode of the same metal attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the mine case, the electrode and antennæ connected respectively to the leads of a detonator within the mine case, and adapted on contact by a ferrous metal hull of a ship with an antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with the sea water as an electrolyte, the detonator adapted to explode by the electrical energy alone received from said circuit, with the internal resistance of said circuit approximately equal to the external resistance of said circuit.

18. A submarine mine comprising in combination, a mine case, an upper antenna insulated from said case provided with a float at its upper end and an anchor antenna of the same metal insulated from said mine case with a strain insulator between the lower extremity of said antenna and the anchor cable, the usual anchor casing attached to said cable, both antennæ of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, said antennæ electrically connected with each other, said connection being of the same metal as said antennæ, two open electrical circuits, not connected, three electrodes attached to said mine case, insulated therefrom and from each other, and adapted to be constantly exposed to the sea water when said mine is planted, one circuit provided with two of said electrodes, each of said two electrodes consisting of elements of widely different electrical potential, an electrical conductor passing from each of said electrodes to the inside of the mine case, a detonator in said circuit within the mine, the second circuit provided with an antenna of metal of different electrical potential from the metal of a ship's hull, said antenna attached to the outside of and insulated from said mine case, and an electrode of the same metal as said antenna electrically connected thereto and attached to the outside of said mine case and insulated therefrom, an electrical conductor passing from the electrode of the second described circuit to an open relay within the mine, an electrical conductor passing from one of the electrodes in the first described circuit to said relay, the antenna and electrode connected thereto adapted on contact by a ferrous hull to form a galvanic couple to close said relay, the conductors leading from the electrodes of the first described circuit in electrical connection with the detonator when the relay is closed and said electrodes of the first described circuit when submerged capable alone of furnishing energy to explode the detonator.

19. A submarine mine comprising in combination, a mine case, an upper antenna provided with a float at its upper end and an anchor antenna of the same metal, a strain insulator between the lower extremity of said anchor antenna and the anchor cable, the usual anchor casing attached to said cable, both antennæ of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the surface of the mine case of the same metal as said antennæ, said antennæ electrically connected with each other and with the surface of the mine case, another open electric circuit comprising two electrodes of elements of widely different electrical potential, attached to the outside of the mine case, insulated therefrom and from each other, and constantly exposed to sea water

when said mine is planted, a detonator in said circuit, an open relay in said mine, a conductor within the mine connected to one side of said relay and to the antenna circuit, a conductor in said mine connected to the other side of said relay and to one of the two electrodes attached to the outside of the mine case, the antenna circuit adapted on contact by a ferrous hull to form a galvanic couple to close said relay, the conductors leading from the two electrodes on the outside of the mine case in electrical connection with the detonator when the relay is closed and said electrodes when submerged capable alone of furnishing energy to explode the detonator.

20. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna atached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, said detonator adapted to explode by the electrical energy alone received from said circuit, and having a closed tube, current leads connected to said circuit leading into the tube, a short fine heating wire in said tube connected to said leads and surrounded by detonating material of low flash point not exceeding 140 degrees centigrade.

21. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, said detonator adapted to explode by the electrical energy alone received from said circuit, and having a closed tube, current leads connected to said circuit leading into the tube, a short fine heating wire in said tube connected to said leads surrounded by a detonating material responsive to the heat of the heating wire, and inert atmosphere hermetically sealed in said tube.

22. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator within the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, said detonator adapted to explode by the electrical energy alone received from said circuit, and having a closed tube, current leads connected to said circuit leading into the tube, a short fine heating wire of platinum with a diameter of substantially .001 inches connected to the leads in the tube and surrounded by detonating material of a low flash point responsive to the heating wire.

23. A submarine mine comprising in combination, a mine case, an antenna of a metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, the antenna insulated from said case, an electrode of the same metal as the antenna attached to the outside of the mine case and insulated therefrom, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the surface of the mine case, the electrode and antenna connected respectively to the leads of a detonator with the mine case and adapted on contact by a ferrous metal hull of a ship with said antenna to furnish electrical energy through the electric circuit formed by said electrode, antenna and hull with sea water as the electrolyte, the detonator adapted to explode by the electrical energy alone received from said circuit, and having a closed tube, current leads connected to said circuit leading into the tube, a short fine heating wire of platinum with a diameter of substantially .001 inches and a length of from 1.4 to 1.5 millimeters, connected to the leads in said tube and surrounded by a low flash detonating material responsive to the heat of the heating wire.

24. A mine barrage consisting of a series of mines, each the same as the others, lateral

antennæ all of the same metal, which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, passing from one mine to the next in series, and a strain insulator in each lateral antenna cutting off the electrical connection from one mine to the next mine, and each mine in the series comprising in combination, a mine case, an upper antenna of the same metal as the lateral antenna insulated from said case provided with a float at its upper end and an anchor antenna of the same metal insulated from said case with a strain insulator between the lower extremity of said antenna and the anchor cable and anchor casing, said antennæ on each mine electrically connected together, an electrode of the same metal as the antennæ attached to the outside of the mine case, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the mine case, the electrode and antennæ connected respectively to the leads of a detonator within the mine case, and adapted on contact by a ferrous metal hull of a ship with one of said antenna to furnish electrical energy through the electric circuit formed by said electrode, antennæ and hull with the sea water as an electrolyte, said detonator adapted to explode by the electrical energy alone received from said circuit, and not requiring substantially more than .08 watt.

25. A mine barrage consisting of a series of mines, each the same as the others, lateral antennæ all of the same metal, which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, passing from one mine to the next in series, and a strain insulator in each lateral antenna cutting off the electrical connection from one mine to the next mine, and each mine in the series comprising in combination, a mine case, an upper antenna of the same metal as the lateral antenna insulated from said case provided with a float at its upper end and an anchor antenna of the same metal insulated from said case with a strain insulator between the lower extremity of said antenna and the anchor cable and anchor casing, said antennæ on each mine electrically connected together, an electrode of the same metal as the antennæ attached to the outside of the mine case, said electrode having less displacement than the mine case and exposing to the sea water, when planted, a surface larger than the mine case, the electrode and antennæ connected respectively to the leads of a detonator within the mine case, and adapted on contact by a ferrous metal hull of a ship with one of said antenna to furnish electrical energy through the electric circuit formed by said electrode, antennæ and hull with the sea water as an electrolyte, said detonator adapted to explode by the electrical energy alone received from said circuit, with the internal resistance of said circuit approximately equal to the external resistance of said circuit.

26. A submarine ordnance device consisting of a depth charge adapted to be put overboard at will, comprising in combination an outer casing of metal, an inner chamber therein, a removable water-tight cover thereover, a plate or plates in said chamber having different electrical potential from that of the outer casing, a wire connected to said plate or plates insulated from and passing out of the chamber through a water-tight opening, a detonator within said casing connected to said wire, a second inner chamber in said casing, a connecting wire from said detonator passing into and insulated from said chamber, a terminal on said wire in said chamber, a connecting wire within said casing in electrical contact with the inside of said casing and passing into and insulated from said second chamber, a terminal on said wire in said chamber, a plunger in said chamber, one end of which is spaced away from said terminals and attached at the other end to an elastic, hydro-static diaphragm closing said chamber and adapted to be pressed inward at a predetermined depth by the pressure of the water thereagainst and force said plunger into electrical contact with said terminals to close the circuit between the outer casing and the plate or plates in the first chamber, both said casing and plate or plates exposed to the sea water as electrolyte when the cover-plate is removed and the device is planted.

27. A submarine mine comprising in combination, a mine case, an antenna of metal which when submerged in sea water has a different electrical potential from the ferrous metal of a ship's hull, said antenna insulated from said case, an electrode of the same metal as the antenna on the outside of the mine case, insulated therefrom and having less displacement than the mine case and exposing a larger surface than that of the mine case, said mine case having a surface of a metal of different potential than that of the electrode and antenna, a plurality of collision contact members of the same metal as said electrode and antenna on the outside of said mine case and electrically connected to said antenna and electrode, said contact members held in collapsible fixtures and spaced away from said case, insulation between said fixtures and said case, an opening through the insulation on the mine case sufficient to permit the contact members to pass therethrough and impinge on the outside of the mine case under the pressure of collision contact to close the circuit, a detonator in said mine sufficiently sensitive to explode on energy alone created by the electrode and the mine case on contact of the hull with a collision member in sea water as electrolyte.

28. An unarmed submarine mine electrically operated comprising in combination a mine case, a chamber within said mine case attached to the inner surface of said case, a detonator in said chamber, a booster charge in said chamber, connecting wires from the source of electrical energy to said detonator, a water-tight cover for said chamber forming a part of the mine case, an extender mechanism in said chamber to arm said mine after the same is planted, said extender at its outer end passing through and held by a solid body soluble in sea water and passing through said cover, a lock within said chamber against movement of said extender mechanism while held in said soluble body, a release mechanism adapted to move said extender within said mine upon the dissolution of said body to contact with the terminals on the leads connected to said detonator, a safety shunt adapted to be broken by said movement, thereby to arm said mine.

In testimony whereof I have hereunto signed my name at Philadelphia, Pennsylvania, this fifth day of March, 1919.

JOHN K. M. HARRISON.