July 14, 1931. J. K. M. HARRISON 1,814,152

MARINE MINE AND FIRING METHOD THEREFOR

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FIG. III.

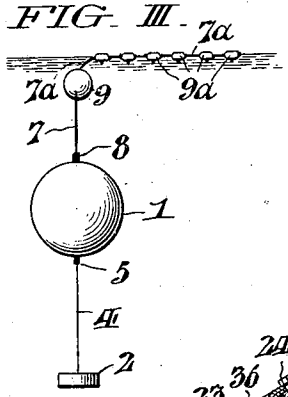


FIG. II.

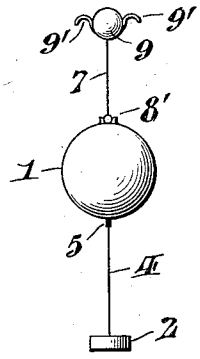


FIG. I.

FIG. IV.

WITNESSES

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FIG. V.

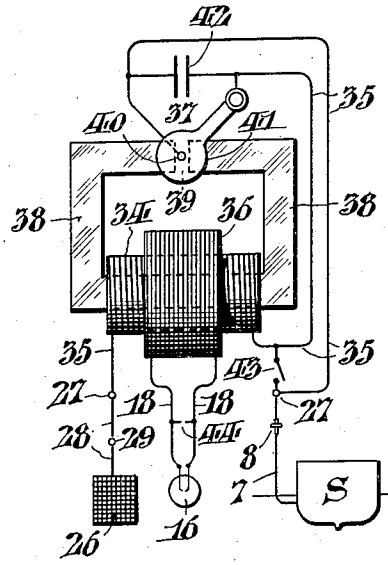


FIG. VI.

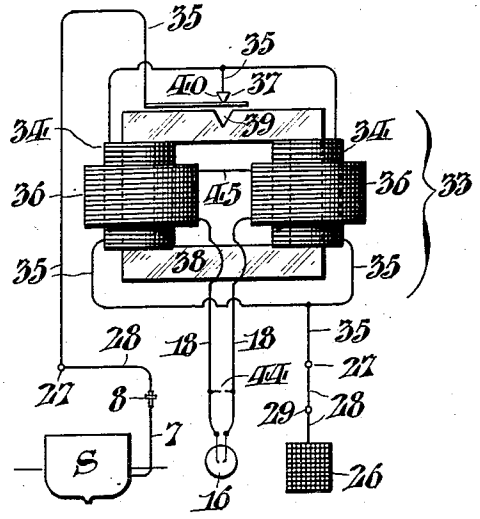


FIG. XIV.

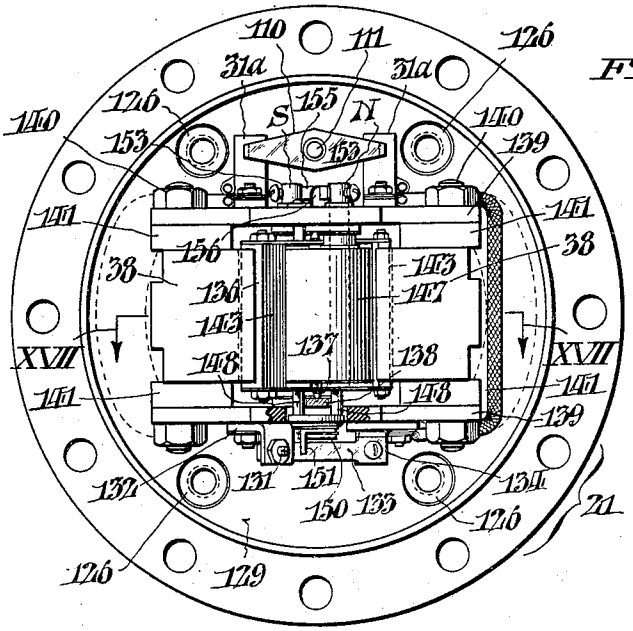


FIG. XIX.

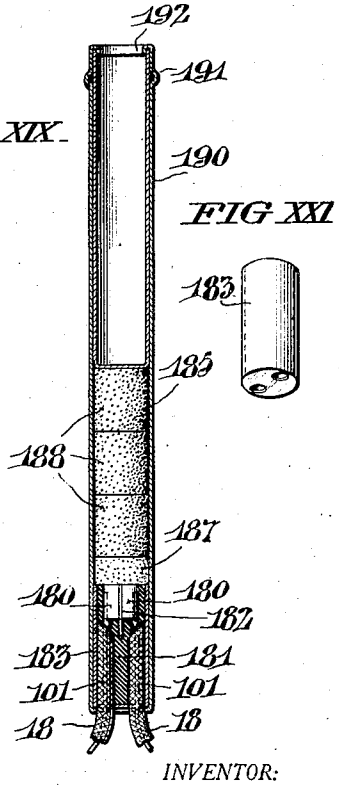
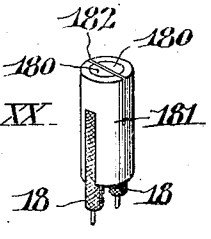


FIG. XXI

FIG. XX.



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FIG. VII.

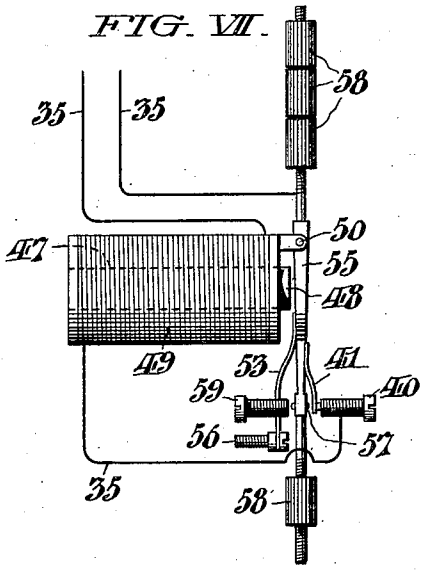


FIG. X.

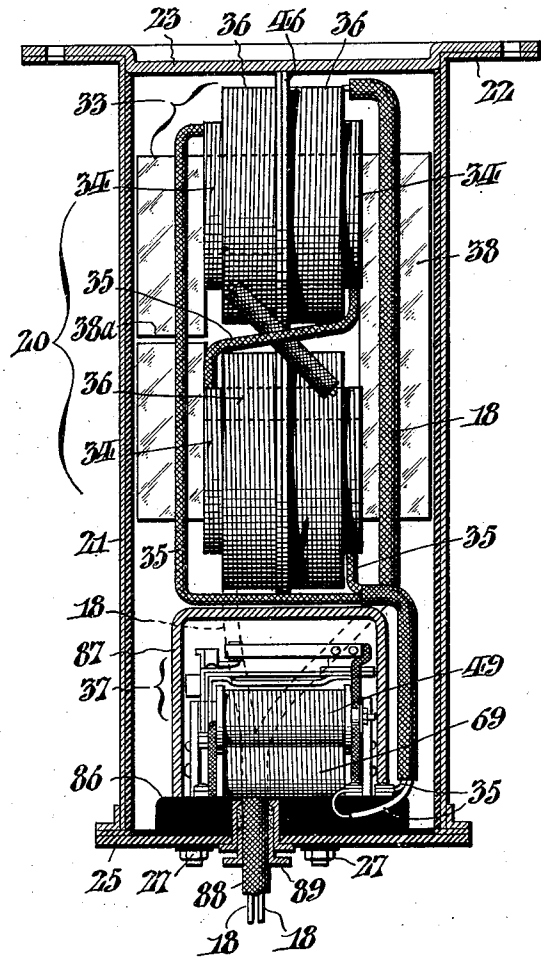
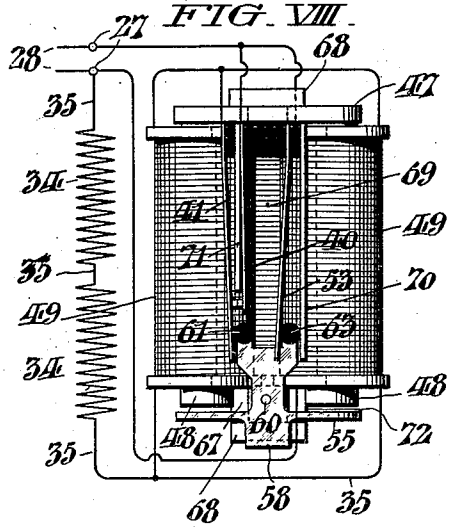


FIG. VIII.



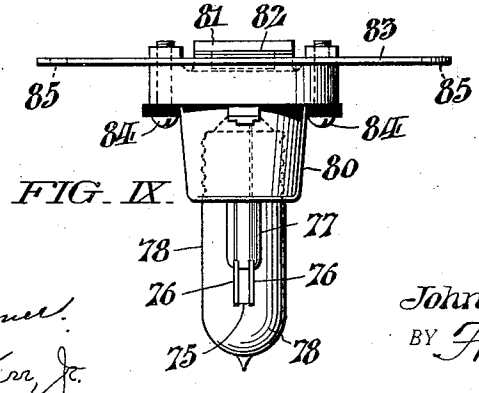


FIG. IX.

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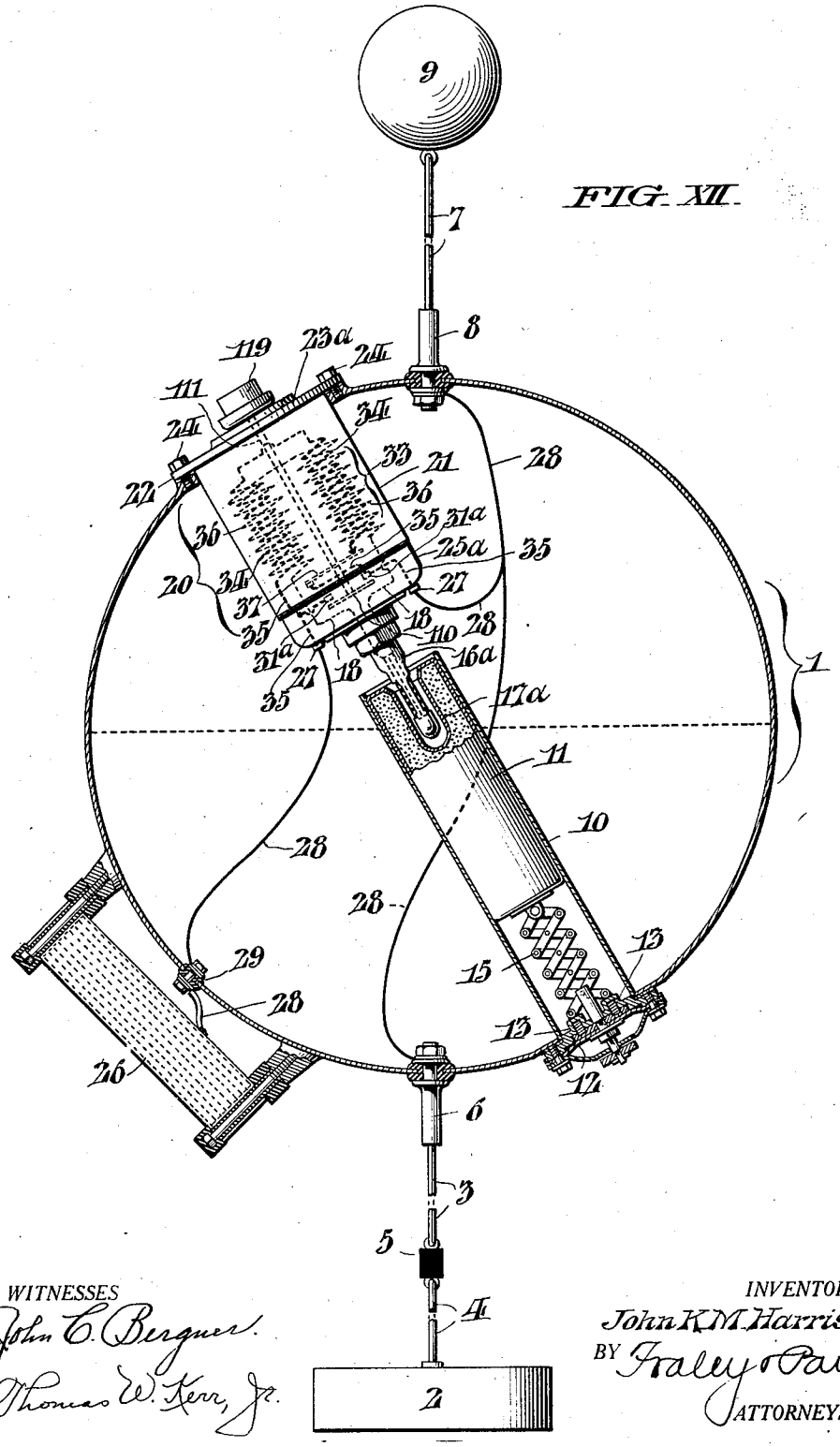
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MARINE MINE AND FIRING METHOD THEREFOR

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FIG. XII.



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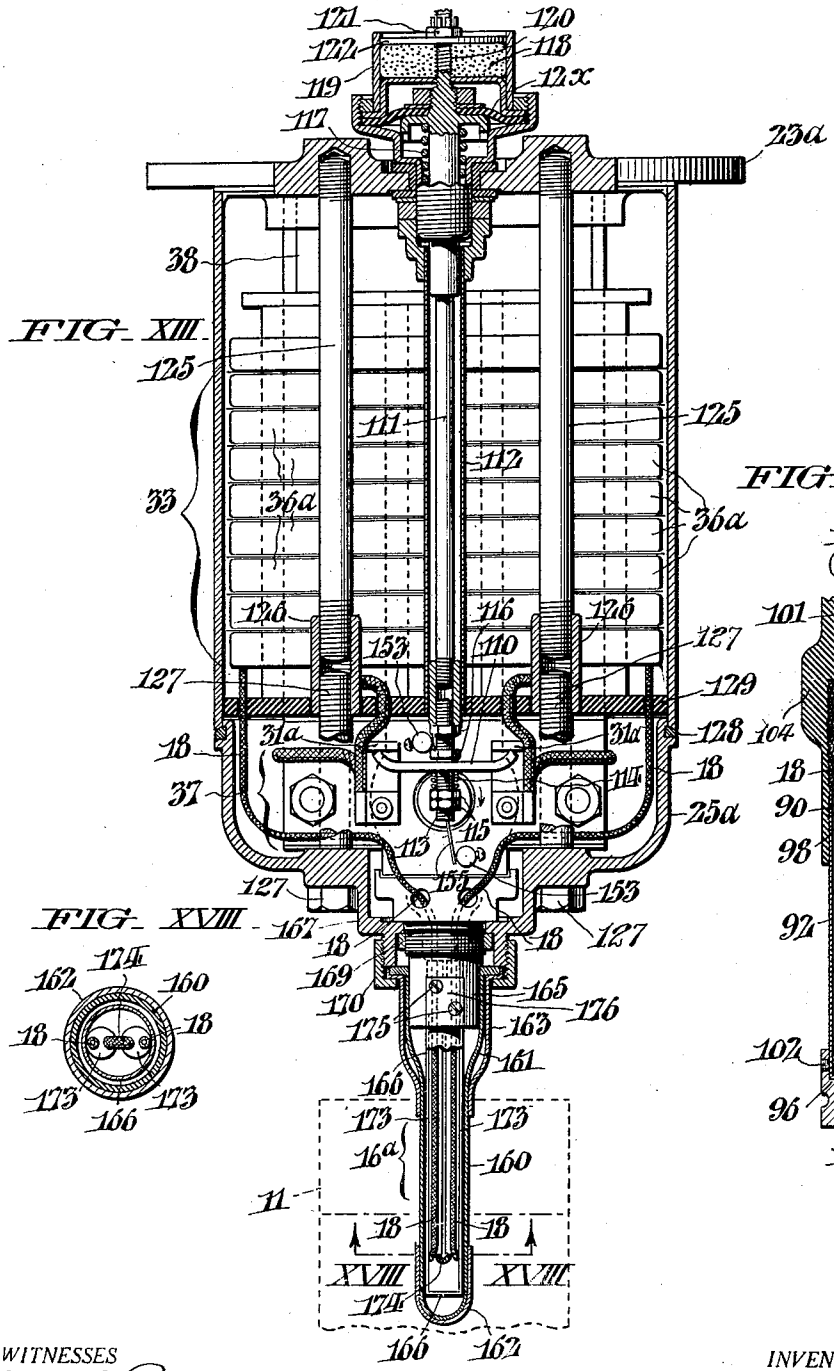
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MARINE MINE AND FIRING METHOD THEREFOR

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WITNESSES

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MARINE MINE AND FIRING METHOD THEREFOR

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FIG XV.

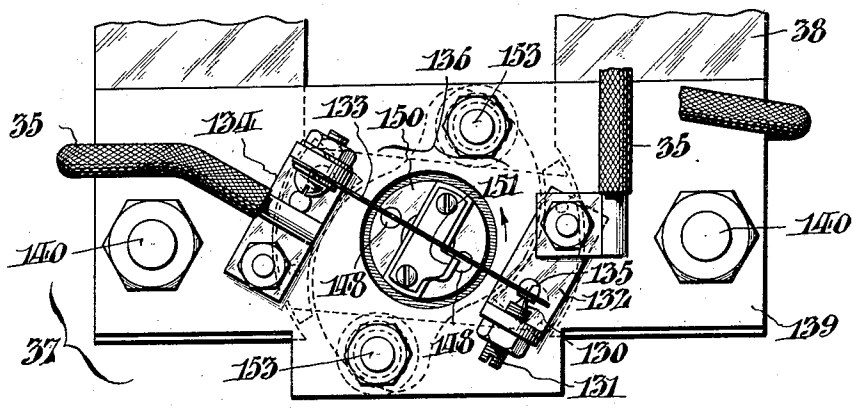


FIG XVI.

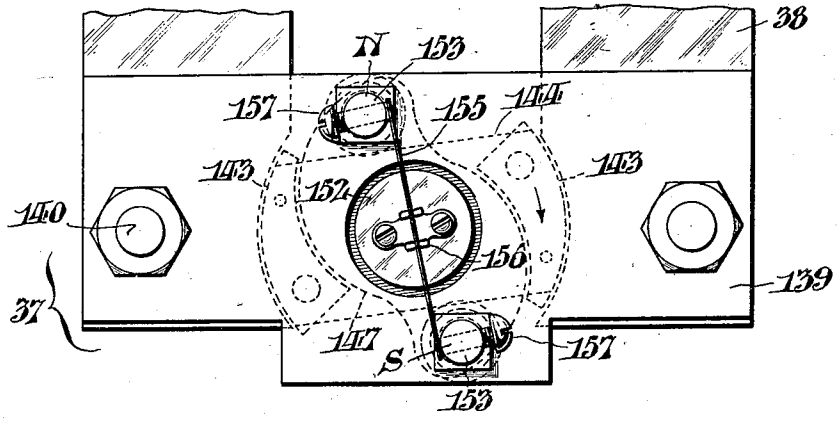
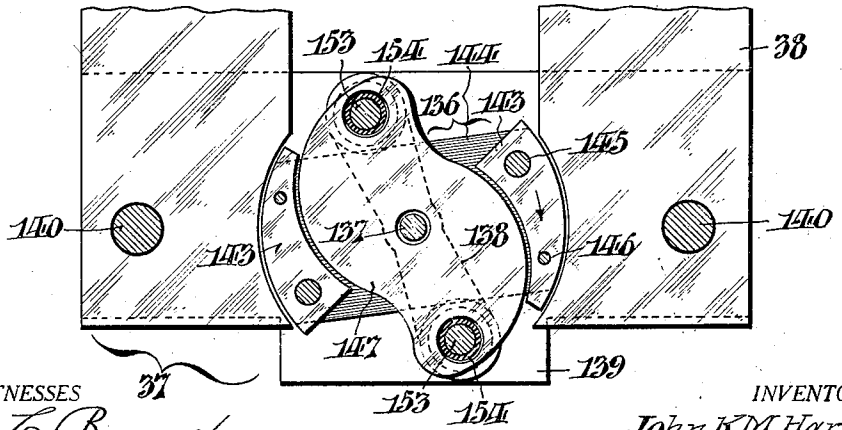


FIG XVII.



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Patented July 14, 1931

1,814,152

UNITED STATES PATENT OFFICE

JOHN K. M. HARRISON, OF OGONTZ, PENNSYLVANIA

MARINE MINE AND FIRING METHOD THEREFOR

Application filed January 13, 1926, Serial No. 81,082. Renewed September 30, 1930.

My invention relates to mines and the like, and particularly mines of the marine type,—whether submerged or floating at the surface of the water. The invention is especially concerned with the supply and application of energy or power for firing such mines, but also involves other features. In general, my objects are certainty and reliability of action; durability and freedom from deterioration or derangement, either in service or in storage; simplicity; and immunity as against counter-measures of an enemy. Other objects and advantages that can be realized through my invention will appear hereinafter. As to common subject-matter disclosed and claimed, this application is a continuation of my prior application, Serial No. 705,741, filed April 11, 1924.

From a narrow point of view, the act of firing a mine consists essentially in the application of energy to explosive to produce initial explosion. The agency or device whereby (or wherein) this initial direct application of energy to explosive takes place is commonly termed a "detonator" or "primer",—employing the terms in a generic sense, without regard to technical niceties of definition. From a broad point of view, on the other hand, the complete process of firing includes every step or operation that intervenes between the occurence of a condition under which the mine is intended to function and the "letting go" of the charge finally relied on to produce the desired effect upon the object of attack. Accordingly, from this point of view, all parts of the mine organization or equipment involved in bringing about ultimate, effective explosion in responsive to conditions of attack (including the detonator) are collectively termed the "firing gear". In practice, one or more subordinate explosions usually intervene between the initial one and the letting go of the main charge,—such an intermediately exploding charge being commonly termed a "booster". Indeed, there may even be a booster action within the detonator itself, as well as between the detonator and the main charge.

It is advantageous to derive energy for the operation of the firing gear from the mine environment, by means of a cell or "battery" device functioning on the galvanic battery principle, with the sea water as electrolyte. Such a sea battery device need not be subject to deterioration or exhaustion like most sources of energy heretofore proposed for marine mines,—as storage batteries, dry cells or ordinary wet cells,—so that in cases where energy is required only for a short period on the occasion 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 may have actuating means automatically responsive to any conditions of attack desired,—such as impact of a vessel against the mine, contact of such vessel with a mine antenna, arm, or horn, sinking of a "depth charge" type of mine to a proper depth, etc. Various sea battery electrodes suitable for my present purpose are described in my U. S. Patent No. 1,485,776, granted March 4, 1924, and in my co-pending application, Serial Number 337,219, filed November 11, 1919. In practice, also, the mine case itself may be used as a sea battery electrode, either alone or in association with an electrode (of either the same or different material) mounted on it.

As explained in my said patent, the power afforded by a sea battery is limited to a very moderate rate of output,—which cannot be exceeded even by the use of extremely and impracticably large electrode surfaces,—and the voltage of such a battery is likewise very limited. I aim, however, to enable a mine to be fired directly and reliably with the energy of a source of such limited capabilities as a sea battery—even using a detonator whose firing requirements exceed the ability of such source to furnish current. This, I have found, can be accomplished by accumulating energy from the source over a period of time before passing or delivering it to the detonator,—raising the voltage of such energy to any extent that may be desirable. In this way, I am enabled to and preferably do use a type of detonator that usefully applies all or most of the energy input, without necessity for dissipating much of such input to heat a relatively large mass of explosive in

order to bring a mere fraction of that mass to detonating temperature, as in detonators heretofore used for marine mines.

Such firing by accumulation of energy intermediate the source and the detonator is, of course, somewhat analogous to the use of a dam to accumulate the water of a stream overnight and thus permit daytime operation of a mill at a rate of energy consumption exceeding the power represented by the steady stream flow and head: i. e., the discharge of energy into or through the detonator may take place quickly as compared with the antecedent accumulation. The process of accumulation need not necessarily involve any great length of time, however; on the contrary, it can be effected in the allowable functional period or interval of the mine,—that is, between the occurrence of the condition of attack and the beginning of the explosion,—as in the forms of firing gear hereinafter described. With the quicker-acting equipment and/or the more sensitive detonator hereinafter described, indeed, the whole process occupies so short a time (less than the tenth part of a second) that it might almost seem a misnomer to use the term "accumulation" in reference to anything so very brief as this flow of sea battery current in the system that precedes the initial explosion. In other words, it might very plausibly be suggested that in such cases the flow represents merely the necessary charging or energizing of means for elevating the sea battery energy to higher voltage in order to fire the detonator employed, rather than accumulation in the narrower sense of gradually building up a "hoard" of energy from a source that would otherwise be of inadequate power. However, this is an academic question of theoretical definition which there is no necessity of deciding; for in a broad sense any charging or energizing of the system represents "accumulation" of energy.

The duration of the accumulation and the discharge of the accumulated energy may be variously determined and brought about. Both can be automatically regulated very simply upon the principle of progressive self-limiting impoundment (so to term it) up to a limit corresponding to or exceeding the firing requirements of the detonator: i. e., in a manner somewhat analogous to the gradual accumulation of the water of a stream behind a dam of loose earth until the water overflows, cuts through, and discharges in a flood or a rush. In the apparatus hereinafter described, sea battery energy is accumulated and stored electromagnetically.

While I have here referred to mines of the marine type and to sea water as electrolyte, it will be understood, of course that the utility of my firing methods and apparatus extends to mines for other bodies of water besides the ocean, and to any feeble or depleted source of energy with which such a mine may be provided.

In the drawings, Fig. I is a somewhat diagrammatic sectional elevation of one form of mine organization embodying my invention, certain parts being broken away.

Fig. II is a diagrammatic elevation representing a mine such as shown in Fig. I with somewhat different provisions for firing.

Fig. III is a similar view showing still different provisions for firing the mine.

Fig. IV is a fragmentary view illustrating a detail of construction of the mine antenna shown in Fig. III.

Fig. V is a wiring diagram illustrating the electrical connections and features of such an organization, with simplification of some of the parts.

Fig. VI is a diagram similar to Fig. V, showing different forms of certain parts.

Fig. VII is a diagrammatic view of an interrupter adapted to be substituted for those shown in other figures.

Fig. VIII is a similar view of still another form of interrupter.

Fig. IX is a side view of a fuse type of interrupter.

Fig. X is a view of the transformer shown in Fig. I, on a larger scale, with an inner case enclosing the associated circuit breaker or interrupter in section, as well as the main transformer case.

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

Fig. XII is a somewhat diagrammatic view, similar to Fig. I, showing another form of mine organization suitable for my purpose.

Fig. XIII shows a longitudinal section through the accumulative means and associated parts illustrated in Fig. XII.

Fig. XIV is a bottom plan view of the accumulative means with a portion of its casing removed and with one of its parts partly broken away,—illustrating particularly the interrupter.

Fig. XV is a fragmentary side view of the interrupter mechanism from the rear of Fig. XIII and the bottom of Fig. XIV, but on a much larger scale.

Fig. XVI is a similar view of the interrupter mechanism from the front of Fig. XIII and the top of Fig. XIV.

Fig. XVII is a view of certain parts of the interrupter mechanism taken similarly to Fig. XVI, with various other parts in section as indicated by the line XVII—XVII in Fig. XIV.

Fig. XVIII shows a section through the detonator device, taken as indicated by the line XVIII—XVIII in Fig. XIII.

Fig. XIX shows a longitudinal mid-section through a detonator, on a larger scale than Figs. XII and XIII.

Figs. XX and XXI are fragmentary per-

spective views of certain parts of the detonator.

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, as indicated by the horizontal dotted line. The mine is secured to any suitable anchor device 2 by a cable comprising sections 3, 4 with an interposed strain insulator 5 and an insulating attachment 6 to the mine case 1. Another cable 7, with insulating attachment 8 to the mine case 1, extends upward to a float 9, usually submerged somewhat. If desired, the mine may be provided with an antenna circuit breaker such as described in my U. S. Patent No. 1,447,951, granted March 6, 1923, and with an anchor swivel and other usual accessories of marine mines.

In the lower portion of the mine shell 1 is an opening from whose edge extends inward a cylindrical casing 10 wherein is mounted a metal can 11 containing the "booster" charge. Over the same opening is secured water-tight a flexible rubber diaphragm 12: for service in hot climates, this diaphragm may be replaced with a sylphon type of bellows. The diaphragm 12 is urged outward against external hydrostatic pressure by helical compression springs 13, 13, and serves to operate a lazy-tongs safety mechanism 15. When the mine is submerged to the desired depth, the mechanism 15 projects and holds the detonator 16 in firing position (as shown) in a tube 17 extending from end to end of the booster can 11; at other times, it holds the detonator withdrawn to such an extent that its action would no longer detonate the booster or explode the mine. From the detonator 16, firing circuit leads 18, 18 extend to means for accumulating sea battery energy and/or elevating it to higher voltage as above described,—such means being here generally and comprehensively indicated by the reference numeral 20.

The accumulating means 20 may be enclosed in a water-tight casing 21 comprising a cylindrical shell extending inward from an opening in the mine shell 1, here shown as diametrically opposite the shell 10. As shown, the outer end of this shell has a flange 22 externally seated against the mine shell 1, with a metal end plate 23 welded thereto; and stud bolts 24 extending through flange and cover secure the casing 21 to the mine shell 1. At the other end of the casing shell is a detachable cover 25, preferably of insulating material for convenience in mounting various electrical connections on it or introducing them through it. Preferably, the length of all leads attached to or entering the casing 21 is made sufficient to allow this whole casing to be bodily withdrawn outside of the shell 1 (after detachment at the bolts 24), and disconnected from the leads,—or vice versa.

While various condition-responsive and sea battery arrangements might be employed for my present purpose, Fig. I shows a battery device consisting of a single pole element 26, together with provisions for utilizing the cable sections 7, 3 as upper and lower contact antennæ, so as to combine the hull of the vessel to be attacked with the pole element 26 as the other pole of a galvanic couple or "battery". Accordingly, the antenna cables 7, 3 are connected together and to one supply terminal 27 of the accumulating means 20 by one supply circuit lead 28; while the pole element 26 is connected to the other supply terminal 27 of said means 20 by the other supply circuit lead 28, with a suitably insulated connection 29 through the mine shell 1. When, therefore, a metallic vessel comes in contact with either antenna 7 or 3, it is thereby automatically combined with the pole element 26 to form a galvanic couple; and energy is thus supplied to the accumulating means 20 until the accumulation is discharged into and fires the detonator 16.

As shown, the pole element 26 is insulatively mounted on the lower portion of the mine shell 1. The material of this pole element 26 must differ sufficiently from those of marine hulls to be encountered as regards galvanic potential characteristic in sea water to form therewith a couple of adequate potential difference or voltage, and such couple must also afford adequate flow of current under service conditions. The choice of materials is necessarily limited by the consideration that all exposed parts of the mine organization 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 requires them to be of the same material. Zinc and copper are suitable; but copper or other cupreous metal (e. g., Monel metal) is, on the whole, preferable, since its properties are well adapted to the peculiar service conditions of marine mine firing gear. When of copper, the pole element 26 acts as anode with reference to ferrous metal, and should be so constructed as to have an exposed surface of from 10,000 to 11,000 square inches,—which in combination with an iron or steel hull (or even a much smaller area of ferrous metal) affords a safely adequate supply of energy for my firing gear and detonator here described,—about 0.4 amperes current at 0.3 volts sea battery voltage with 0.43 ohms resistance in the circuit external to the sea battery, for example, or 0.32 amperes with 0.61 ohms resistance in the external circuit, or, again, 0.56 amperes with 0.23 ohms resistance. The internal resistance of such

a sea battery is about 0.32 ohms. To give the pole element 26 such a large active surface in anything like the small space indicated by its proportion in Fig. I to the standard steel mine shell 1 (of 34 inch diameter), it may be of cellular or other interstitious character: e. g., composed of a pack of perforated and corrugated thin metal plates slightly spaced apart,—.006 in. sheet copper being suitable.

As a safe-guard against accidental explosion additional to that afforded by the shifting of the detonator 16, provision may be made for shunting the supply circuit 28, 28 across the accumulator terminals 27, 27. As shown, shunt leads 30, 30 extend from said terminals 27, 27 to flexible spring contacts 31, 31 insulatively mounted in the casing 10. When the extender mechanism 15 is expanded, as in Fig. I, the contacts 31, 31 are held apart by an insulating wedge block 32 suitably mounted on said mechanism 15, and the shunt is broken so as to permit the detonator 16 to be fired; but when the extended mechanism 15 starts to contract, it quickly withdraws the wedge block 32 and allows the contacts 31, 31 to come together and shunt the accumulating means 20. The resistance of this shunt being a mere hundredth (say) of that of the accumulating means 20, it affords most effectual protection against accidental firing.

For the accumulative mode of operation hereinbefore described, a quick-acting type of detonator is naturally suitable, and particularly an electrical impact spark-gap type which I have devised. Such a detonator can be made to fire on a rush of current so moderate and brief as to be without perceptible effect on an electro-thermal "bridge-wire" detonator, which requires a more sustained or intense flow to heat the bridge wire and the surrounding detonating material sufficiently. An advantage of such extreme quickness of the detonator is that it leaves practically the whole allowable service period of the mine available for accumulation of sea-battery energy. High voltage (much higher, that is, than that of a sea-battery such as above described) is favorable to vary quick passage of adequate firing energy, and is likewise, of course, a requirement for sparking. Various methods and arrangements may be used in raising the voltage of the sea-battery energy to meet the firing requirements of a high-voltage detonator: as here shown, the energy is accumulated under the characteristic low voltage of the sea-battery, and subsequently discharged or delivered to the detonator at the higher voltage. In the present instance, also, the accumulation is effected electromagnetically, as above mentioned, and the voltage is raised by the accumulating means itself.

The accumulating or storage means 20 here illustrated comprises a transformer 33 with low voltage primary 34 connected between the supply terminals 27, 27 by leads 35, 35, and thus in circuit with the sea battery device 26 and the antennæ 3, 7 through the leads 28, 28, and with high voltage secondary 36 connected directly to the firing leads 18, 18 and thus in circuit with the detonator 16. Said means 20 may have a circuit breaker or interrupter 37 of any suitable sort in its primary or supply circuit,—say in the lead 35 between one of the terminals 27 and the transformer primary.

When a metallic hull (of potential characteristic different from that of the pole element 26, of course) comes in contact with one of the antennæ 3, 7, current from the complete galvanic couple or battery thus formed at once begins to flow in the transformer primary 34, gradually increasing toward a limited maximum value. During the growth of this current, alterations representing a conversion and an accumulation of or charging with sea battery energy, in the relatively "static" or potential form represented by magnetization, are produced in the magnetic conditions of the transformer 33. Not all the energy supplied by the sea battery during the period of current growth is thus converted and stored up, of course: on the contrary, part goes to overcome the electrical resistance of the circuit between the vessel's hull and the pole element 26 (including that of the transformer primary 34); and only the residuum over the amount thus consumed is available to produce the electromagnetic effects that represent accumulation.

So long as current continues to flow in the transformer primary 34, this charge or accumulated residuum of energy from the sea battery is kept stored up. Cessation of the primary current, on the other hand, has the effect of liberating the energy, which thereupon reconverts and discharges itself in the form of electric current, at a rate proportioned (inter alia) to the rate of extinction of the primary current. If, then, cessation of the primary current be brought about suddenly, by interrupting the primary circuit in any suitable manner, the discharge will take the form of a rush of current at high voltage in the transformer secondary 36 and the firing circuit 18, 18; and with a suitable transformer and a gap detonator such as hereinafter indicated, the voltage and energy of the discharge will suffice to jump the gap and fire the detonator.

The breaking of the primary circuit may be effected in various ways, either with or without an interrupter 37 of any suitable type. One simple automatic method would be represented by the mere cessation of contact between hull and antenna which natu-

rally occurs as the ship moves on its course past the anchored mine. With the most sensitive type of detonator 16 hereinafter described, this alone may suffice,—notwithstanding the fact that when such loss of contact occurs, a considerable length of antenna cable 3, 7 that has acquired the potential of the ship hull is left connected to the transformer primary 34, so that the sea battery current in the primary tends to die away gradually instead of ceasing abruptly. To assure a greater margin of firing ability, however, the antenna 7 (the lower antenna 3 being preferably omitted) may be secured to the mine shell 1 by a detachable or breakable attachment 8′, as shown in Fig. II, and provision may be made for this antenna 7 to become entangled or otherwise fast to the vessel, so as to be pulled away by the latter. For example, the antenna 7 may be provided with grappling hooks 9′ (e. g., on the float 9) for this purpose. When the charged antenna 7 is thus detached from the rest of the primary circuit, the accumulation or charge of energy will be discharged through the secondary 36 with great suddenness and intensity. However, such expedients are not infallible, since the antenna grapples 9′ may fail to find a hold on the vessel.

One way of breaking the primary circuit without any such drawbacks involves the progressive self-limiting impoundment method of energy accumulation already referred to: viz, letting the accumulation determine the break in the primary circuit and the resultant discharge. This can be effected with an interrupter 37 automatically responsive to the sea battery current in the primary circuit, or to the transformer conditions created thereby. Such an interrupter 37 may be electro-magnetic, with a mechanical break; or electro-thermal, like an overload fuse; or of any other preferred type and construction. In use, it will be so designed or adjusted as to open only when the increasing sea battery current reaches a value corresponding to an electro-magnetic energization of the system sufficient to fire the detonator 16 with a safe margin to spare,—50%, for example, or even much more. This opening point need not, of course, coincide with the greatest attainable value of the current, but may be lower than that, so as to make the functional period of the mine as short as possible. In practice, this period—that is to say, the interval between contact with a hull at one of the antennæ 3, 7 and the firing of detonator and mine—can be made as short as one-tenth of a second or less.

To assure firing of the mine when its antenna comes in contact with a vessel, it is, of course, necessary that the contact be sufficiently prolonged to permit adequate energization of the system. While perfectly satisfactory in this respect against submarines, the type of upper antenna 7 shown in Figs. I and II is less so against surface ships; because the sustaining buoyancy is concentrated in the single float 9, which may readily be thrown off from the ship by its bow waves after a mere momentary contact, or even without any contact at all. To obviate this, it may be found desirable to replace or supplement the float 9 with an upward extension 7*a* of the antenna 7, of more distributed but subdivided buoyancy. It is not necessary that the buoyancy of this antenna 7*a* be so completely distributed as would be represented by a hollow multicellular tubular construction or the like; on the contrary, it will suffice to provide it with a number of small floats 9*a* (Fig. III) at suitable intervals. As shown in Fig. IV, these floats 9*a* may consist of pieces of cork or other light material, grooved on one side to accommodate the antenna cable 7*a* and on the other side for a wire binding strap 7*x* secured around the cable at either end of the float, so as to form a loop around the latter and hold it securely. One or both sides of this loop may even be provided with contact points such as indicated at 9*a*′. Extending upward from the submerged float 9 and lying loose along the surface of the water in a considerable length, as shown in Fig. III, such an antenna 7*a* is sure to be drawn into sufficiently prolonged contact with a passing surface ship. Moreover, an antenna 7*a* of distributed buoyancy will not sink and become useless on detachment or destruction of a single float, as the antenna 7 shown in Figs. II and III would do.

In Fig. III, various parts and features not mentioned above have been marked with the same reference characters as in Figs. I and II, as a means of dispensing with merely repetitive description.

Figs. V and VI show mine firing gear with various types of transformer and interrupter; Figs. VII and VIII illustrate other types of interrupter that may be used in any of the firing gears shown in Figs. I, V, and VI; and Fig. X shows the accumulative means of Fig. I on a larger scale, with the transformer 33 and interrupter 37 of Figs. VI and VIII. Throughout Figs. I, VIII and X, corresponding parts and features are marked with the same reference characters, as a means of dispensing with merely repetitive description.

In Fig. V, the transformer has its primary and secondary coils 34, 36 wound one inside the other around one side of its rectangular laminated core 38. The interrupter is of an electromagnetic vibrator type, and operated directly by the magnetization of the core 38, which has a gap 39 entirely through one side. As shown, this interrupter comprises a fixed contact point 40 above the gap 39, and a cooperating spring-mounted or spring-actu-

ated sheet iron contact 41 interposed between said point 40 and the portion of the core 38 containing the gap. When a ship S comes in contact with the antenna 7, as shown, the magnetization of the core 38 due to the sea battery current in the primary 34 corresponds in strength to the accumulation of energy in the system; and as soon as this accumulation reaches the desired amount, the spring tension on the contact 41 is overcome, and the primary circuit is broken. In case (owing to poor contact at 40, 41) the detonator 16 fails to fire on the first break, the action will be repeated.

As shown in Fig. V, a condenser 42 is connected in parallel across the interrupter contacts 40, 41 to reduce sparking. A shunt with normally open switch 43 is also provided across the interrupter 37, for rendering the interrupter ineffective in case it should be desired to rely on the vessel attacked for breaking the primary circuit, as described above. Also, the firing circuit 18, 18 is shunted with a one-eighth inch safety gap 44, to safe-guard the transformer during factory tests.

In Fig. VI, there are double or divided primary and secondary windings 34, 34 and 36, 36 around opposite sides of the core 38. Of these, the primary windings 34, 34 are connected in parallel by the leads 35, 35, so as to minimize the primary resistance, while the secondary windings 36, 36 are connected in series at 45, so as to give the greatest possible voltage on the firing circuit 18, 18. Instead of being cut clear through the core 38, the gap 39 is only a V-shaped notch cut deep into the outer edge of the core, so that it does not greatly impair the effectiveness of the transformer.

Fig. VII shows a vibrator type of interrupter devised by me for use with a transformer in an accumulative firing gear. Its movable contact 41, in the form of a light spring, is mounted on an armature member 55, pivoted at 50, and cooperates with the stationary adjustable screw contact 40. A leaf spring 53 with an adjustable screw abutment 56 urges the member 55 toward the contact 40, and not only presses the contact 41 against said contact 40, but also presses a stud 57 on the member 55 against the other side of said spring 41. The member 55 is weighted to give it considerable inertia in starting and considerable momentum in its operating movements, thus not only assuring firm contact and a clean break, but also a period of operation in harmony with the requisite period of accumulation of sea battery energy. As shown, the weights for the member 55 have the form of nuts 58 threaded on the upper and lower arms of said member,—for convenience of adjustment at the factory to balance the member about its pivot, so that it shall operate equally well in any position of the device. When once adjusted, these weights are soldered or otherwise fastened in place. The light spring 41 increases the period of contact at each operation of the device, by remaining in contact with the screw 41 during a portion of the swing of the member 55 each way; and thus the relatively heavy member 55 has time to gather momentum for a clean, sharp, definite break during its opening movement under the influence of the coil 49. This coil may consist of 240 turns of #19 copper wire, of 0.3 ohms resistance. An adjustable screw stop 59 presents the member 55 from actually striking the core pole 48 and thus being held fast by residual magnetism. With the interrupter thus constructed, its total resistance will be about 0.32 ohms.

The interrupter shown in Fig. VIII has a U-shaped iron core 47 with operating windings 49, 49 of opposite pitch on its legs 48, 48. The windings 49, 49 are connected in parallel with one another, but in series with the light leaf-spring contacts 40, 41 and with the serially connected transformer primaries 34, 34. For operating the movable contact 41, there is an armature rocker 55 pivoted at 60 and carrying pins 61, 63. This rocker 55 is balanced about its pivot 60 by a mass of metal 58 between the pivot and the adjacent permanent magnet pole 68. A leaf spring 53 (stronger than the light contact springs 40, 41) acts on the pin 63 to swing the rocker 55 to the right, clockwise. Instead of a permanent polarizing magnet, there is a polarizing winding 69 wound around a part 67 of annealed iron, and connected between the supply terminals 27, 27 in parallel with the group composed of the transformer primaries 34, 34, operating windings 49, 49, and contacts 40, 41. One end of this piece of iron 67 lies against the cross member of the core 47, and the other end 68 adjacent the middle of the armature rocker 55. Flow of current through the polarizing winding 69 acts to magnetize the core legs 48 equally. Each operating winding 49 may consist of 600 turns of No. 17 enamelled copper wire (or of 600 double turns of No. 20 enamelled copper wire) of 0.54 ohm resistance, while the polarizing winding 69 may consist of 700 turns of No. 18 enamelled copper wire, with a resistance of 0.88 ohm. In service, the operative resistance of the interrupter so constructed will be about 0.207 ohm.

Normally, the rocker 55 is held in mid-position, as shown, by the leaf spring 53 which urges the pin 63 against the rigid stop bar 70. When sea battery current flows through the primary circuit, one of the operating coils 49 acts cumulatively with the polarizing coil 69 and the other acts in opposition thereto; so that ultimately the rocker 55 is swung or flopped to the left (counter-clockwise) to open the circuit in much the

same way as already explained in connection with Fig. I. As shown, there is a clearance between the pin 61 and the light contact spring 41, so that the pin 61 only acts on the contact 41 during the latter part of its movement. A stop bar 71 may be provided alongside the light stationary contact spring 40, to prevent it from following the contact 41 to the left, and thus frustrating the break. With a light contact spring 41 and a spring 53 of suitable stiffness properly adjusted, such an interrupter can be made to open very reliably on a sea battery current of about 0.30 amp. or less, thus affording an ample factor of safety in reference both to the sea battery power and the firing demand of the sensitive detonator 16 hereinafter described.

It will be seen that with this type of interrupter the operation and movements are just the same for flow of current in either direction, since when the current in the operating coils 49, 49 is reversed, it is also reversed in the polarizing coil 69,—so that the relative action of these coils set forth above remains the same. Hence charging or sheathing a steel ship so as to reverse its polarity in reference to a copper grid 26,—i. e., so as to make the ship anode and the grid cathode,—would not affect the action of the interrupter. There is no likelihood of the device being rendered inoperative by shocks or jars in handling, since there is no magnetism to make the rocker 55 stick to either core pole 48, 48 when the sea battery current is not flowing. As shown, the right-hand end of the rocker 55 is faced with a thin sheet of brass or other non-magnetic metal 72 on its side adjacent the core pole 48, to prevent sticking as a result of any residual magnetism in the core 47 if the mine should for any reason fail to fire on the first operation of the interrupter.

In cases where greater resistance in the interrupter is desired, the device shown in Fig. VIII may be constructed with operating windings 49 each consisting of 750 turns of No. 18 enameled copper wire of 0.52 ohm resistance, and a polarizing winding 69 consisting of 1270 turns of No. 21 enameled copper wire, with a resistance of 3.44 ohms. The operative resistance of the interrupter in service will then be 0.61 ohm. For use as hereinafter indicated, such an interrupter may be set to open on a sea battery current of about 0.23 amp. or less. Or, in case still greater sensitiveness is desired, 1161 turns of No. 20 wire of 1.21 ohms resistance may be used in each of the operating windings 49, and 630 turns of No. 19 wire of 1.08 ohms resistance in the polarizing winding 69. The operative resistance of the interrupter in service will then be about 0.63 ohm. It may be set to open on a sea battery current of about 0.12 amp. or less.

In the interrupter shown in Fig. VIII, it is advantageous to make all parts that carry the magnetic flux (e. g., those marked 47, 48, 67, 68 and 55 in Fig. VIII) of special magnetic iron alloy of high permeability and low inductance,—such as "permalloy", or an alloy of 50 per cent. nickel and iron,—giving low eddy current and hysteresis losses. For current values below saturation, such material gives greater field strength for a given value of the current. In some cases, therefore, its use may make the interrupter operate more quickly. For cases where the mine fails to fire at the first contact between a ship and the antenna, such material offers the advantage of quick demagnetization and reclosure of the circuit by the interrupter, thus increasing the chances of operation of the mine by renewed contact between ship and antenna.

In Fig. IX is shown an interrupter of the electro-thermal fuse type devised by me. In general, this interrupter is constructed like an incandescent electric lamp. Instead of a tungsten filament, however, it has a short length of very fine fusible wire 75 connected between its leads 76, 76 by fused or welded joints of minimum thermal conductivity. I prefer to make the fuse wire 75 of pure tin of 1½ mil size, about 4.9–5.2 mm. long between welds; or it may be of Wood's metal (fusing at 70° C.) of 3 mil size, about 4–4½ mm. between welds. Wire of this order of fineness cannot be made of such fusible metals by ordinary wire-drawing methods, but can be produced, I have discovered, by the Wollaston process, using a sheath of aluminum. The tin may be drawn bare to 0.015 or 0.02 inch and then enclosed in an aluminum tube externally ten times its own diameter for drawing down to final size. After the last passage of the composite wire through the wire drawing dies, the aluminum sheath can be removed with weak nitric acid. The welds to the fuse wire 75 must, of course, be made with great care, to avoid melting the fusible wire 75 itself. For this purpose, the nickel ends of the leads 76, 76 should first be tinned, and the welding done on a standard spot welding machine, at as low a temperature as possible. In sealing the rather long glass stem 77 into the rest of the glass bulb 78, a plug of damp asbestos should be firmly stuffed into the stem, to obviate possible fusion of the wire 75 by heat conduction along the leads 76, 76. Evacuation must, of course, be effected without passage of current through the wire 75, as by means of a condensation vacuum pump with liquid air attachment, operated for about ten minutes. During evacuation, the vacuum may be tested by means of a dummy tube (with wire 75 of tungsten, for example) connected to the exhaust manifold, using a Rosenthal coil at full power in the usual manner. After sealing off, the vacuum in each fuse bulb should be directly tested with a Rosenthal coil (at

the lowest output power sufficient to show the condition) connected to one only of the leads 76; this test should show a blue color or better. The cold resistance of the completed device—after sealing in and evacuation, basing, etc.—should be about 0.61 to 0.65 ohm. Such a fuse will open on 0.12 to 0.15 ampere, which corresponds to a sea battery voltage of 0.26 to 0.28 and 0.32 ohms internal resistance for such battery.

In use, this fuse interupter may be mounted in an ordinary porcelain lamp socket 80, as shown in Fig. IX. Preferably, it will be provided with a resilient or other suitable shock absorbent mounting, such as rubber pad 81 over a stiff steel bow spring 82 attached to the bottom of the socket 80. As shown, there is a flexible springy strip 83 secured to the socket 80 by bolts 84 and serving to hold the rubber pad 81 in place, as well as to cushion movement downward in Fig. IX. This strip 83 may have its ends apertured as at 85 for conveniently securing it to the insulative cover 25 of the case 21, or to any other suitable part.

To enable a source of energy so relatively feeble as a sea battery to fire detonators 16 of the less sensitive types hereinafter described reliably, I have devised what may be termed a "low power accumulative" type of transformer, characterized by a large accumulative capacity in proportion to the current flow in the primary, as in a core of mass anomalously disproportionate (according to all ordinary criteria) to energy involved. I also prefer to make the magnetic circuit of the transformer as short as possible. While, of course, the form, construction, connections, etc., of such a transformer may vary a great deal (see Figs. V–VIII), yet for the convenience of those desiring to practice my invention, I will describe in detail one such construction, such as illustrated in Figs. I, VI and X.

The transformer 33 shown in Figs. I, VI and X may be built with a laminated core 38 of silicon iron (or other special transformer iron) of about 2.95 square inches cross section and about 18 lbs. total weight, with a window about 3½ in. by 3¾ in. Or a special magnetic iron alloy may be used in the core, such as "permalloy" or an alloy of 50 per cent nickel and iron (likewise in laminæ), thus increasing the inductance of the transformer for current values below the saturation point, and increasing the energy stored in the transformer for a given current. Tests show that the functional period of the mine may be reduced some 20 per cent simply by the use of 50 per cent nickel-and-iron in the transformer 4, instead of the usual silicon transformer steel of the best quality. The inductance of the transformer 33 may be reduced by a gap in the magnetic circuit, such as a narrow slot, 38*a* (say from $\frac{1}{16}$ in. wide, down to 0.001 or 0.002 in. or thereabout) cut clear through one of its legs, as shown in Fig. X. Thus such a gap not only reduces the time required for the primary current to build up, and thus reduces the functional period of the mine, but also increases the rapidity and voltage of the secondary discharge when the primary circuit is broken. Indeed, the functional period of the mine may be reduced 75 per cent in this way and the factor of assurance concomitantly increased,—notwithstanding the slight reduction (due to such a gap) in the energy stored in a given time for a given current. Each of the primary windings 34 may consist of 154 feet of cotton covered No. 14 copper wire wound in a coil of about 220 turns,—45 turns to the layer. The secondary windings 36 may consist in the aggregate of 17,500 feet of No. 31 enameled copper wire, wound in four coils (as above described) with about 3750 turns each,—100 turns to the layer. Thus constructed, the total resistance of the serially connected transformer primaries 34, 34 will be about 0.201 ohm; and with a voltage of 0.22 on the primary, the voltage of the secondary kick or rush of current will be about 5000 volts. Hence great care should be taken to assure ample insulation for the transformer 33 (especially in its secondary windings), as well as for all leads and connections of the secondary circuit. The ratio of this transformer is about 68 to 1. This, of course, is in no wise inconsistent with the high voltage mentioned above for its "kick" when used as an induction coil,—which must not be confused with the secondary alternating current voltage of a transformer in ordinary use as such.

Referring, now, to Figs. I and X, it will be seen that the transformer 33 there shown has its primaries 34, 34 serially connected as in Figs. VII to X (to obviate unbalanced operation from any slight differences in construction); and that the interrupter 37 shown is of the Fig. VIII type. This interrupter 37 is mounted on a base 86 attached to the inside of the insulative cover 25 of the casing 21. An iron casing 87 encloses the interrupter 37 and shields it against influence of outside iron on its operation. Care should be taken to provide a most thorough insulation of all the electrical parts and connections, especially in the case of the high tension secondary or firing circuit. The connection 45 and the firing circuit leads 18, 18 may preferably be of red enameled copper, with a covering of cotton and tar composition, and may be enclosed in insulated tubing such as varnished cambric. As shown in Figs. I and X, these leads 18, 18 are also enclosed in a double bored cylindrical cover 88 of flexible rubber, which extends from the interior of the casing 21 out through a watertight rubber stuffing box 89 on the cover 25,

and through the booster can tube 17 right to the detonator 16. The lead conductors 18, 18 themselves are preferably unbroken from the transformer 37 right into the detonator 16 itself.

The total aggregate resistance in the external primary circuit of the firing gear shown in Fig. I (with transformer 33 and interrupter 37 such as set forth in connection with Figs. X and VIII) will be about 0.43, 0.63, or 0.65 ohm, according to the winding of the interrupter,—allowing some 0.02 ohms or more for the various supply leads and connections 28, 35, etc.

Under average normal service conditions, the internal resistance of a sea battery such as indicated above (comprising a copper pole element 26 such as described, and an iron or steel hull in contact with the antenna 3 or 7) is about 0.32 ohm; under unfavorable conditions,—such as the merely brackish water of a tidal river during a freshet, when the tide is at ebb,—the internal sea battery resistance may be as high as 0.6 or 0.7 ohms.

Inasmuch as a sea battery gives its greatest output of power when internal and external resistance are approximately equal, it will be seen that while the interrupters giving the higher resistances in the primary circuit appear most suitable for unfavorable conditions, the lower resistance interrupter would apparently be preferable under normal conditions. On the other hand, when the external resistance is low (e. g., 0.43 ohm), polarization in the sea battery tends to reduce the current quickly; so that higher resistance (e. g., 0.63 or 0.65 ohm) is likely to give a greater margin or factor of assurance that the interrupter will function, because such relatively high resistance tends to prevent polarization, and thus obviates reduction of the sea battery current below its initial value. Disregarding polarization, I find that in practice a lower total resistance of the primary circuit gives more rapid accumulation of energy and results in quicker firing. Practically, I aim to design the system so as to operate at current values too low for polarization to occur within the functional period of the mine.

In order to fire with a sea battery device 26 and a transformer 33 such as described above, the detonator 16 must be more sensitive than spark-gap detonators heretofore known. One form of electrical impact detonator that I have devised for the purpose is shown in Fig. XI. As shown, the sparking terminals 90, 90 are preferably formed by suitably shaping and bending the ends of the firing circuit conductors or transformer leads 18, 18 themselves. However formed, they may conveniently be embedded and held in place in a plug 91 of hard rubber, somewhat loosely screwed into the end of a copper tube 92 of 0.255 inch internal diameter. The plug 91 may be secured in place in the tube 92 by a seal 93 of fused sulphur poured around the leads 18, 18. The bare end portions of the soft copper lead wires 18, 18 (from which the red enamel insulation has been removed) are forced with a tight fit through holes in the plug 91, and their ends (either pointed, or cut with pliers so as to leave a slight burr) are bent over at a sharp right angle to form the sparking terminals 90, 90, with a clean gap of as much as 0.003 in. but less than 0.004 in. The varnished cambric insulating tubes 101, 101 on the leads 18, 18 are embedded in the sulphur 93, which is poured hot enough to be of thin consistency and seal well. A deep cupped copper plug 96 is held in the other end of the tube 92 by friction,—reinforced by set screws 102, 102 that grip the wall's of tube and plug together in an annular groove of a brass mounting piece 103 that serves for attaching the detonator to the extender mechanism 15. The bores for the cambric tubes 101, 101, in the flexible rubber lead cover 88 (see Fig. X) are loose-fitting, to facilitate insertion. At the detonator, the lead-bores open into a single large bore that fits the detonator tube 92 tightly and is cemented around it air-tight. The cover 88 is considerably enlarged and thickened at 104, in the region where the lead bores end, so as to stiffen it and prevent any working or bending of the leads 18, 18 at and adjacent the detonator seal 93. The enlargement 104 also acts as a guide and rubbing surface in the booster tube 17, and prevents cramping at this point during operation of the extender mechanism 15. The detonating material 98 should be dense or tight in the gap between the terminals 90, 90; for in this condition, I have discovered, it fires on a much weaker spark than if relatively loose. Density of the material 98 causes an impact of the spark on it, and even disruption of it by the spark, and thus brings about detonation without necessity for heating the material to a detonating temperature, as in spark-gap detonators heretofore used; at any rate, such a detonator will fire on a spark whose energy would be quite insufficient for such heating. The detonator is preferably loaded with a 5 gr. charge 98 of fine gray fulminate of mercury (that will pass a 100 mesh sieve) under a pressure of 6000 lbs. per sq. in.,—which compresses it to a column about 0.1 in. high in a tube 92 of 0.255 in. internal diameter. The smallness of this primary charge increases the pressure and density of the material in the spark-gap. An additional secondary charge of 45 gr. standard fulminate of mercury is preferably loaded and pressed in three equal batches with 5000 lbs. per sq. in. pressure on each.

Thus constructed and loaded, this form of detonator will fire with about 0.02 volt and

0.08 to 0.10 amp. in the primary 34 of the Figs. I and X transformer 33 when there is no gap 38*a* in its core 38, and with about 0.028 volts and 0.10 to 0.14 amp. with the gap 38*a*.

Electrical impact detonators can be made more sensitive still by employing in their spark gaps detonating materials more sensitive to shock or impact than fulminate of mercury; particularly, fulminate of silver, fulminate of gold, or the diazobenzene-perchlorates, such as simple diazobenzeneperchlorate, paramethyldiazo-benzeneperchlorate, and paranitrodiazo-benzeneperchlorate. Of the last three, the last mentioned (commonly known as "paranite") is generally preferable. The diazobenzeneperchlorates mentioned are more sensitive than the fulminates, and gold fulminate is more sensitive than that of silver. However, very good results indeed can be secured by simply replacing 5 gr. of gray mercury fulminate with 4 gr. of silver fulminate in loading the detonator as just described,—using, say, silver fulminate the greater part of which will pass a 150 mesh screen and all of which will pass an 80 mesh screen. Thus loaded, this detonator will fire on 0.004–0.008 volts and 0.02–0.04 amp. in the transformer primary (without gap in the core 38) representing an expenditure of only 0.00032 to 0.00008 watts energy,—as compared with 0.042 watts required in the bridge wire of a special, extra-sensitive electro-thermal detonator heretofore devised for firing marine mines. With the gap 38*a*, the corresponding figures are 0.008–0.016 volts, 0.04–0.08 amp., and 0.00032–0.00128 watts.

For firing a detonator thus loaded with silver fulminate, a transformer with the large accumulative power of that shown in Figs. I and X (when constructed as specifically described above) naturally affords an extravagantly large factor of assurance; so that a transformer of lighter and more compact build could be employed. It is even possible, indeed, to fire this detonator from a sea battery with a relatively light built transformer having an open magnetic circuit, such as a commercial type of spark coil of suitable ratio. One such coil, for example, has a core consisting of a bundle (about ½ in. in diameter) of soft iron wires some 6 in. or 7 in. long; a primary of 0.299 ohms resistance consisting of 250 turns of No. 19 enameled copper wire wound on the core in a couple of layers, a secondary of 3340 ohms resistance consisting of some 16000 or 17000 turns of No. 41 enameled copper wire wound over the primary in about 40 layers of some 200–205 turns; and, consequently, a ratio of about 65 or more. Without vibrator or condenser, this induction coil will fire the detonator in question with about 0.096 volts and 0.32 amp. in its primary, and will do so from the copper pole device 26 in combination with an iron ship even with the interrupter of Fig. VIII in circuit. However, such a combination affords no factor of assurance, and will not repeat (owing to residual magnetism or choke effects in the core) after one operation until it had "rested" some 24 hours. Hence a transformer more effective than this coil must in practice be used with the silver fulminate loading.

With the Figs. I and X transformer, the Fig. VIII interrupter of either of the high resistance types described above will fire the Fig. XI detonator when loaded with either mercury fulminate or silver fulminate, under favorable conditions. However, the less sensitive Fig. VIII interrupter described above (opening when the sea-battery current is 0.23 amp.) is naturally better adapted for mercury fulminate, because when it acts it gives a greater margin or factor of assurance for the firing of the detonator when the interrupter opens. For silver fulminate, on the other hand, the more sensitive Fig. VIII interrupter described above (opening when the sea-battery current is 0.12 amp.) is better adapted, because it gives a greater margin or factor of assurance for the opening of the interrupter, as well as ample assurance of firing of the detonator when the interrupter opens. Using a transformer of the Fig. I and X type with core gap 38*a*, serially connected primaries 34, 34, and total primary resistance reduced to about 0.1 ohm by employment of larger wire in its primary windings, the silver fulminate detonator and the Fig. VIII interrupter opening when the sea-battery current is 0.12 amp.,—corresponding to a sea-battery voltage of 0.126 volt.,—a factor of assurance of about 100 per cent can be secured both for the opening of the interrupter and for the firing of the detonator when the interrupter opens. This, of course, is assuming the figures for sea-battery voltage mentioned above in connection with the copper pole element 26: under less favorable conditions, the factor of assurance will be correspondingly less.

In view of the much greater sensitiveness of my electrical impact detonator with silver fulminate to take the spark instead of mercury fulminate, it is of interest to note that while the flash points of both these substances are about 200° C., the silver fulminate is about three times as sensitive as the mercury fulminate by weight impact test.

The mine organization shown in Fig. XII differs from that of Fig. I in various particulars. The casing 10 extends inward in the mine shell 1 somewhat further than in Fig. I, serving as a guideway for movement of the booster can 11. Accordingly, it is the booster can 11 that is shifted by the lazy tong safety mechanism 15, while the detonator device 16*a* remains stationary. The accumulating means 20 is enclosed in a water tight

casing 21 which is mounted in an opening in the mine shell 1 as before, its end plate 23*a* being integral with its cylindrical wall or shell and with its flange 22. A detachable metal cover 25*a* at the inner end of the casing shell is shown as of a shallow cup shape. The accumulating means 20 is shown as comprising a transformer 33 and a circuit-breaker or interrupter 37 in series therewith, as in Figs. I and X. The detonator device 16*a* is shown mounted directly on the cover 25*a*, and is shown as of greater diameter than in Fig. I. The detonator-receiving tube 17*a* in the booster can 11 is flared at its mouth and closed at its end; it only extends into the booster can 11 far enough to accommodate the detonator device 16*a*.

Instead of being in the booster casing 10 and operated by the lazy tongs 15, the safety shunt for the supply circuit 28, 28 is arranged in the accumulator casing 21, and is operated by a separate hydrostatic diaphragm 12*x* of its own,—see Fig. XIII,—substantially similar to that for the booster can 11, but mounted on the cover 23*a*. Besides contact terminals 31*a*, 31*a* connected to the transformer primary leads 35, 35 within the casing 21, the supply circuit shunt comprises a metal bridge or shunt member 110 carried by a rod 111 extending down from the diaphragm 12*x* through a metal tube 112. As shown in Fig. XIII, the lower screw threaded portion 113 of the rod 111 extends loose through a hole in the bridge or shunt member 110, and the latter is urged upward against the contacts 31*a*, 31*a* by a helical compression spring 114 acting against an abutment formed by lock nuts 115, 115 adjustable on the rod end 113. To break the circuit, the member 110 is pushed away from the contacts 31*a*, 31*a* by a superjacent abutment member 116 on the rod portion 113. Preferably, the abutment 116 is normally a short distance away from the member 110, as shown in Fig. XIII, so as to assure that the member 110 shall ordinarily be firmly pressed against the contacts 31*a*, 31*a* by the spring 114, to afford an effective shunt.

Until after the mine is put overboard, the rod 111 and the diaphragm 12*x* may be held in their upper positions (as shown in Fig. XIII) by a helical compression spring 117 beneath the diaphragm and by a safety washer 118 (of common salt or other soluble material), seated in the upper end of the diaphragm housing 119. A screw threaded extension 120 of the rod 111 extends through a hole in the washer 118 and carries a nut 121 which bears on a metal washer 122 resting on the safety washer 118. Thus the mine remains harmless until the water has dissolved the safety washer 118 and the mine has reached a sufficient depth for the spring 117 to be overcome by the hydrostatic pressure on the diaphragm 12*x*. When this happens and the booster 11 is projected on the detonator device 16*a* by the safety mechanism 15, operating similarly, the mine is fully "armed" and ready to fire.

As compared with that shown in Fig. I, the arrangement of Figs. XII and XIII just described presents the advantage of considerable shortening of the high voltage secondary leads 18, 18. It also avoids all necessity for flexure of these leads 18, 18, or for bringing them outside the casing 21.

As shown in Fig. XIII, the bottom cover 25*a* of the transformer casing 21 is suspended from its top cover 23*a* by four rods 125 screwed into said cover 23*a*. Sleeves 126 are screwed on the lower ends of these rods 125, and bolts 127 extend through the cover 25*a* and take into the sleeves 126. A gasket 128 is interposed between the lower edge of the casing shell and the shouldered upper margin of the cover 25*a*, to make a tight joint. As shown in Fig. XIII, there is a circular insulating diaphragm 129 in the lower end of the casing shell, just above the upper edge of the cover 25*a*. This diaphragm 129 is apertured for the passage of the sleeve 126 and the tube 112, as well as for the legs of the transformer core 38 and the various electrical connections. As will be seen from comparison of Figs. XIII and XIV, the transformer 33 and the interrupter 37 are arranged centrally in the casing 21, in the midst of the four rods 125, with the transformer windings 34 and 36 above the diaphragm 129, and the interrupter 37 below it. Preferably, the interior of the casing 21 above the diaphragm 129 is completely filled with an insulating compound, poured in molten and allowed to solidify around the transformer parts.

The transformer 33 is of the same general character and form as that shown in Fig. X, though arranged with the primary and secondary windings 34, 36 on its elongated vertical legs instead of on its short horizontal legs (giving greater efficiency), and with a gap in the bottom horizontal member of its core 38, instead of in one of its vertical legs. The primary coils 34, 34, on the two legs are connected in series between the terminals 27, 27 by the leads 35, 35, with the interrupter 37 interposed in one of these leads. The sectionalization of the secondary windings 36 to minimize voltage difference and risk of short circuit between adjacent convolutions is carried much further than in Fig. X; i. e., as shown there are nine individual coils 36*a* on each leg of the core 38, instead of two as in Fig. X. Each of these coils 36*a* starts at a point on the outside diameter of the primary coil 34 and is wound outward in successive layers. Adjacent individual coils 36*a* on each transformer leg are connected in series, and the sets on the two legs are likewise serially connected between the secondary leads 18, 18. The core 38 may be of such materials

as mentioned in connection with Fig. X, and preferably of similarly laminated construction. It may be made of "Apollo" silicon transformer steel, #29 gauge, with a window about 1⅞ in. by 7 in., and may approximate some 19 pounds in total weight. The primary windings 34 may consist of No. 11 copper wire, with cotton enamel insulation, wound in 120 turns per leg, so that the total primary turns amount to 240,—the total length of wire being such as to give the primary a resistance of 0.26 ohm. Each secondary coil 36*a* may consist of No. 36 copper wire, with enamel insulation, wound in 3500 turns per individual coil 36*a*,—making 31,500 turns for each transformer leg, and a total of 63,000 turns for the secondary winding.

In Figs. XII–XIV, various parts and features have been marked with the same reference characters as in Figs. I, V–VIII, and X, as a means of dispensing with repetitive description.

From the foregoing description and Figs. XIII to XVII, it will be seen that the transformer resembles those of Figs. V, VI and VIII in having a gap in the core. In the present instance, the interrupter 37 resembles those shown in Figs. V and VI in being operated by the magnetic flux at the core gap, instead of by separate coils like that of Fig. VIII. From the description which follows, it will be seen that this interrupter 37 also presents inertia features analogous to those of the interrupter shown in Fig. VII.

Referring first to Fig. XV, it will be seen that the interrupter 37 shown in Figs. XIII to XVII comprises a fixed silver point contact 130 carried by an adjusting screw 131 in a terminal bracket 132, and a movable contact member in the form of a flexible steel spring 133. This spring 133 is fixed at one end to a terminal bracket 134, and carries at its other (free) end a silver contact 135 riveted into a hole therein. The resilience of the spring 133 normally holds the contacts 134, 135 together with a degree of pressure determined by the adjustment of the screw 131. For operating the movable contact member 133, there is a rocker 136 mounted on a rotatable spindle 137 (of high-tempered tool steel) whose conical ends (Figs. XIV) turn in conical bearing seats in brass pieces 138 (Figs. XIV and XVII) mounted on insulating members 139, 139 spanned between the lower ends of the legs of the transformer core 38 at either side, and secured by bolts 140, 140 through the core legs. As shown in Fig. XIV, insulating spacing blocks 141 are interposed between the transformer core legs and the members 139, to give room for the parts hereinafter described. As best shown in Figs. XIV and XVII, the rocker 136 comprises a pair of magnetic core pieces or members 143, 143 connected by aluminum side plates 144, 144 clamped against their ends by aluminum bolts 145, 146. The spindle 137 extends through and is fastened in the side plates 144, 144. The rocker 136 is preferably balanced about its axis at 137, so as to be in substantially neutral equilibrium, without intrinsic bias toward any particular position. As shown in Figs. XIV and XV, studs 148, 148 fixed in the corresponding rocker side plate 144 extend out at either side of the corresponding brass piece 138 (with sufficient clearance to permit ample oscillatory movement of the rocker) through an opening in the corresponding insulating member 139, and carry a metal disc 150 with a crank arm 151 for actuating the movable contact member 133. As indicated in Figs. XIV and XVI, a metal disk 152 is similarly mounted on the other rocker side plate 144 in a similar opening in the other insulating member 139, for a purpose to be hereinafter described. Between the movable core pieces 143, 143 is a stationary magnetic filler piece 147, held in place by steel bolts 153, 153 that extend through the insulating members 139, 139 and also serve to hold in place the brass blocks 138, 138, As shown in Fig. XVII. there are insulating sleeves 154, 154 around the bolts 153, 153 in the holes provided for the latter in the filler piece 147.

As shown in Figs. XV–XVII, each of the movable core pieces 143, 143 is of a curved wedge-like or half-crescent-like cross-section The outer sides of these movable core pieces 143, 143 and the corresponding surfaces of the legs of the transformer core 38 are curved concentrically with the axis of rotation 137 of the rocker 136. The inner surfaces of the movable core pieces 143, 143 and the corresponding surfaces of the fixed filler piece 147 are curved in correspondence with one another, though not concentrically with the axis 137. The clearance between the core piece 143 and the legs of the core 38 is made as small as possible without risk of rubbing; and the direction of rotation of the rocker 136 to open the circuit is clockwise (as indicated by the arrows in Figs. XIII, XVI, and XVII), so that in the opening movement the gaps between the core pieces 143, 143 and the filler 147 are reduced,—thus increasing the magnetic pull and the vigor of the opening movement. The angle of divergence between the inner and outer surfaces of the core pieces 143, 143 is such that the latter will not wedge in the gap between the filler piece 147 and the legs of the core 38. Preferably, the core pieces 143, 143 and the filler 147 are of the same material and construction as the transformer core 38, with their laminations extending parallel with those of the core 38. If desired, the corners of the movable core pieces 143, 143 may be rounded, to reduce the magnetic flux at their points as well understood.

While various means might be employed

to keep the operating rocker 136 normally in the inactive position shown in Fig. XV, so as to permit the primary circuit to remain closed, I prefer to do this in such a way as to oppose a definite initial resistance to movement of the rocker 136, so as to assure accumulation of sufficient energy to fire before the interrupter 37 operates. In Figs. XIII, XIV, and XVI, I have shown means for doing this magnetically. For this purpose, the bolts 153, 153 above mentioned are made permanent magnets, with north and south poles N and S projecting from the insulating member 139 at the opposite side of the device from the interrupter members 130, 133. These magnets 153, 153 act on a diametral stop member 155 carried by the rocker 136, consisting of a gold plated spring steel strip securely mounted in a four pronged clip 156 carried by the disc 152 above mentioned. As shown, adjustable screw stops 157, 157 are provided in the magnets 153, 153, for adjusting the exact distance of the ends of the stop member 155 from the north and south poles and the strength of the magnetic pull that must be overcome in order to open the circuit.

Normally, the magnets hold the stop member 155 against the stops 157, 157 with the contact-operating arm 151 in the position shown in Fig. XV,—separated from the movable contact member 133 by a slight clearance. When, however, sea battery current flowing through the transformer primary 34 has built up the magnetic field affecting the movable core pieces 143, 143 to a value corresponding to an amply sufficient accumulation of energy in the system for firing the detonator device 16*a*, the pull due to this field overcomes the pull of the permanent magnets 153, 153 and rotates the rocker 136 clockwise (Figs. XIII, XVI, and XVII). The clearance between the arm 151 and the movable contact member 133 allows this movement to gain substantial momentum before the arm strikes the member and opens the circuit, thus assuring a definite, quick break and giving the maximum voltage in the secondary circuit to fire the device 16*a*. As soon as the circuit is thus opened, the magnetic field of the transformer fades, and the magnets 153, 153 acting on the member 155 return the rocker 136 to its initial position, allowing the contacts to reclose the circuit.

This action is repeated as long as current continues to flow in the primary circuit.

I ordinarily prefer to adjust this interrupter to open on a sea battery current of from 0.22 to 0.24 amp. With a sea battery voltage of 0.3 volt. and an internal resistance of 0.32 ohm in the sea battery, the device will operate in about 0.086 sec. after contact is made with the antenna 7 or 7*a*.

The detonator device 16*a* is enclosed in a tubular casing 160 of rubber or other flexible insulating material, closed at its lower end and provided with a flange 161 at its upper end. The lower end of this casing 160 is protected by a tight fitting sheet metal ferrule 162, and its upper portion by a sleeve 163, flanged at its upper end in conformity to the flange 161. The upper portions of the casing 160 and the sleeve 163 are enlarged to take the lower end of an insulating block 165, which is socketed to take a metallic inner detonator casing 166. The upper portion of the insulating block 165 is housed in a downward extension 167 of the cover 25*a*, and is clamped firmly in place on an external flange 168 in said extension 167 by a nut 169 screwed on a threaded portion of said block 165. The casing 160 and its protecting sleeve 163 are clamped against the lower end of the cover extension 167 by a gland nut 170.

The inner detonator casing 166 contains a pair of counterpart detonators 173, 173, which are serially connected between the secondary leads 18 by a short lead 174. These detonators 173, 173 are clamped in place in the block 165 by screws 175, 175 extending through a separate piece 176 which forms one wall of the socket in the block 165.

As will be seen from Figs. XIII and XVIII, the secondary leads 18, 18 are connected to the detonators 173, 173 at their lower ends, extending up through passages 177, 177 in the block 165 that open laterally from the upper portion of said block into the interior of the downward extension 167 of the cover 25*a*.

The construction of one of the detonators 173 is illustrated in Figs. XIX and XX. As will be seen from these figures, this detonator 173 is a spark gap detonator of the general type illustrated in Fig. XI, but of somewhat different construction. Its sparking terminals 180, 180 consist of semicircular copper pieces set in a sleeve of insulating material 181 (about 1/8 in. in internal diameter, and preferably made of pure, uncolored bakelite), and separated by a sheet of insulating material 182, preferably mica. As shown in Figs. XIX and XX, the insulating sheet 182 is set into a slot in the end of the insulating sleeve 181, and extends diametrically clear across it from one outer surface to the other, and well below the terminals 180, 180. The secondary leads 18, 18 are soldered or welded in grooves in the outer sides of the terminals 180, 180, and extend down through external lateral grooves in the insulating piece 181. With the insulating sheet 182 (preferably of 4 mil. thickness) between them, the terminals 180, 180 fit tightly in the sleeve 181, so as to be held securely against displacement. Preferably, the mica sheet 182 may consist of a couple of separate laminæ, aggregating 4 mils. in thickness. After assembly of these parts, additional sheet mica is pressed into

the cracks between the mica sheet 182 and the sides of the slot in the wall of the sleeve 181, so as to fill them completely. Finally, the upper ends of the parts are filed or ground down to give them a common true, flush upper surface, and carefully brushed off to remove all small particles of copper from the mica-filled slot between the terminals 180, 180. This is checked by examination under a magnifying glass. The assembly is then inserted in a thin-walled sheet metal (copper) sleeve 183 having a closed bottom apertured for passage of the leads 18, 18. A few drops of shellac or other cement may preferably be placed in the bottom of the sleeve 183 before the insertion of the terminal assembly, to hold fast the cambric coverings 101, 101 of the leads 18, 18. The sleeved assembly is then inserted in a copper tube 185 having its bottom apertured for passage of the cambric-covered leads 18, 18.

In preparation for charging, the empty detonators constructed as above described are dried in an oven, at a temperature of from 80° to 90° F., for at least an hour. Standard (Hercules Powder Company) fulminate of mercury, 98 per cent pure, is carefully dried and sifted so as to pass #40 mesh bolting cloth and be held on #72 mesh cloth. The sifted material is then further dried in an oven or a desiccator, at from 80° to 90° F., for at least four hours, and kept at that temperature until required for loading. The charge in contact with the terminals 180, 180 consists of 0.2 grams of this sifted fulminate: it is filled in and then pressed with a loading pin 0.252 in. in diameter, while the detonator is held in a suitable jig. It is pressed home with a pressure of 250 pounds on the loading pin, the pressure being allowed to act for about ten seconds. The load is relieved at least once during this period, to make sure that the fulminate is fully compressed and driven into all crevices around the copper terminals. For the main charge may be used standard Hercules fulminate of mercury, unsifted, but dried for at least four hours at from 80° to 90° F. The main charge is loaded into the detonator on top of the priming charge 187 in three successive one-gram lots, 188, 188, 188, each separately pressed home with 250 pounds on the loading pin. The charge is then sealed into the detonator tube 185 by a tight-fitting copper capsule 190, which is pressed home with a loading pin 0.240 in. in diameter and a load of 250 pounds. This capsule 190 serves to hold the fulminate charge firm in the detonator tube 185, preventing access of moisture and reinforcing the tube where it is to be held in the clamps as before described. As shown, the tube 185 has an annular ridge or bead 191 near its upper end, to assist in securing it in the clamps. After loading, the detonator is tested with direct current, under a voltage of 500 volts, to make absolutely sure that there is no shortage at the 4 mil. gap between the terminals 180, 180. If a delayed action is desired in the detonator, it can be secured by a supplemental charge of black powder loaded between the priming charge of fulminate 187 and the first one-gram loading 188 of the main charge.

With the transformer 33 described in connection with Figs. XII–XIV, one of the detonators 173 constructed as described above will fire on a current of about 0.2 amp. in the transformer primary 34 when the primary circuit is broken quickly by hand. The two detonators 173, 173 in series will fire on a current of about 0.25 amp. in the transformer primary 34 when the circuit is broken by hand. If, therefore, the interrupter 37 of Figs. XIII–XVII be set to open at 0.22 to 0.24 amp. current in the transformer primary 34, as described above, there is a very ample factor of assurance for the firing of both detonators, since this interrupter gives a very much more effective break than any that can be produced by hand. As, moreover, the total resistance of the primary circuit (exclusive of the sea battery) of the Fig. XII system is altogether just about 0.3 ohm, and the sea battery current through this resistance will rarely fall below 0.3 amp. under even the most unfavorable conditions (e. g., such as represented by the mouth of a tidal river in flood), there is a very good factor of assurance for the opening of the interrupter when a vessel strikes the mine antenna. The use of two detonators 173, 173 in series gives a very greatly increased factor of assurance for the firing of the mine, because even though one detonator in a hundred should be prevented from firing by a shortage of the circuit therein (the characteristic occasional defect of detonators built under careful inspection), the chance of both in any given mine being both defective would be only about one in ten thousand.

I do not herein claim firing a bridge-wire detonator from a sea battery directly in circuit therewith, without either accumulation or voltage transformation of sea battery energy intermediate sea battery and detonator; but I do claim:

1. The method of firing a marine mine detonator directly with the energy of a sea battery, which comprises accumulating energy from the sea battery intermediate the same and the detonator for a period of time before passing such energy to the detonator.

2. The method according to claim 1, wherein the sea battery energy required to fire the detonator is accumulated, as set forth in claim 1, during the functional period of the mine.

3. The method of firing a high-voltage marine mine detonator according to claim 1, wherein the sea battery energy is accumulated, as set forth in claim 1, under the char-

acteristic low voltage of the sea battery and discharged at the required firing voltage of the detonator.

4. The method of firing a quick-acting marine mine detonator according to claim 1, wherein the sea battery energy is accumulated, as set forth in claim 1, substantially throughout the functional period of the mine, and discharged in a rush of current through the detonator.

5. The method according to claim 1, wherein the sea battery energy is accumulated, as set forth in claim 1, by progressive self-limiting impoundment, and the accumulation thus automatically discharged into the detonator when sufficient to fire it.

6. The method according to claim 1, wherein the sea battery energy is accumulated, as set forth in claim 1, by progressive self-limiting impoundment during the functional period of the mine, and the accumulation thus automatically discharged into the detonator when sufficient to fire it.

7. The method of firing a quick-acting, high-voltage marine mine detonator according to claim 1, wherein the sea battery energy is accumulated, as set forth in claim 1, under the characteristic low voltage of the sea battery substantially throughout the functional period of the mine, and discharged in a rush of current at the required firing voltage of the detonator.

8. The method of firing a quick-acting, high-voltage marine mine detonator according to claim 1, wherein the sea battery energy is accumulated, as set forth in claim 1, under the characteristic low voltage of the sea battery, by progressive self-limiting electro-magnetic impoundment, substantially throughout the functional period of the mine, and the accumulation is thus automatically discharged in a rush of current at the required firing voltage of the detonator when sufficient to fire it.

9. The method according to claim 1, wherein the voltage of the energy from the sea battery is raised, and the accumulated energy sparked into impact on dense detonating material.

10. The method of firing a marine mine detonator directly with the energy of a sea battery, which comprises elevating the energy of the electric current furnished by the sea battery at its characteristic low voltage to a high voltage for passage through the detonator.

11. The method according to claim 10, wherein the high voltage energy is sparked into impact on dense detonating material.

12. The method of firing a marine mine detonator directly with the energy of a sea battery, which comprises converting the energy of the electric current from the sea battery to a static form, and reconverting it into a flow of current through the detonator at higher voltage.

13. The method according to claim 12, wherein the reconversion and passage of energy to the detonator is automatically determined by the amount of static energy.

14. The method of firing a marine mine detonator directly with the energy of a sea battery, which comprises creating a magnetic field with the electric current from the sea battery under its characteristic low voltage, and converting the energy of such field into electric current through the detonator at a higher voltage.

15. The method of firing a spark-gap marine mine detonator directly with the energy of a sea battery, which comprises building up a magnetic field with the electric current from the sea battery under its characteristic low voltage, and suddenly releasing the energy of such field into the detonator as a rush of current at high voltage.

16. Firing gear for a marine mine comprising a sea battery device, a detonator, and means for accumulating energy from the sea battery intermediate the same and the detonator for a period of time, and thereafter delivering to the detonator the sea battery energy thus accumulated.

17. Firing gear for a marine mine comprising a sea battery device, a detonator, and means for progressively and self-limitingly impounding energy from the sea battery until the accumulation discharges into and fires the detonator.

18. Firing gear for a marine mine comprising a sea battery device, a quick-acting detonator, electro-magnetic means for accumulating energy from the sea battery, and means for discharging the accumulated sea battery energy in a rush of current through the detonator.

19. Firing gear for a marine mine comprising a sea battery device, a high-voltage detonator, and means for raising the voltage of and accumulating energy from the sea battery, so that the detonator may be fired directly by discharge of such accumulated energy thereinto.

20. Firing gear for a marine mine comprising a sea battery device, a high-voltage detonator, and voltage-raising electromagnetic means for progressively and self-limitingly impounding energy from the sea battery until the accumulation discharges into and fires the detonator.

21. Firing gear for a marine mine comprising a sea battery device, a spark-impact detonator with detonating material dense in its gap, and means for accumulating electrical energy from the sea battery and discharging the accumulation in a rush of current through the detonator.

22. Firing gear for a marine mine comprising a sea battery device, a quick-acting

high-voltage detonator, and means for accumulating the required firing energy from the sea battery and thereafter discharging the accumulation in a rush of current through the detonator at effective firing voltage.

23. Firing gear for a marine mine comprising a sea battery device, and means for combining therewith the hull of a vessel to be attacked to form a complete sea battery; a spark-impact detonator; and a transformer with low voltage primary in circuit with said sea battery device and said combining means, and high voltage secondary in circuit with the detonator; so that sea battery energy in the transformer may be discharged into the detonator to fire the same when the primary circuit of the complete sea battery formed as aforesaid is broken.

24. Firing gear for a marine mine comprising a sea battery device; a quick-acting high-voltage detonator; and a low-power transformer of high accumulative capacity with low voltage primary in circuit with said sea-battery device, and high voltage secondary in circuit with the detonator, and a gap in its core.

25. Firing gear for a marine mine comprising a source of energy of such low power capacity as a sea battery, a spark-impact detonator with detonating material dense in its gap, a transformer with low voltage primary in circuit with such source and high voltage secondary in circuit with the detonator, and means for breaking the primary circuit after the accumulation of energy from said source in the system suffices to fire the detonator.

26. Firing gear for a marine mine comprising a sea battery device; a detonator; and self-limited impounding means for the sea battery energy, of capacity to accumulate the amount of sea battery energy required for firing the detonator and to discharge such accumulated sea battery energy into the detonator within the allowable functional period of the mine.

27. Firing gear for a marine mine comprising a sea battery device; a quick-acting detonator; storage means for the sea battery energy, of capacity to accumulate the amount required for firing the detonator within the allowable functional period of the mine; and means for discharging the accumulation of sea battery energy into the detonator.

28. Firing gear for a marine mine comprising a sea battery device; a quick-acting high-voltage detonator; electromagnetic means for accumulating from the sea battery, under its characteristic low voltage and within the allowable functional period of the mine, the amount of energy required to fire the detonator; and means controlled by such accumulation for discharging the accumulated energy in a high-voltage rush of current through the detonator.

29. Firing gear for a marine mine comprising a sea battery device; a high voltage detonator; a transformer with low voltage primary in circuit with said sea battery device, and high voltage secondary in circuit with the detonator; and an interrupter in the primary circuit responsive to the current therein; the external resistance in the primary circuit being sufficiently above the normal internal resistance of the sea battery to prevent material diminution of the sea battery current by polarization.

30. Firing gear for a marine mine comprising a sea battery device, a detonator, and means for elevating to a high voltage and delivering to the detonator the energy of the electric current furnished by the sea battery.

31. Firing gear for a marine mine comprising a sea battery device, a detonator, and means for converting the energy of the electric current from the sea battery to a static form and reconverting it into a flow of current through the detonator at higher voltage.

32. Firing gear for a marine mine comprising a sea battery device, a detonator, means for converting the energy of the electric current from the sea battery to a static form, and means controlled by the amount of static energy for reconverting it into a flow of current through the detonator.

33. Firing gear for a marine mine comprising a sea battery device, a detonator, means for creating a magnetic field with the electric current from the sea battery under its characteristic low voltage, and means controlled by the strength of such field for reconverting its energy into electric current through the detonator.

34. Firing gear for a marine mine comprising a sea battery device, a spark-impact detonator with detonating material dense at its spark-gap, and means for elevating to a high voltage and passing through the detonator the energy of the electric current from the sea battery.

35. Firing gear for a marine mine comprising a sea battery device; a spark-gap detonator comprising terminals with an intervening layer of insulation, all substantially flush with one another in a common plane, and detonating material against the terminals and their intervening insulation; and means for elevating to a high voltage and passing through the detonator the energy of the electric current from the sea battery.

36. Marine mine firing gear comprising a sea battery device; means for elevating to high voltage the energy of the electric current furnished by the sea battery; and a plurality of spark-impact detonators connected in series to receive the high voltage energy from said means.

37. Firing gear for a marine mine comprising a sea battery device; a detonator; a transformer with primary in circuit with

said sea battery device, and secondary in circuit with the detonator, and an interrupter for the primary circuit responsive to the magnetic flux in the transformer core.

38. Firing gear, of the character described, for a marine mine, comprising a sea battery device; a detonator; a transformer with primary in circuit with said sea battery device and secondary in circuit with the detonator, and a gap in its core; and an interrupter for the primary circuit comprising a movable flux-carrying member responsive to the core flux across said gap.

39. Firing gear, of the character described, for a marine mine, comprising a sea battery device; a detonator; a transformer with primary in circuit with said sea battery device and secondary in circuit with the detonator, and a gap in its core; and an interrupter for the primary circuit comprising a pair of cooperating flux-carrying members responsive to the core flux across said gap, and a flux-carrying filler in said gap between said members.

40. Firing gear, of the character described, for a marine mine, comprising a sea battery device; a detonator; a transformer with primary in circuit with said sea battery device and secondary in circuit with the detonator, and a gap in its core; and an interrupter for the primary circuit comprising a flux-carrying filler in said gap with oppositely tapering clearances between it and the transformer core, and a rocker for opening the circuit comprising cooperating flux-carrying wedges in said clearances.

41. Firing gear, of the character described, for a marine mine, comprising a sea battery device; a detonator; a transformer with primary in circuit with said sea battery device and secondary in circuit with the detonator; and an interrupter for the primary circuit comprising a movable flux-carrying member responsive to the transformer core flux, and permanent magnetic means for normally holding said movable member in inactive position and opposing a definite resistance to its initial opening movement.

42. Firing gear, of the character described, for a marine mine, comprising a sea battery device; a detonator; a transformer with primary in circuit with said sea battery device and secondary in circuit with the detonator; and an interrupter for the primary circuit comprising relatively movable contacts, a movable flux-carrying member responsive to the transformer core flux, with a lost motion connection for separating the contacts, and permanent magnetic means for normally holding said movable member in inactive position and opposing a definite resistance to its initial movement.

43. Marine mine firing gear comprising a detonator and a booster shiftable relative to one another to arm the mine; an electric circuit for firing the detonator, with a safety shunt to prevent premature firing; and means for breaking the shunt controlled independently of the shifting of the booster as aforementioned.

44. The combination with a marine mine case, a sea battery device, and a detonator for the mine; of converting means for the energy of the sea battery current interposed between the sea battery and the detonator, with a casing for said means within the mine case; a safety shunt for said converting means within its casing, to prevent premature firing; and means automatically responsive to the mine environment for breaking said shunt.

45. The combination with a marine mine case and a sea battery device of converting means for the energy of the sea battery current, with a casing for said means within the mine case; and a detonator for the mine mounted on the casing of said converting means to receive energy therefrom.

46. The combination with a marine mine case and a sea battery device of converting means for the energy of the sea battery current, with a casing for said means within the mine case; a booster shiftable toward said casing, with means automatically responsive to the mine environment for shifting it; and a detonator mounted on the casing of said converting means to receive energy therefrom, and in position to fire the booster after the same has been shifted as aforesaid.

47. Marine mine firing gear of the character described, firing electrically by contact with a ship's hull more prolonged than a mere instantaneous touch, and comprising a contact antenna of subdivided distributed buoyancy floating loose substantially at and below the surface of the water, so as to be drawn into prolonged contact with a passing surface ship.

In testimony whereof, I have hereunto signed my name at Philadelphia, Pennsylvania, this 13th day of January, 1926.

JOHN K. M. HARRISON.