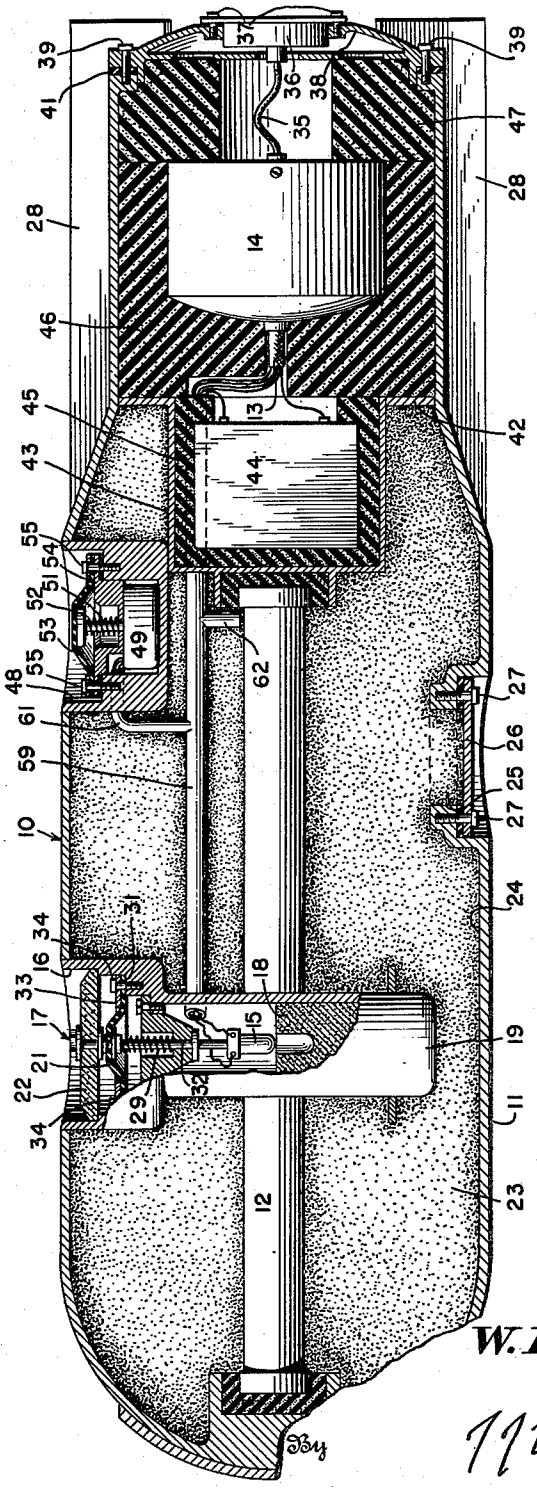
Nov. 28, 1961 W. R. MALTBY 3,010,395

MINE FIRING MECHANISM

Filed Oct. 19, 1943 3 Sheets-Sheet 1

FIG. 1.



Inventor
W. R. Maltby

By

Attorney

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MINE FIRING MECHANISM

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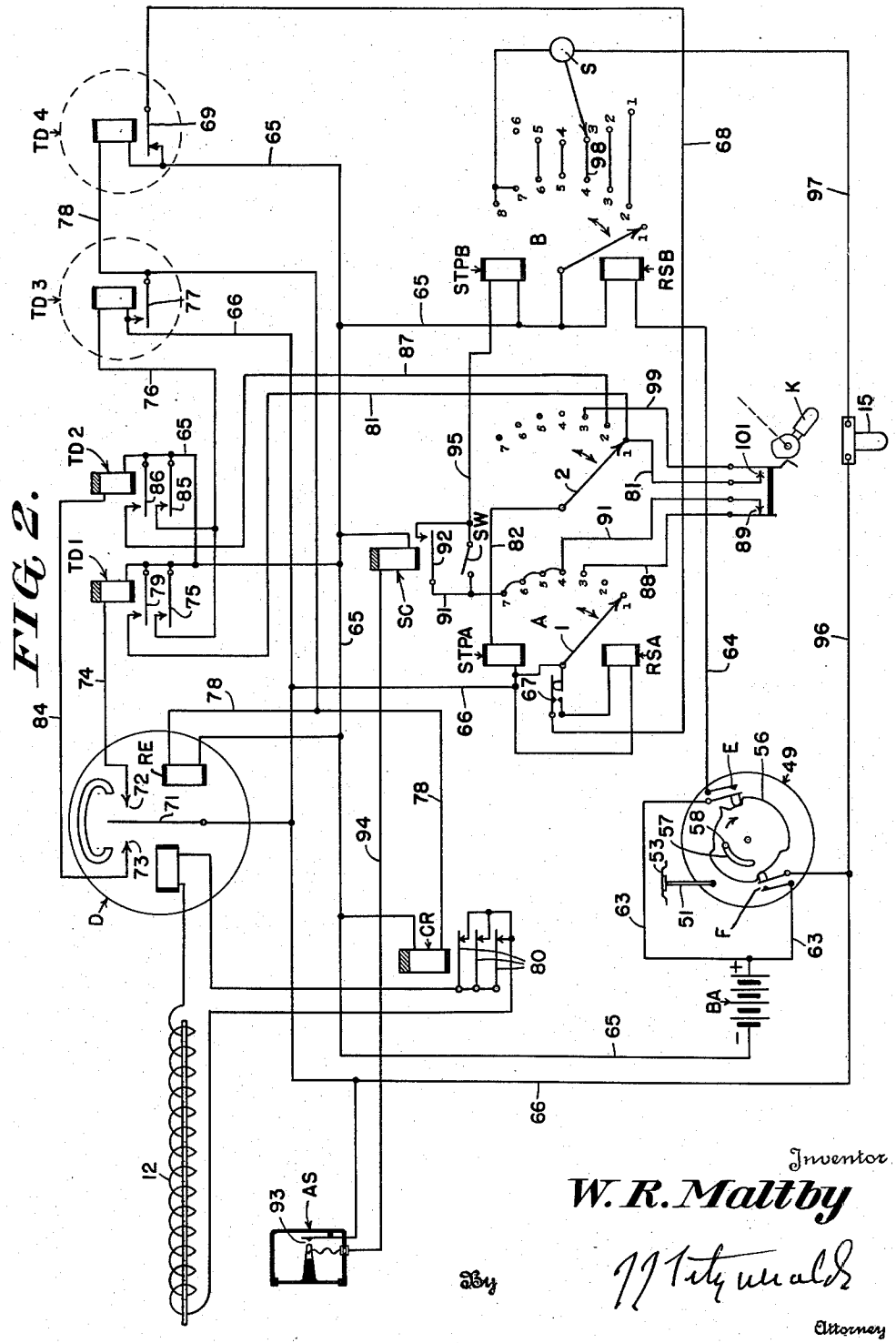

FIG. 2.

Inventor
W. R. Maltby
By
Attorney

Nov. 28, 1961 W. R. MALTBY 3,010,395

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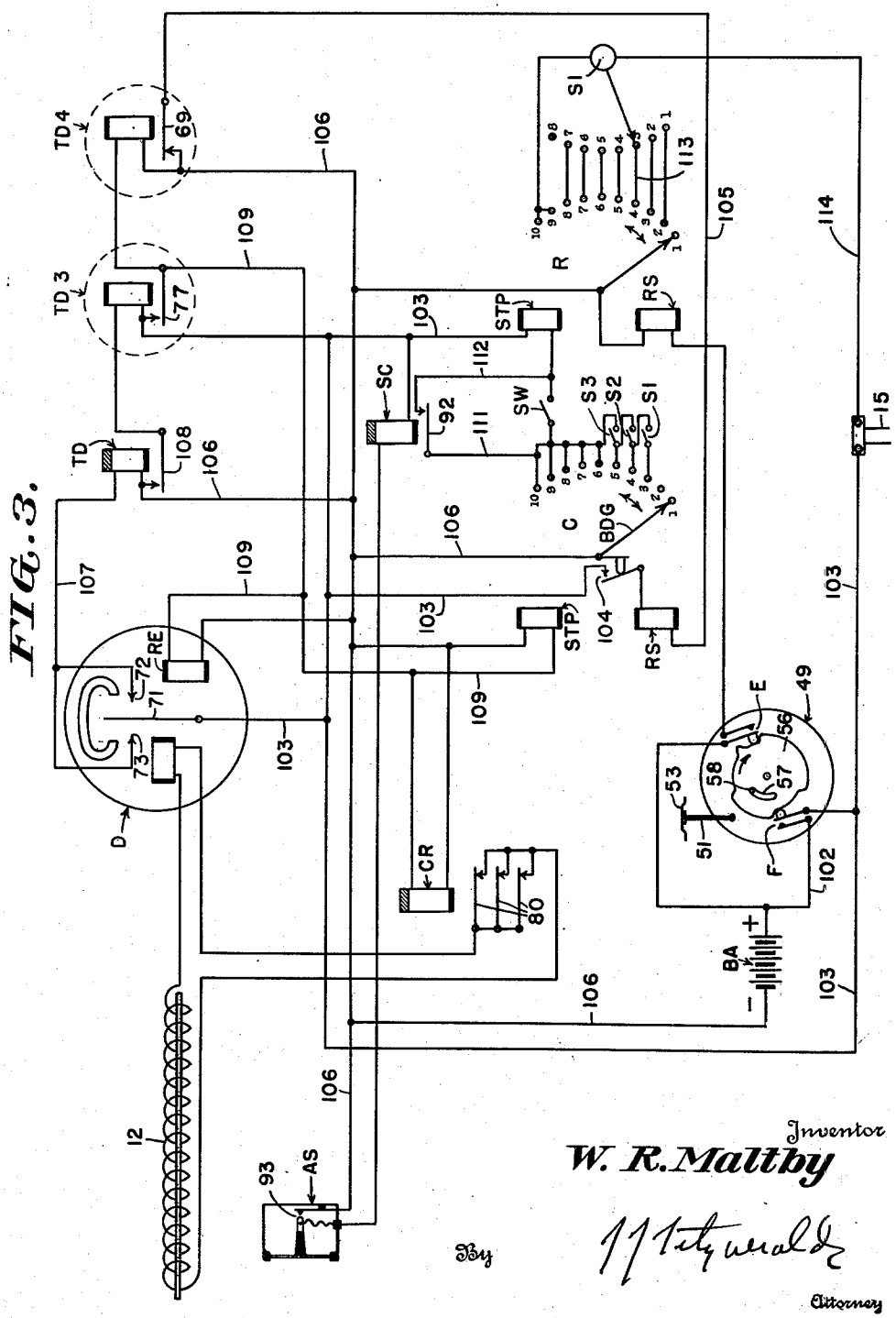
FIG. 3.



Inventor

W. R. Maltby

By

Attorney

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3,010,395

MINE FIRING MECHANISM

Wilson R. Maltby, Arlington County, Va.

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(Granted under Title 35, U.S. Code (1952), sec. 266)

This invention relates to mine firing mechanisms of the electromagnetic induction type in which a changing magnetic field is employed to fire the mine in the event that the changing magnetic field is accompanied by an acoustic signal of sufficient strength to operate an acoustically controlled switch and in which the possibility of detonation by a mine sweeping operation is extremely remote. More specifically, the present invention contemplates the provision of means for detecting at intervals a changing magnetic field adjacent the mine in which the magnetic field continues to change over a predetermined period of time after a change in the field has been detected and in which the mine is fired selectively in accordance with the changing nature of the magnetic field detected by the device and in accordance with signals detected by an acoustic device in predetermined time spaced relation with respect to the detection of the changing magnetic field.

In devices of this character heretofore proposed in which a changing magnetic field is employed for firing a submarine mine, it has been found that an impulse of heavy current applied to an electrical conductor attached to a vessel moving within the vicinity of the mine and insulated from the sea water within which it is immersed except at the furthermost end thereof, causes a magnetic field to be set up within the water about the conductor of sufficient strength to explode the mine. This method of detonating a mine is referred to herein as mine sweeping, the electrical conductor employed for the purpose is also referred to herein as a sweep wire, and the vessel as a mine sweeper. Thus with the types of submarine mines heretofore devised employing firing mechanisms controlled by changes in the terrestrial magnetic field, a mine field may be swept and the mines thereof detonated by a mine sweeper systematically cruising over the field and applying current impulses at periodic intervals of time to a sweep wire trailing from the vessel.

In order to establish an effective magnetic field of considerable size about the sweep wire, it has been found necessary to employ an electric current therein of such strength that the source of electrical energy is only sufficient to allow the current to be applied to the sweep wire periodically for short intervals of time.

In the system of the present invention the mine firing mechanism includes certain selecting and time delay elements in combination with the magnetic field sensing device in which the mine firing mechanism performs a fractional part of a cycle of operations in response to changes in the magnetic field which continue to change for a predetermined period of time after a change in the field has been detected such, for example, as the changes of a magnetic field caused by the movement of a steel vessel, or any vessel having a considerable amount of magnetic material thereof, past the mine disposed adjacent the path of travel of the vessel and in which the aforesaid cycle of operations is completed in response to signal indications of predetermined strength received by an acoustic detecting device in communication with the surrounding water. The acoustic detecting device is provided with switching means for closing an electrical control circuit as the device operates. It will be readily understood that the changing condition in the magnetic field detected by the magnetic detecting device in response to the approach of a vessel within the vicinity of the mine is a prerequisite to the firing of the mine and causes the mine firing mechanism to perform said fractional portion of a cycle of operations while the ship's propeller is moving toward the mine. The signals received by the acoustic detecting device, therefore, are increasing in strength while the mine firing mechanism is performing said fractional portion of a cycle of operations. At the completion of the performance of the fractional portion of a cycle of operations, the acoustic signal received from the vessel has reached such proportions as will cause the acoustic detecting device to respond thereto sufficiently to close an electrical circuit and thereby apply a control to the mine firing mechanism sufficient to cause the mine firing mechanism to complete the cycle of operations.

In the case of a changing magnetic field set up by a current impulse flowing within a sweep wire towed by a mine sweeper, the acoustic signal received from the mine sweeper decreases while the mine firing mechanism is performing a fractional part of a cycle of operations in response to the changing magnetic field detected by the field detecting means for the reason that the sweep wire is towed through the water astern the mine sweeper and the mine sweeper, therefore, is moving away from the mine while the changing magnetic conditions are detected and when the fractional portion of the cycle of operations of the mine firing mechanism is completed, the vessel has moved a sufficient distance past the mine such that the acoustic signal received therefrom is of insufficient strength to actuate the acoustically controlled switch to circuit closing position and the mine, therefore, is thus rendered immune to destruction by a mine sweeping operation, as will more clearly appear as the description proceeds.

Furthermore, the present invention contemplates the provision of a mine firing control mechanism in which, if desired, the signals respectively corresponding to changes in the magnetic field detected by the magnetic field detecting means are required to be received in a predetermined plurality sequence as a prerequisite to firing the mine. In the preferred embodiment of the invention a predetermined number of sets of magnetic signals of predetermined polarity corresponding respectively to a predetermined number of vessels moving past the mine accompanied by acoustic signals of predetermined strength occurring in predetermined time spaced relation with respect to the magnetic signals are required to arm the mine, each of the sets of signals corresponding respectively to the movement of a vessel past the mine. When a sufficient number of vessels have moved past the mine causing the mine to be armed, the movement of the next succeeding vessel into the vicinity of the mine causes the mine to explode beneath a vulnerable portion of the vessel. Furthermore, the mine is rendered absolutely safe for transportation and handling and becomes active only after being launched by reason of the provision of certain safety control devices and circuits therefor, the operation of which will become more clearly apparent as the description proceeds.

One of the objects of the present invention is to provide a new and improved magnetic influence mine firing mechanism, selectively responsive to a changing magnetic field and to an acoustic signal received through the surrounding water, of simple and rugged construction which will be economical to manufacture and which possesses the desired qualities of reliability and efficiency in use and operation.

Another object is to provide a mine firing device of the above general character having new and improved means for detecting changes in the magnetic field adjacent thereto periodically during successive predetermined periods of time after each change in the magnetic field has been detected and detonating the mine when a predetermined number of changes in the magnetic field has been detected.

Another object is to provide a mine firing device con-

trolled by changes in the magnetic field detected at intervals in which the mine is fired selectively in accordance with the strength of a signal received through the surrounding water by an acoustic detecting device when a predetermined number of changes in the magnetic field has been detected in predetermined time spaced relation.

Another of the objects resides in the provision of new and improved means responsive to a changing magnetic field for firing a submarine mine in proximate amidship relation to a vessel moving past the mine.

Another of the objects resides in means in which different portions of the magnetic signature of a vessel are employed for firing a submarine mine selectively under control of an acoustic signal received from the vessel.

Another object is the provision of new and improved means for arming a submarine mine under control of a predetermined number of vessels moving past the mine.

Another object is the provision of means responsive to a changing magnetic field for comparing each of the magnetic changes therein with a plurality of uniform intervals of time respectively and selectively firing an explosive in accordance with the results of such comparison.

Another of the objects resides in the provision of means for registering signal indications representing changing conditions of a magnetic field detected at intervals and for registering in succession signal indications respectively corresponding to acoustic signals received from a plurality of vessels after each of the first named signal indications has been registered in which a detonating device is operated when a selected number of acoustic signal indications has been registered.

A further object is the provision of means for registering a plurality of signal indications corresponding respectively to changes in a magnetic field detected during uniform intervals of time after each change in the magnetic field has been detected and for registering acoustic signals received within a predetermined period of time after the first named indications have been registered in which the first named registering means is restored to an initial registering condition when any of the first named signal indications are not received in regular order during any of said uniform intervals of time.

Still other objects, advantages and improvements will be apparent from the following detailed description taken in connection with the accompanying drawings, of which:

FIG. 1 is a view partly in section and partly broken away of a marine mine employing the system of the present invention;

FIG. 2 illustrates in diagrammatic form a complete system in accordance with a preferred embodiment of the invention; and,

FIG. 3 illustrates in diagrammatic form a complete system in accordance with an alternative form of the invention.

Referring now to the drawings for a more complete understanding of the invention and more particularly to FIG. 1 thereof, there is shown thereon a mine indicated generally by the numeral **10** having a casing **11** within which is disposed a magnetic field change detecting mechanism comprising an induction or search coil **12** connected as by certain of the wires within the cable **13** to a mine firing control unit **14** operatively connected to a detonator **15**. The mine is provided with a suitable aperture **16** within which is disposed a hydrostat **17** in sealed relation to the casing of the mine and adapted to extend the detonator within an explosive booster charge **18** contained within the compartment **19** in response to the pressure of the surrounding water against the flexible diaphragm **21** when sufficient time has elapsed to allow a soluble washer **22** to dissolve. An explosive charge **23** surrounds the compartment **19** and completely fills the explosive chamber **24**, the explosive charge being preferably introduced within the chamber by an aperture **25**

within the casing **11** adapted to be sealed by a cover **26** and a plurality of bolts **27**. The mine is also provided preferably with a plurality of fins **28** by means of which the mine is directed along a predetermined line of flight or path of travel as the mine is launched from a mine laying craft.

The extender hydrostat is normally held in an outward position by a spring **29** acting against a shoulder **31** secured to the shaft or plunger **32** to which the flexible diaphragm **21** is attached. The peripheral portion of the diaphragm is secured to the casing **11** in sealed relation thereto as by the clamping ring **33** and bolts **34**. The control mechanism comprising the unit **14** is connected as by the cable **35** to an acoustically controlled switch mechanism **36** secured in any suitable manner as by the bolts **37** to a cap **38** enclosing one end of the mine casing **11**, the cap being secured to the mine casing as by the bolts **39** and rendered watertight with respect thereto as by the gasket **41**. There is also arranged within the mine casing a wall or partition **42** having a recessed portion **43** therein within which is disposed a battery **44**, a resilient pad or cushion **45** composed of material suitable for the purpose such, for example, as rubber or any of the synthetic varieties thereof, being arranged between the battery and the recessed portion **43** of the mine to prevent injury or damage to the battery during the launching of the mine. The mine firing control unit **14** is also disposed within a pair of flexible pads or cushions **46** and **47** thereby to prevent damage or injury to the firing control unit during the handling, transportation and planting of the mine.

The mine casing **11** is also provided with a well **48** within which is arranged a hydrostatically controlled clock mechanism **49**, the clock being adapted to be set in operation by a plunger **51**, as the plunger is moved inwardly against the pressure of a spring **52** by the pressure of the surrounding water against the flexible diaphragm **53** of the hydrostat. The diaphragm **53** is secured at the peripheral portion thereof in watertight relation to the mine casing **11** in any suitable manner as by the clamping ring **54** and bolts **55**. The clock mechanism comprises a rotatable cam member **56**, FIGS. 2 and 3 adapted to rotate through a fractional part of a revolution controlled by the arcuate slotted portion **57** therein within which is disposed the fixed stop pin **58**. As the cam member **56** rotates from an initial position to a final position of rest, the pair of contacts E are momentarily closed and the contacts F are closed in the order named, the contacts F remaining closed during the life of the mine. The contacts E and F are in electrical connection with the detonator **15**, the battery **44** and the firing mechanism **14** as by the electrical cable **13** extending therebetween and arranged within a duct **59** having branches **61** and **62** extending to the arming clock and search coil respectively.

The firing control unit **14** comprises a sensitive relay D FIG. 2, having a movable contact element adapted to be actuated in either direction into engagement with a pair of contacts selectively in accordance with the polarity of electrical signals received from the search coil **12** and a reset or restore magnet RE being provided to restore the movable contact element forcibly to an initial position intermediate the pair of contacts and disconnected therefrom. The relay is preferably of a sensitive type in which means including at least one small permanent magnet is employed for preventing the premature disconnection of the movable contact element from the aforesaid contacts until the restore magnet thereof has been energized. The sensitive relay controls the operation of a pair of slow releasing relays TD1 and TD2, FIG. 2, respectively connected to each of the contacts of the sensitive relay and adapted to be operated selectively in accordance with the direction of movement of the movable contact element of the sensitive relay from an initial position. The operation of either one of the slow releasing relays TD1 and TD2 causes a time delay device or relay

TD3 to operate and move a contact element thereon into circuit closing position, the contact element remaining in circuit closing position until a predetermined period of time such, for example, as two seconds has elapsed after the operating circuit to the time delay device has been interrupted. The time delay device TD3 controls the operation of the second time delay device or relay TD4 having a pair of normally closed contacts adapted to be moved to open circuit position as the time delay device TD4 operates, the contacts remaining in open circuit position continuously for a suitable period of time, such for example, as ten seconds after the operating circuit to the time delay device TD4 has been interrupted. Each of the time delay devices TD3 and TD4 is provided with a suitable time delay mechanism such, for example, as an escapement mechanism adapted to be set in operation as the circuit to the operating magnet thereof is interrupted thereby to delay the return of the respective contact element to an initial position thereof until a predetermined period of time has elapsed after the escapement mechanism has been set in operation.

The mine firing control mechanism also comprises a slow releasing control relay CR adapted to interrupt the operating circuit to the relay D as the restore magnet RE operates and maintain the circuit between the relay D and the search coil 12 interrupted until sufficient time has elapsed for the circulating currents within the core and casing of the search coil to subside sufficiently to prevent the operation of relay D as the result of such circulating currents.

There is also provided a stepping switch A having a reset magnet RSA adapted to restore a pair of wipers to an initial starting position as the reset magnet operates, the wipers being adapted to be stepped ahead successively into engagement with a plurality of bank contacts in succession in response to the operation of a stepping magnet STPA, as is well known in the electrical art. A second stepping switch B having a wiper adapted to be stepped ahead successively into engagement with a plurality of bank terminals in succession is also provided, the circuit to a selected bank terminal being established by a selector switch settable at will to different settings corresponding respectively to the number of cycles of operations of the mechanism necessary to fire the mine.

In addition to the foregoing, the mine firing mechanism includes a slow releasing relay SC controlled by an acoustic switch AS and having a pair of normally open contacts adapted to be closed as the relay operates and thereby control the advance of the wiper of stepping switch B into engagement with the next succeeding bank terminal.

It will be understood that a steel vessel or a vessel having a ponderance of magnetic material distributed unequally throughout the vessel is adapted to influence the earth's magnetic field in varying degrees as different portions of the vessel move past a fixed point of reference, the variation in the strength of the magnetic field being discontinued shortly after the stern of the vessel passes the point of reference. The magnetic field adjacent the point of reference or observation is thus varied or changed and the direction of the field is also changed in accordance with different portions of the vessel moving past the reference point. Stated differently, each portion of the vessel may be regarded as exerting a magnetic influence upon the terrestrial magnetic field of varying degree whereby the influence of the terrestrial field is increased or decreased by the presence of the vessel, as the case may be. A steel vessel, for example, may acquire a certain degree of magnetism imparted thereto during the process of fabrication of the vessel and may additionally acquire magnetic properties by reason of the movement of the vessel in the earth's magnetic field, and thus a steel vessel casts a particular magnetic shadow or zone of magnetic influence about the vessel in accordance with a particular pattern, referred to herein as a ship's magnetic signature. As a vessel moves past the mine the magnetic signature of the ship causes an electromotive force to be set up within the coil 12 in a direction to effect the flow of current within the operating magnet of relay D, first in one direction and subsequently in the opposite direction, the direction of the first flow of current within the operating magnet depending upon the electrical connection between the coil 12 and the relay D, whether the vessel was fabricated in the northern or southern hemisphere, the magnetic heading of the vessel during the fabrication thereof, and the character and extent of degaussing applied to the vessel. The first reversal of current flowing through the operating magnet of relay D as the result of the electromotive force generated within the search coil 12 has been found to occur during the passage of the forward portion of the vessel past the mine, the current being repeatedly reversed as different portions of the vessel move past the mine such that several reversals occur during the passage of the vessel past the mine, the number of such reversals being controlled by the magnetic signature of the vessel.

The manner in which the magnetic signature of the vessel is employed during a plurality of intervals of time jointly with signals of vibratory or impulsive character received through the water from the vessel during the movement of the vessel past the mine to fire the mine selectively will now be described with reference to the system shown in diagrammatic form on FIG. 2 of the drawings. The operation of the system in FIG. 2 will best be understood by consideration of a specific illustration. Let it be assumed, by way of example, that the switch K is set to the position shown and that the ship selector switch S is set to position 3 thereby to select for damage or destruction the third vessel moving past the mine. Let it further be assumed that the stepping switches A and B have been set to their normal or initial positions with the wipers thereof in engagement with contact 1 of their respective switch banks and that the mine has been launched in a body of water of sufficient depth to cause the clock hydrostat to operate as the mine sinks within the water. When the mine has rested on the bed of the body of water for a predetermined period of time, the soluble plug or washer 22 dissolves or is softened sufficiently to allow the detonator extender hydrostat to be operated by the pressure of the surrounding water and thereby move the detonator 15 within the explosive booster charge 18.

The operation of the clock hydrostat causes the clock mechanism 49 to be set in motion by a spring motor, as is well known in the art to which devices of this character relate. The operation of the clock causes the cam member 56 thereof to rotate from the initial position shown on the drawing to a final position with the stop pin 58 in engagement with the opposite end of the arcuate slotted portion 57 of the cam member. The cam contacts E are momentarily closed during movement of the cam member thereby completing a circuit from positive terminal of battery BA by way of conductor 63, contacts E of the arming clock, conductor 64, reset magnet RSB of switch B, from whence the circuit is continued by way of conductor 65 to the negative terminal of battery BA thereby causing the reset magnet to operate and restore the wiper of switch B to the initial or home position in engagement with contact 1 of the switch bank in the event that the wiper should have been moved away from the home position as the result of the shock or blow which the mine receives at the time of launching. As the cam member 56 continues to rotate, the clock contacts E are disengaged and the reset magnet RSB is deenergized. As the cam member 56 continues to move toward the final rest position thereof contacts F of the clock are closed and remain closed during the life of the mine.

The closure of the cam contacts F causes a test cycle of operations of the system to be performed thereby to restore the movable contact element of relay D to an

initial position intermediate the relay contacts and disengaged therefrom as follows:

A circuit is closed from the positive terminal of battery BA by way of conductor 63, cam contacts F, conductor 66, winding of reset magnet RSA, contacts 67 (in the event that the wipers of switch A were moved away from their home or rest position as a result of the shock received during the launching of the mine), conductor 68, armature 69, and break contact of the time delay device TD4, conductor 65, thence to the negative terminal of battery BA thereby operating the reset magnet RSA of switch A and causing the wipers 1 and 2 of switch A to be restored to their initial positions. As the wipers move into engagement with contacts 1 of their respective switch banks, the switch contacts 67 are disengaged thereby interrupting the circuit to the reset magnet RSA and causing the reset magnet to be released.

A circuit is also closed from the positive terminal of battery BA, conductor 63, cam contacts F, conductor 66, movable contact element 71, contact 72 or 73, as the case may be, of relay D with which the contact element 71 is engaged as the result of the shock received during the planting of the mine. It will be assumed, for the purpose of description, that the contact element 71 is resting at this time in engagement with contact 72 and the foregoing circuit, therefore, is continued by way of conductor 74, winding of slow releasing relay TD1 and thence by way of conductor 65 to the negative terminal of battery BA thereby causing relay TD1 to operate. As armature 75 of relay TD1 moves into engagement with the make contact thereof a circuit is closed from the negative terminal of battery BA, conductor 65, armature 75 and make contact of relay TD1, conductor 76, winding of the time delay relay TD3 from whence the circuit is continued by way of conductor 66, cam contacts F, and conductor 63 to the positive terminal of battery BA thereby operating the time delay relay TD3. As armature 77 of relay TD3 moves into engagement with the make contact, a circuit is closed from positive battery on conductor 66, by way of make contact and armature 77 of relay TD3, conductor 78, winding of relay TD4 to negative battery on conductor 65 thereby causing relay TD4 to operate and the armature 69 thereof to remove negative battery from conductor 68.

As armature 79 of relay TD1 moves into engagement with its make contact, a circuit is closed from the negative battery on conductor 65 by way of armature 79 and make contact of relay TD1, conductor 81 and contact 1 and wiper of switch A, conductor 82, winding of stepping magnet STPA and thence to positive battery on conductor 66 thereby causing the stepping magnet to operate and move the switch wiper into engagement with terminal 2 of the switch bank. The movement of armature 77 of time delay relay TD3 into engagement with the make contact thereof also applies positive battery to conductor 78 extending to the winding of the restore magnet RE of relay D and to the winding of control relay CR in parallel, from whence the circuit is continued by way of conductor 65 to negative battery thereby causing the restore magnet RE and the control relay CR to operate. The operation of the control relay CR at the armatures 80 thereof interrupts the control circuit between the search coil 12 and the operating magnet of relay D whereby any electromotive force generated by the search coil, whether produced as the result of circulating eddy currents flowing within the magnetic portion of the search coil or from other causes, are rendered ineffective to actuate the movable contact element of the relay D until relay CR releases. Relay CR, however, is a slow releasing relay by reason of the provision of a copper sleeve or slug disposed about the core of the electromagnet and for this reason does not release and restore the control connection between the search coil and the operating magnet of relay D until a predetermined period of time has elapsed after armature 77 is moved out of engagement with the make contact of relay TD3.

The operation of the restore magnet RE of relay D causes the movable contact element 71 thereof to be forcibly restored to a position intermediate the contacts 72 and 73 and disengaged therefrom. As contact element 71 is disengaged from contact 72 of relay D positive battery is removed from the winding of relay TD1 thereby causing relay TD1 to release. As armature 75 of relay TD1 moves away from its make contact the operating circuit to the electromagnet of time delay relay TD3 is interrupted and the time delay mechanism of relay TD3 set into operation to cause armature 77 thereof to be disengaged from its make contact when a predetermined period of time such, for example, as two seconds has elapsed. The disengagement of armature 77 of relay TD3 from the make contact thereof removes positive battery from conductor 78 thereby causing the restore magnet RE of relay D, relay CR, and time delay relay TD4 to release. The release of the restore magnet RE removes the restraint from the movable contact member 71 whereby relay D is again responsive to signals received from the search coil 12 when relay CR releases. Relay TD4, it will be recalled, is provided with suitable time delay mechanism adapted to prevent the movement of armature 69 thereof into engagement with its contact until a suitable perod of time such, for example, as ten seconds has elapsed after the operating circuit to the relay magnet has been interrupted. When this period of time has elapsed, armature 69 engages its contact thereby applying negative battery to conductor 68 and thence by way of contacts 67 of switch A to the winding of reset magnet RSA and causing RSA to operate and restore the switch wipers to their home position in engagement with contact 1 of the respective switch banks. As the wipers move into engagement with their contacts 1, the contact elements 67 are disengaged thereby causing the reset magnet RSA to release. The test cycle of operations is now complete and the mine firing mechanism is in readiness to detect the passage of a vessel or to respond to a mine sweeping operation, as the case may be.

In the event that the movable contact element 71 of relay D should be moved into engagement with contact 73 as the result of the shock received during the planting of the mine, the closure of contacts F of the clock 49 causes positive battery to be applied to conductor 84 and thence to the winding of relay TD2 from whence the circuit is continued to negative battery on conductor 65 thereby causing relay TD2 to operate and at armature 85 thereof apply negative battery to conductor 76 extending to the winding of relay TD3. Relays TD3 and TD4 operate as heretofore described to control the test cycle of operations including the resetting of relay D and the operating of relay CR concurrently therewith. In the instant case, however, the wipers of switch A are not stepped away from contact 1 of their associated switch banks during the test cycle of operations for the reason that the operating circuit to the stepping magnet STPA is interrupted at armature 79 of relay TD1.

The operation of the system in response to a change in the magnetic field caused by a mine sweeping operation will now be described. Let it be assumed, by way of example, that a magnetic impulse is received from a sweep wire by the search coil 12 of sufficient strength and duration to cause the movable contact element 71 of relay D to be moved into engagement with one of its contacts as, for example, the contact 72 and that the mine sweeper has moved a sufficient distance beyond the mine to prevent the operation of the acoustic switch AS by pressure impulses received through the water from the mine sweeper. When this occurs, a circuit is closed from positive battery on conductor 66 by way of movable contact element 71 and contact 72 of relay D, conductor 74, winding of slow releasing relay TD1, thence by way of conductor 65 to the negative terminal of battery BA

thereby causing relay TD1 to operate. As armature 75 of relay TD1 engages its make contact time delay relay TD3 operates and at armature 77 thereof applies positive battery to conductor 78 thereby operating relay CR, the restore magnet RE of relay D, and the time delay relay TD4. The operation of the restore magnet RE resets the movable contact element 71 of relay D to an initial unoperated position, the operating circuit for relay D being interrupted during the resetting operation and for a predetermined time thereafter at armatures 80 of relay CR. The operation of relay TD4 causes armature 69 thereof to be moved quickly away from the associated contact thereby removing negative battery from conductor 68.

As armature 79 of relay TD1 engages its make contact, negative battery is applied by way of conductor 81, contact 1 and wiper 2 of switch A, conductor 82 and thence to stepping magnet STPA thereby operating the stepping magnet and causing the switch wipers to be moved into engagement with contacts 2. As wiper 2 of switch A moves away from contact 1 of the associated switch bank, negative battery is removed from conductor 82 thereby deenergizing the stepping magnet STPA.

As the movable contact element 71 of relay D moves away from contact 72 in response to the operation of the restore magnet RE, positive battery is removed from conductor 74 and relay TD1 releases. The release of relay TD1 at armature 75 thereof removes negative battery from conductor 76 extending to the winding of relay TD3 thereby causing relay TD3 to release. As armature 77 of relay TD3 moves away from its make contact in time delayed relation with respect to the interruption of the circuit to the operating magnet of relay TD3, the restore magnet RE releases thereby removing the restraint from the movable contact element 71 of relay D and relay CR releases thereby reestablishing the control connection between the operating magnet of relay D and the search coil 12. Relay TD4 is sufficiently slow in releasing, however, to prevent the engagement of the relay contact by armature 69 thereof until a predetermined period of time such as ten seconds, has elapsed.

In the event that the next succeeding impulse from the sweep wire occurs within the predetermined time of release of relay TD4, and the impulse is of the same polarity as the first impulse from the sweep wire, movable contact 71 of relay D again moves into engagement with contact 72 thereby causing the operation of relays TD1, TD3 and TD4. The wipers of switch A, however, are not stepped ahead at this time for the reason that contact 2 associated with wiper 2 of switch A is connected to an open contact on relay TD2. The operation of relay TD4, it will be noted, occurring within the ten second release period of the relay, extends the time of release of the relay by an interval corresponding to the combined energized time of the winding of relay TD4 and an additional time interval, such as ten seconds, after the winding is deenergized, and the time interval before the wipers of switch A may be restored to their initial setting is increased by a like amount. A uniform period of time is thus provided after each magnetic change is detected within which the next succeeding magnetic impulse may be detected and registered as a prerequisite to registering the passage of a vessel or exploding the mine, as the case may be.

In the event, however, that the second impulse received from the sweep wire is of the opposite polarity, the movable element 71 is moved into engagement with contact 73 of relay D and relay TD2 operates. The operation of relay TD2 causes relays TD3, TD4, CR and the restore magnet RE to operate. As armature 86 of relay TD2 moves into engagement with its make contact, negative battery is applied by way of conductor 87, contact 2 and wiper 2 of switch A, conductor 82, winding of stepping magnet STPA and thence to positive battery on conductor 66 thereby causing the stepping magnet to operate and advance the switch wipers into engagement with their contacts 3. As the wipers move away from their contacts 2 and the operating circuit to the stepping magnet is interrupted and the stepping magnet releases.

With wipers of switch A in engagement with their contacts 3 a circuit is closed from positive terminal of battery BA, conductor 63, contacts F of the clock, conductor 66, wiper 1 and contact 3 of switch A, conductor 88, contacts 89 of switch K, conductor 91 and thence to armature 92 of relay SC. Relay SC, however, is unoperated for the reason that the underwater signal impulses received from the mine sweeper are of insufficient strength at this time to operate the acoustic switch AS to circuit closing position and the stepping magnet STPB of switch B, therefore, does not step the B switch wiper ahead into engagement with the next succeeding terminal of the switch bank.

The operation of the restore magnet RE of relay D causes the movable contact element 71 of relay D to be reset thereby interrupting the operating circuit to relay TD2 and causing relay TD2 to release. The release of relay TD2 at armature 85 thereof interrupts the operating circuit of relay TD3 thereby causing relay TD3 to release. As armature 77 of relay TD3 moves away from the make contact thereof, positive battery is removed from conductor 78 thereby causing the restore magnet RE, relay CR and time delay relay TD4 to release. As armature 69 of relay TD4 moves into engagement with its associated contact at the expiration of a uniform period of time of ten seconds after the operating circuit to the relay winding has been interrupted, a circuit is closed from positive battery on conductor 66, reset magnet RSA of switch A, contacts 67 of switch A, conductor 68, armature 69 and break contact of relay TD4, conductor 65 and thence to negative battery thereby causing the reset magnet RSA to operate and restore the wipers of switch A to their normal home position in engagement with contacts 1 of the associated switch banks. As the wipers move into the home position, switch contacts 67 are disengaged and the reset magnet RSA releases.

The operation of the mine in response to a changing magnetic field caused by a moving vessel will now be described. Let it be assumed, by way of example, that a vessel having a magnetic signature in which the polarity of the first elemental portion thereof is adapted to cause the movable contact element 71 of relay D to be moved into engagement with contact 72 and the next succeeding elemental portion of the ship's signature is of the opposite polarity, is approaching the mine. As the bow of the vessel moves past the mine the intensity of the magnetic field is changed thereby causing an electromotive force to be generated by the search coil 12 of sufficient magnitude to cause the movable element 71 of relay D to be moved into engagement with contact 72. When this occurs relay TD1 operates thereby operating relay TD3 and causing the wipers of switch A to be stepped ahead into engagement with contact 2 of the associated switch banks and register a change in the magnetic field adjacent the mine. The operation of relay TD3 causes the movable contact element 71 of relay D to be reset by the restore magnet RE to an initial position and relay CR to be operated thereby disconnecting the search coil 12 from the operating magnet of relay D while the movable contact element 71 is being restored and for a predetermined period of time thereafter. The operation of relay TD3 also operates relay TD4 thereby removing negative battery from conductor 68 and preventing the operation of the reset magnet RSA until armature 69 of relay TD4 engages its contact at the completion of a ten second interval of time after the circuit to the operating winding has been interrupted or at the completion of a subsequent ten second interval of time

in the event that relay TD4 is reoperated during the first named ten second interval. The restoration of relay D causes relays TD1, TD3, CR, stepping magnet STPA to release, and the operating circuit to relay TD4 to be interrupted.

As the second elemental portion of the ship's magnetic signature moves past the search coil 12, the movable contact element 71 of relay D is brought into engagement with contact 73 thereby operating relay TD2 and causing the switch A to be stepped ahead to position 3 with the wipers thereof in engagement with contacts 3 of their switch banks. When this occurs the switch B is stepped ahead to position 2 to register the elemental portions of the ship's magnetic signature detected by the search coil 12. The operation of relay TD3 in response to the movement of armature 85 of relay TD2 into engagement with its make contact reoperates relay TD4 thereby setting up an additional uniform period of time before armature 69 thereof moves into engagement with its break contact. The operation of relay TD3 also operates relay CR and causes relay D to be restored to an original unoperated setting thereby releasing relays TD2, TD3, TD4, CR and the restore magnet RE of relay D.

The vessel by this time has moved ahead sufficiently for the acoustic signal received through the water from the vessel's propulsive mechanism to cause the acoustic switch AS to operate and close the contacts thereof and thus close a control circuit from the positive terminal of battery BA, by way of conductor 63, contacts F of the clock, conductor 66, contact 93 of the acoustic switch AS, conductor 94, winding of relay SC, conductor 65 and thence to the negative terminal of battery BA thereby causing relay SC to operate. Relay SC, it will be recalled, is a slow releasing relay and the armature 92 thereof is adapted to be maintained in continuous electrical engagement with the make contact during the time that the contacts 93 of the acoustic switch AS are vibrating in response to impulses received by the acoustic switch of sufficient strength to move the contacts 93 into engagement with each other.

As switch A moves into position 3, a circuit is closed from positive battery on conductor 66 by way of wiper 1 and contact 3 of switch A, contacts 89 of switch K, conductor 91, armature 92 and make contact of relay SC, conductor 95, winding of the stepping magnet STPB of switch B, conductor 65 and thence to the negative terminal of battery BA, thereby operating the stepping magnet STPB and moving the associated switch wiper into engagement with terminal 2 to register the passage of a vessel. The movement of a vessel past the mine is thus registered on the switch B when a predetermined number of changes in the magnetic field adjacent the mine have been registered on the switch A and an acoustic signal is received of sufficient strength to cause relay SC to be operated.

Subsequent operations of the relay D in response to the remaining elemental portions of the ship's magnetic signature are ineffective to cause the switch A to be stepped ahead beyond position 3 for the reason that the operating circuit to the stepping magnet STPA of switch A is interrupted at an open contact on the switch K. At the expiration of a period of time of ten seconds after the operating circuit to relay TD4 is interrupted, armature 69 of relay TD4 moves into engagement with its break contact thereby operating the reset magnet RSA of switch A and restoring the switch wipers to their normal position in engagement with contact 1 of their associated switch banks. As the switch wipers move into the normal position the operating circuit to the reset magnet RSA is interrupted at the switch contacts 67 and the reset magnet releases. When the vessel has moved beyond the mine sufficiently to prevent further continued operation of the acoustic switch AS, relay SC releases thereby removing positive battery from stepping magnet STPB of switch B and causing the stepping magnet to release.

As the second vessel moves into the vicinity of the mine, the foregoing cycle of operations is repeated, the wipers of switch A moving into engagement with their switch bank contacts 3 and the wiper of switch B moving into engagement with contact 3 of the B switch bank thereby to register the changes in the magnetic field detected by the search coil and relay D, and the movement of a second ship past the mine respectively. The subsequent release of relay TD4 as armature 69 thereof engages its break contact causes the wipers of switch A to be restored to their home position. The mine firing mechanism is now in readiness to respond to the movement of a third vessel past the mine, the third vessel being selected for destruction by reason of the setting of the selector switch S to position 3.

The operation of the detecting and control elements of the mine firing mechanism in response to the movement of the third vessel into the vicinity of the mine causes the switch A to be stepped ahead to position 3 and switch B to be stepped ahead from position 3 to position 4 on a circuit including armature 92 and make contact of relay SC. When this occurs a circuit is closed from positive terminal of battery BA, conductor 63, cam operated contacts F, conductor 96, detonator 15, from whence the circuit is continued by way of conductor 97, wiper and contact 3 of switch S, conductor 98, contact 4 and wiper of switch B, conductor 65 and thence to the negative terminal of battery BA thereby operating the detonator and exploding the mine beneath a vulnerable portion of the vessel.

Whereas in the foregoing example, the third vessel passing the mine was selected for destruction, it will be understood that a greater or lesser number of vessels may precede the vessel to be destroyed by merely setting the switch S to a different setting prior to the launching of the mine.

In the event that the switch K is set to the position shown by a dashed line prior to the launching of the mine, the switch B is stepped ahead in response to three elemental portions of a ship's magnetic signature detected in succession by the detecting element of the mine firing mechanism, provided an acoustic signal of sufficient strength to operate the acoustic switch AS is received while the third elemental portion of the ship's magnetic signature is being detected, or within a predetermined period of time thereafter controlled by the time delay relay TD4. Furthermore, in the arrangement of FIG. 2 the polarity of the first and third elemental portions of the ship's magnetic signature are the same and of opposite polarity to the second elemental portion of the signature although it will be understood that, if desired, the polarity of each of the elemental portions of the ship's magnetic signature employed for controlling the mine firing mechanism may be selected at will by interchanging the electrical connections between the bank terminals associated with wiper 2 of switch A and the conductors 81 and 87 connected thereto. Also, if desired, the electrical connections between key K and the aforesaid bank terminals may be changed in accordance with the polarity and sequence of the magnetic signals received by the search coil 12 necessary to effect the registration of a vessel.

With the switch K set in the position indicated by the dashed line, the contacts 89 thereof are disengaged and switch B is prevented from being stepped ahead until wiper 1 of switch A has moved into engagement with contact 4 of the associated switch bank. With the wipers of switch A in engagement with their terminals 3, a circuit is closed from the winding of the stepping magnet STPA by way of conductor 82, wiper 2 and contact 3 of the switch bank, conductor 99, contacts 101 of switch K, conductor 81 and thence to the make

contact associated with armature 79 of relay TD1 whereby the operation of relays D and TD1 in response to the third elemental portion of the magnetic signature of the vessel causes the stepping magnet STPA to operate and advance the wipers of switch A to position 4. The operation of relay SC causes the stepping magnet STPB of switch B to operate and step the wiper ahead to the next terminal as wiper 1 of switch A moves into engagement with contact 4 of the associated switch bank.

The mine firing mechanism of FIG. 2 may, if desired, be employed to register the passage of a plurality of vessels and explode the mine under a selected vessel by signals corresponding to variations in the magnetic signature of the vessel without regard to the acoustic signal received therefrom, it being merely necessary to move the switch SW to closed position whereby the wiper of switch B is stepped ahead in response to positive battery applied to conductor 91 by wiper 1 of the switch A regardless of the operated condition of relay SC.

On FIG. 3 is shown a complete system in accordance with an alternative form of the invention in which the mine firing control mechanism is adapted to be set in operation and respond selectively to changes in the magnetic field adjacent the mine corresponding respectively to elemental portions of the magnetic signature of a vessel regardless of the polarity of the magnetic changes. In the arrangement of FIG. 3 the contacts 72 and 73 of relay D are connected together and to the winding of a slow releasing relay TD thereby providing an arrangement in which relay TD is adapted to be operated by relay D regardless of the polarity of the signals detected by the search coil 12. Also, in the system of FIG. 3 a stepping switch C comprising a single bridging wiper BDG and bank of contacts, otherwise generally similar to the switch A of FIG. 2, is employed to register changes in the magnetic field adjacent the mine. A stepping switch R, generally similar to the stepping switch B of FIG. 2, is also employed to register the passage of vessels and to fire the mine when the wiper thereof moves into engagement with a selected contact to which an external electrical circuit has been established by the setting of the selection switch S1.

The operation of the system of FIG. 3 will now be described with particular reference to the features of the circuit arrangement and operative characteristics which distinguish the system from the system of FIG. 2. The momentary closure of cam E of clock 49 causes the reset magnet RS of switch R to be momentarily operated thereby assuring that the wiper of switch R will be in the home position in engagement with contact 1 as the first vessel is detected. It may be assumed for the purpose of description that the selector switch S1 has been set in position 3 with the wiper thereof in engagement with the switch contact 3 thereby selecting for destruction the third vessel passing the mine. It may also be assumed that the switch SW is moved to the open position and that the switches S1, S2, and S3 are closed.

As the contacts F of the clock 49 are moved to closed position, a circuit is closed from positive terminal of battery BA by way of conductor 102, cam contacts F, conductor 103, contacts 104 of switch C, reset magnet RS of switch C, conductor 105, armature 69 and break contact relay TD4, conductor 106 and thence to the negative terminal of battery BA thereby causing the reset magnet RS to operate and restore the wiper of switch C to the initial position in the event that the wiper had been moved therefrom prior to the instant cycle of operations of the mine firing control mechanism. As the switch wiper moves into the home position contacts 104 are disengaged and the reset magnet RS releases. A circuit is also closed from the positive terminal of battery BA by way of conductor 102, cam contacts F, conductor 103, movable element 71 of relay D and contacts 72 or 73, as the case may be, conductor 107, winding of slow releasing relay TD, conductor 106 and thence to the negative terminal of battery BA thereby causing relay TD to operate.

As armature 108 of relay TD moves into engagement with its make contact negative battery is applied to relay TD3 causing relay TD3 to operate and at armature 77 thereof apply positive battery to conductor 109 extending to the windings of relays TD4, CR, the restore magnet RE of relay D, and the stepping magnet STP of switch C in parallel connection, thereby causing relays TD4, CR, restore magnet RE, and the stepping magnet STP to operate. The operation of the stepping magnet STP of switch C causes the switch wiper to be moved ahead into engagement with contact 2 of the switch bank. The operation of the restore magnet RE resets the movable contact element 71 of relay D thereby releasing relay TD. As armature 108 of relay TD moves away from its make contact the operating circuit to the winding of the time delay relay TD3 is interrupted and relay TD3 releases in predetermined time delay relation with respect to the interruption of the operating circuit thereto. As armature 77 of relay TD3 moves away from its make contact, the restore magnet RE of relay D, relay CR, the stepping magnet of switch C, and time delay relay TD4 release, armature 69 of relay TD4 being prevented from engaging its contact until a suitable period of time of at least ten seconds has elapsed. As armature 69 of relay TD4 moves into engagement with its break contact negative battery on conductor 106 is applied to the winding of the reset magnet RS of switch C from whence the circuit is continued by way of contacts 104 to positive battery on conductor 103 thereby operating the reset magnet RS and restoring the wiper of switch C to normal. As the wiper moves into the home position contacts 104 are disengaged and the reset magnet releases. A test cycle of operations of the system has now been completed with all relays released and the wipers of switches C and R resting in their home positions in engagement with contact 1 of their respective switch banks.

As the first vessel moves within the vicinity of the mine, the first elemental portion of the ship's magnetic signature causes the movable contact element 71 of relay D to be moved to circuit closing position thereby operating relay TD. As armature 108 of relay TD moves into engagement with its make contact relay TD3 operates and at armature 77 thereof applies positive battery on conductor 103 to conductor 109 thereby causing the operation of relays TD4, CR, the restore magnet RE of relay D, and the stepping magnet STP of switch C. The operation of the stepping magnet causes the wiper of switch C to be moved ahead into engagement with contact 2 of the switch bank and contacts 104 to be closed concurrently therewith and subsequent to the disengagement of armature 69 of relay TD4 from the break contact associated therewith. The first elemental portion of the ship's magnetic signature has now been registered by the switch C. As the movable contact element 71 of relay D moves away from the operating position thereof in response to the operation of the restore magnet RE, positive battery is removed from the conductor 107 and relay TD releases thereby causing relay TD3 to release. As armature 77 of relay TD3 moves away from the make contact thereof in time delayed relation with respect to the interruption of the circuit to the operating magnet of relay TD3, positive battery is removed from conductor 109 thereby releasing the restore magnet RE, relay CR, the stepping magnet of switch C, and interrupting the operating circuit to the magnet of relay TD4. Armature 69 of relay TD4, it will be recalled, does not engage its break contact until ten seconds has elapsed after the operating circuit to the relay has been interrupted and a uniform period of time is thus provided during which an additional portion of the ship's magnetic signature may be registered by the switch C.

The continued onward movement of the vessel past the mine causes the second elemental portion of the ship's magnetic signature to be effective to actuate the movable contact element 71 of relay D to circuit closing position thereby operating relay TD during the period of time before armature 69 of relay TD4 moves into engagement with its break contact. As armature 108 of relay TD engages its make contact, relay TD3 operates and the foregoing cycles of operations of restore magnet RE, relay CR, stepping magnet STP of switch C and the time delay relay TD4 are repeated, the second elemental portion of the ship's magnetic signature being registered as the wiper of switch C moves into engagement with contact 3 of the associated switch bank. Relay SC by this time is operated by an acoustic signal received by the acoustic switch device AS and as the wiper of switch C engages contact 3 of the switch bank, a circuit is closed from negative battery on conductor 106 by way of wiper of switch C and contact 3 of the switch bank, switches S1, S2, and S3, conductor 111, armature 92 and make contact of relay SC, conductor 112, winding of the stepping magnet STP of switch R, conductor 103 and thence by way of contacts F of the clock 49 and conductor 102 to the positive terminal of battery BA thereby operating the stepping magnet STP of switch R and causing the switch wiper to be moved ahead into engagement with terminal 2 of the switch bank to register the passage of a vessel. The energization of the operating magnet of relay TD4 causes the time of release of the armature 69 thereof to be extended an additional period of ten seconds after the operating circuit thereto has been interrupted. The operation of the reset magnet RE of relay D causes relay D to release and thereby interrupt the operating circuit to relay TD. Relay TD releases thereby interrupting the operating circuit of relay TD3 and causing relay TD3 to release. As armature 77 of relay TD3 moves away from the make contact thereof, positive battery is removed from conductor 109 thereby releasing relay CR, the restore magnet RE, the stepping magnet STP of switch C, and interrupting the operating circuit to relay TD4. The stepping magnet STP of switch R, however, remains operated by reason of the engagement of the brush of switch C with contact 3 of the switch bank and the operated condition of relay SC.

As relay D operates in response to additional elemental portions of the ship's magnetic signature detected during movement of the vessel past the mine, the foregoing cycle of operations is repeated and switch C is stepped ahead to the next succeeding contact of the switch bank as each additional elemental portion of the ship's magnetic signature is detected. The stepping magnet of switch R, however, remains continuously energized during these stepping operations of switch C as additional elemental portions of the ship's magnetic signature are detected by reason of the provision of a bridging wiper for the switch C adapted to make contact with the next succeeding terminal of the switch bank before being disengaged from a bank contact. The magnetic signature of a vessel has been found to attenuate rapidly after the stern of the vessel passes a point of observation and the changing magnetic field conditions corresponding to elemental portions of the magnetic signature detected by the search coil 12 are, therefore, of insufficient strength to operate the detecting relay D shortly after the vessel has moved past the mine. The acoustic signal received from the vessel, however, continues to operate the acoustic switch AS while the vessel is passing the mine thereby maintaining relay SC operated until the vessel has passed beyond the mine.

When a predetermined period of time such, for example, as ten seconds has elapsed after the operating circuit to the relay TD4 has been closed and interrupted in response to the last elemental portion of the magnetic signature detected by the mechanism, armature 69 of relay TD4 moves into engagement with its break contact thereby causing the wiper of switch C to be restored to the initial home position in response to the operation of the reset magnet RS thereof. As the wiper of switch C moves past contact 3 of the switch bank during the return movement of the wiper to the home position, negative battery is removed from conductor 111 thereby releasing the stepping relay STP of switch R. In the event that the acoustic signal received by the acoustic switch AS is of insufficient strength to maintain relay SC operated before the wiper of switch C moves past contact 3 of the switch bank during the return of the wiper to the home position, the operating circuit to the stepping magnet STP of switch R is interrupted at armature 92 of relay SC as the armature moves away from its make contact and switch R, therefore, is adapted to make but a single step in response to the passage of a vessel within the vicinity of the mine regardless of the order of sequence of the release of relay SC with respect to the period of time controlled by time delay relay TD4 corresponding to the movement of armature 69 thereof into engagement with its break contact.

As the second vessel moves past the mine, the foregoing cycle of operations is repeated, the switch C stepping ahead in response to the elemental portions of the ship's signature detected by the search coil 12 and relay D, and the wiper of switch R moving into engagement with contact 3 of the associated switch bank. As armature 69 of relay TD4 moves into engagement with the break contact thereof at the completion of a predetermined period of time after the last elemental portion of the ship's magnetic signature has been detected, switch C is restored to the initial home position.

As the wiper of switch C moves into engagement with contact 3 of the associated switch bank in response to the movement of the third vessel past the mine, the stepping magnet STP of switch R is operated thereby moving the associated switch wiper into engagement with contact 4 of the switch bank. When this occurs, a circuit is closed from negative terminal of battery BA by way of conductor 106, wiper and contact 4 of switch R, conductor 113, contact 3 and wiper of the selection switch S, conductor 114, detonator 15, from whence the circuit is continued by way of conductor 103, cam contacts F, conductor 102 to the positive terminal of battery BA thereby causing the detonator to operate and explode the mine beneath the vulnerable portion of the vessel.

Whereas in the foregoing example the switch R is stepped ahead in response to two elemental portions of the magnetic signature of the vessel detected by the search coil and relay D, it will be understood that, if desired, the switch R may be stepped ahead in response to a different number of elemental portions of the ship's magnetic signature by setting the switches S1, S2, and S3 to a combination corresponding to the number of elemental portions of the magnetic signature to be employed for controlling the operation of switch R. Furthermore, it will be noted that, whereas in the foregoing example the third vessel had been selected for destruction, this is by way of example only, as a preceding vessel or a succeeding vessel may be selected to fire the mine, it being merely necessary to set the selection switch S1 to a desired setting. The system of FIG. 3 is also adapted to control the operation of switch R regardless of the acoustic signal received by the mine, as may be deemed advisable in cases where the mine is planted within enemy waters in locations where the possibility of mine sweeping operations by the enemy is extremely remote, it being merely necessary to close the switch SW prior to the planting of the mine.

The system of FIG. 3 provides means for preventing the registration operation of switch R in response to a mine sweeping operation for the reason that the operating circuit for the stepping magnet STP of switch R is interrupted at armature 92 of relay SC while the changing magnetic field conditions set up by the sweep wire are received by the search coil 12 and relay D. When the

sweep wire has moved past the mine for a distance such that the changes in the magnetic field adjacent the mine are of insufficient strength to operate the relay D within the time of release of relay TD4, armature 69 of relay TD4 engages its contact and switch C returns to normal thereby canceling the magnetic field changes registered therein without operating switch R.

Briefly stated in summary, the present invention contemplates the provision of an influence type mine firing control mechanism in which the possibility of detonating the mine by a mine sweeping operation is extremely remote, the mechanism being adapted to be restored to normal within a predetermined uniform period of time after each elemental portion of a ship's magnetic signature is detected and registered, and in which the movement of each vessel past the mine is registered selectively in accordance with an acoustic signal received through the surrounding water, means being also provided for firing the mine in response to the movement of a selected vessel within the vicinity of the mine. The invention also contemplates the provision of a signal responsive device normally connected to the magnetic field detecting means and adapted to be controlled thereby in which means are employed for interrupting the control connection between the signal responsive device and the magnetic field detecting means for a predetermined period of time after a change in the magnetic field has been detected by the detecting means. The invention also contemplates the provision of a new and improved combined influence and acoustic type of firing control mechanism for a mine in which the mine firing mechanism performs a test cycle of operations within a predetermined period of time after the mine has been planted within a body of water.

While the invention has been described with reference to two examples thereof which give satisfactory results, it will be understood by those skilled in the art to which the invention pertains, after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is my intention, therefore, in the appended claims to cover all such changes and modifications.

The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of any royalties thereon or therefor.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In a submarine mine of the character disclosed arranged within a magnetic field, a relay, means including said relay for detecting a plurality of successive changing magnetic conditions in the magnetic field, means controlled by said relay for counting said changing conditions of the magnetic field detected in succession by said detecting means, means effective when each of said changing conditions is detected respectively for measuring a predetermined interval of time, and means for causing the mine to explode when a predetermined number of changing conditions in the magnetic field have been counted prior to the expiration of the predetermined interval of time corresponding to the next to the last changing magnetic condition detected by said detecting means.

2. In a submarine mine of the character disclosed arranged within a magnetic field, means for detecting in succession a plurality of changing magnetic conditions within said field, a relay operatively connected to said detecting means and adapted to be operated thereby as each of said changing magnetic conditions is detected, means controlled by said relay for counting said changing conditions of the field detected by said detecting means, means effective when each of said changing conditions is detected for measuring a predetermined interval of time, and means for restoring said counting means to an initial counting position when a changing magnetic condition is not detected within one of said predetermined intervals of time.

3. In a submarine mine of the character disclosed, means for detecting magnetic changes in a magnetic field within which the mine is disposed, an electrical relay adapted to be operated by said detecting means as each of said magnetic changes is detected, means controlled by said relay and adapted to measure uniform intervals of time respectively corresponding to said magnetic changes, means for counting said magnetic changes respectively detected during said intervals of time, acoustic detecting means, a relay adapted to be operated by said acoustic detecting means as acoustic signals are received through the surrounding water, a pair of normally open contacts on said last named relay, and a firing control circuit including said pair of contacts and adapted to be closed by said counting means when a predetermined number of changing conditions in said magnetic field have been counted prior to the expiration of the predetermined interval of time corresponding to the next to the last changing condition detected by said magnetic detecting means.

4. In a submarine mine of the character disclosed, means responsive to variations in the terrestrial magnetic field for sensing the movement of a vessel within the vicinity of the mine, means controlled by said sensing means for producing signal indications, each of said signal indications corresponding respectively to one of a predetermined number of vessels moving past the mine in successive order, means for counting said signal indications, means for arming the mine selectively in response to the number of signal indications counted by said counting means, and means including an acoustic detecting device in communication with the surrounding water for causing the armed mine to explode as acoustic signals are received from the next succeeding vessel moving past the mine.

5. In a submarine mine of the character disclosed, an electrical relay, means including said electrical relay for detecting the movement of a vessel within the vicinity of the mine, means controlled by said electrical relay for invariably measuring a predetermined interval of time immediately following each operation of the relay, acoustic means for detecting vibrations received through the water from the vessel, a control relay adapted to be operated by said acoustic means, a pair of normally open contacts on said control relay, and means controlled by said control relay and effective when a predetermined number of operations of the electrical relay has been performed within a corresponding number of said predetermined intervals of time for firing the mine selectively under control of said pair of normally open contacts.

6. In a submarine mine of the character disclosed, an electrical relay, means including said electrical relay for detecting the movement of a vessel within the vicinity of the mine, means controlled by said relay for rendering the detecting means effective to detect magnetic variations in the magnetic field during predetermined intervals of time respectively corresponding to variations in the magnetic field detected by said detecting means, means controlled by said electrical relay for measuring each of said predetermined intervals of time, means for counting each variation in the magnetic field detected by said detecting means within each of said predetermined intervals of time, and means for registering the cycles of operations of said counting means when a predetermined number of variations in the magnetic field detected by said detecting means has been counted within a corresponding number of predetermined intervals of time.

7. In a mine adapted to be laid on the bed of a body of water, the combination of an electrical relay, means including said electrical relay for detecting magnetic variations in the magnetic field adjacent the mine, means controlled by said relay for rendering the detecting means effective to detect magnetic variations in the magnetic field during predetermined intervals of time respectively corresponding to the number of operations of the relay, means controlled by said relay and adapted to measure each of said intervals of time, a control circuit, a device

for counting a predetermined number of operations of said relay occurring respectively within each of said predetermined intervals of time, means on said counting device for closing said control circuit when a predetermined number of operations of said relay have been counted, a registering device adapted to be operated by said circuit closing means, a movable contact element on said registering device and adapted to engage a plurality of electrical contacts in succession as the said registering device operates, a detonating device, means settable at will for operatively connecting said detonating device selectively to the contacts of said registering device, and means for causing the mine to be exploded by said detonating means as the selected contact of said registering device is engaged by said movable contact element.

8. In a submarine mine of the character disclosed arranged within a magnetic field, an electrical relay, means including said electrical relay for detecting a plurality of changes in magnetic conditions within said field, means controlled by said relay for counting the changes in the field detected by said detecting means, means effective as each of said changes is detected by said detecting means for measuring a predetermined interval of time corresponding respectively thereto, and means controlled by said time measuring means for restoring said counting means to an initial starting position when a change in said magnetic field is not detected by said detecting means within one of said predetermined intervals of time.

9. In a submarine mine of the character disclosed arranged within a magnetic field, a relay, means including said relay for detecting a plurality of uniform groups of changing magnetic conditions within said field, means controlled by said relay for measuring predetermined intervals of time respectively corresponding to said changing conditions, means for counting in succession each of said changing conditions detected by said detecting means within said predetermined intervals of time, means controlled by said time measuring means for restoring said counting means to an initial starting position when a changing condition is not detected during one of said predetermined intervals of time, an electroresponsive registering device adapted to register a predetermined number of uniform groups of changing magnetic conditions counted by said counting means, an acoustically controlled device having means for normally preventing the operation of said registering device when an acoustic signal is not received through the surrounding water, and means controlled by said electroresponsive registering device for causing the mine to explode when a predetermined number of uniform groups of changing magnetic conditions in the magnetic field have been counted by said counting device and the acoustically controlled device is operated concurrently with the last signal of each group of changing magnetic conditions counted by said counting device.

10. In a submarine mine of the character disclosed arranged within a magnetic field, a relay, means including said relay for detecting a plurality of uniform groups of changing magnetic conditions within said field, each of said groups corresponding to different portions of the magnetic signatures of a plurality of vessels respectively, means controlled by said relay for counting in succession each of said changing magnetic conditions detected by said detecting means, means effective as each changing condition is counted by said counting means for measuring predetermined intervals of time respectively corresponding to said changing conditions, an electroresponsive device adapted to register each uniform group of changing magnetic conditions counted by said counting means, means controlled by said time measuring means for restoring said counting means to an initial counting position when a changing condition is not counted by said counting means during one of said predetermined intervals of time, and means including a device settable at will to different settings for causing the mine to explode when a predetermined number of uniform groups of changing magnetic conditions have been registered by said electroresponsive device.

11. In a submarine mine of the character disclosed arranged within a magnetic field, a relay, means including said relay for detecting a plurality of uniform groups of changing magnetic conditions within said field, means controlled by said relay for counting in succession each of said changing conditions detected by said detecting means, means effective as each of said changing magnetic conditions is counted by said counting means for measuring predetermined intervals of time respectively corresponding to said changing magnetic conditions, means for restoring said counting means to an initial starting position when a signal is not counted by said counting means during one of said predetermined intervals of time, means including a device settable at will to different settings for causing the mine to explode when the predetermined number of uniform groups of changing magnetic conditions in the magnetic field have been counted by said counting means, and means settable at will for changing the number of signals of each group counted by said counting means.

12. In a submarine mine of the character disclosed arranged within a magnetic field, mine firing mechanism, means included within said mine firing mechanism for sensing changing magnetic conditions within said field during different intervals of time, relay means connected to said sensing means and adapted to be operated thereby, means controlled by said relay means for causing the relay means to be restored in time delayed relation with respect to operation of the relay means, a counting device controlled by said relay means, said counting device having a contact element movable to an initial setting and to a plurality of moved settings, a control circuit, registering means, an electroresponsive actuating element for said registering means and operatively connected to said control circuit, an acoustically controlled contact device, a slow releasing relay adapted to be operated by said acoustically controlled device in response to acoustic signals received through the surrounding water, means on said slow releasing relay for closing in part said control circuit as the relay operates, and means effective when the contact element of said counting device has been moved to a predetermined moved setting for closing said control circuit.

13. In a submarine mine of the character disclosed arranged within a magnetic field, an induction coil for sensing changing magnetic conditions within said field, a source of electrical power, a relay adapted to be operated and released in succession by said induction coil and by said source of electrical power respectively, normally open contacts on said relay adapted to be engaged as the relay operates, means controlled by said relay contacts for measuring a plurality of uniform intervals of time respectively associated with each closure of the relay contacts, means on said time measuring means for establishing an electrical connection between the relay and said source of electrical power thereby to cause the relay to release as the time measuring means operates, a control circuit between the induction coil and said relay, and electroresponsive means controlled by said time measuring means for interrupting said control circuit as the normally open contacts on said relay are disengaged.

14. In a submarine mine of the character disclosed arranged within a magnetic field, a combination of mine firing mechanism, a relay included within said mine firing mechanism, an induction pickup coil adapted to generate signals variably in accordance with changing magnetic conditions within said field, a control connection between said induction coil and the relay, a movable contact element on said relay adapted to be moved from an initial position to circuit closing position as the relay operates in response to a signal received from said induction coil, means controlled by said movable contact element for

measuring a predetermined interval of time as the contact element moves to circuit closing position, electroresponsive means on said relay adapted to restore said movable contact element to said initial position, means on said time measuring means for operating said relay restoring means during said predetermined interval of time, and means controlled by said time measuring means for interrupting said control connection while the movable contact element is being restored to said initial position by said relay restoring means.

15. In a submarine mine of the character disclosed arranged within a magnetic field, a combination of mine firing mechanism, an induction coil adapted to detect a changing magnetic condition within the field, a relay operatively connected to said induction coil, a pair of contacts on said relay and adapted to be closed as the relay operates, a time delay device controlled by said relay contacts, means on said relay and controlled by said time delay device for restoring the relay to normal, means for counting the number of operations of the relay, means for measuring a uniform interval of time whenever said time delay device operates, and means for restoring said counting means to an initial starting position when said relay is not subsequently operated within said uniform interval of time.

16. In a submarine mine of the character disclosed arranged within a magnetic field, a combination of mine firing mechanism, an induction coil adapted to detect a changing magnetic condition within the field, a relay operatively connected to said induction coil, a pair of contacts on said relay and adapted to be closed as the relay operates, a time delay device controlled by said relay contacts, means controlled by said time delay device for restoring the relay to normal, means for counting the number of operations of the relay, means for measuring a uniform interval of time whenever said time delay device operates, means for restoring said counting means to an initial starting position when said relay is not subsequently operated within said interval of time, an acoustically controlled device, a slow releasing relay controlled by said acoustically controlled device and having means for closing a circuit in response to vibrations received by the device through the surrounding water, a registering device controlled by said circuit closing means for registering a predetermined number of operations of said first named relay occurring within respective intervals of time measured by said time measuring means, and means for firing the mine when a predetermined number of registrations have been effected by said registering device.

17. In a submarine mine of the character disclosed arranged within a magnetic field, the combination of mine firing mechanism, means for sensing magnetic variations in said field, a sensitive relay operatively connected to said field sensing means and having a contact element adapted to be moved to circuit closing position as the relay operates, a time delay device controlled by said contact element, means controlled by said time delay device for restoring the relay to an initial unoperated condition, means controlled by said time delay device for measuring a uniform interval of time as the time delay device operates, means controlled by said time delay device for counting a predetermined number of operations of said relay within respective uniform intervals of time, means for registering said predetermined number of operations of said relay counted by said counting means, and means controlled by said time measuring means for preventing a registration by the registering means when less than said predetermined number of operations of the relay are counted within corresponding predetermined intervals of time.

18. In a submarine mine of the character disclosed arranged within a magnetic field, means for detecting magnetic changes in said field, a relay operatively connected to said detecting means, a pair of contacts on said relay adapted to be closed as the relay operates, a time delay device controlled by said relay contacts, means controlled by said time delay device for disengaging said relay contacts as the time delay device operates, means controlled by said time delay device for measuring predetermined intervals of time respectively corresponding to magnetic changes in said field detected by said detecting means, means for counting a predetermined number of operations of said relay corresponding respectively to magnetic changes in said field detected by said detecting means within said predetermined intervals of time, and means controlled by said time measuring means for restoring the counting means to an initial starting position when less than said predetermined number of operations have been counted and the relay is not operated within the next successive predetermined interval of time.

19. In a mine firing mechanism disposed within a magentic field, means for detecting in succession a plurality of changing magnetic conditions of the field, means for measuring uniform intervals of time respectively corresponding to each changing magnetic condition of the field detected by said detecting means, electroresponsive counting means, and means for selectively operating said counting means in accordance with the number of changing magnetic conditions of the field detected by said detecting means within said predetermined intervals of time respectively.

20. In a mine of the character disclosed arranged in in a magnetic field and adapted to be planted within a body of water, in combination, means for detecting a predetermined plurality of changing magnetic conditions in the magnetic field adjacent thereto received during respective measured intervals of time, means controlled by said detecting means for measuring said intervals of time respectively corresponding to each of said changing magnetic conditions, an acoustic detecting device in communication with the surrounding water, and means effective when said predetermined plurality of changing magnetic conditions in the magnetic field have been detected for firing the mine selectively in accordance with the strength of a signal received by said acoustic detecting device.

21. In a system of the character disclosed for firing a mine adapted to be planted within a body of water, means for detecting changes of either polarity in the terrestrial magnetic field adjacent the mine, a relay operatively connected to said detecting means and having a movable contact element operable selectively in either direction from an initial position in accordance with the polarity of the magnetic changes of the field detected by said field detecting means, a pair of contacts on said relay adapted to be engaged by said movable contact element selectively in accordance with the direction of movement of the contact element from said initial position, a pair of slow releasing relays respectively connected to said contacts, a time delay device adapted to beo perated by either of said slow releasing relays, means controlled by said time delay device adapted to be operated by either of said slow restored to said initial position as the time delay device operates, a stepping switch mechanism for counting the number of operations of said relay, means including a plurality of electrical circuit connections for causing the switch stepping mechanism to be stepped ahead to successive settings in accordance with a predetermined sequence of operation of said slow releasing relays, a registering device, means for operating said registering device, when a predetermined number of operations of said relay have been counted by said switch stepping mechanism, and means controlled by said time delay device for measuring predetermined intervals of time respectively corresponding to the operations of the time delay device.

22. In a system of character disclosed for firing a mine adapted to be planted within a body of water, means for detecting changes of either polarity in the terrestrial

magentic field adjacent the mine, a relay operatively connected to said detecting means and having a movable contact element operable selectively in either direction from an initial position in accordance with the polarity of the magnetic changes of the field detected by said field detecting means, a pair of contacts on said relay adapted to be engaged by said movable contact element selectively in accordance with the direction of movement of the contact element from said initial position, a pair of slow releasing relays respectively connected to said contacts, a time delay device adapted to be operated by either of said slow releasing relays, means controlled by said time delay device for causing said movable contact element to be restored to said initial position as the time delay device operates, a stepping switch mechanism for counting the number of operations of said relay, means including a plurality of electrical circuit connections for causing the switch stepping mechanism to be stepped ahead to successive settings in accordance with a predetermined sequence of operation of said slow releasing relays, a registering device, means for operating said registering device when a predetermined number of operations of said relay have been counted by said switch stepping mechanism, means controlled by said time delay device for measuring predetermined intervals of time respectively corresponding to the operations of the time delay device, and means for restoring said switch stepping mechanism to an initial starting position when the movable contact element of said relay is not operated in a predetermined direction during one of said predetermined intervals of time.

23. In a submarine mine of the character disclosed arranged within a magnetic field, means for detecting in succession a plurality of changing magnetic conditions within said field, a relay adapted to be operated by said detecting means as each of said changing magnetic conditions is detected, means controlled by said relay for counting a predetermined number of said changing conditions of the field detected by said detecting means within respective unform intervals of time, means effective when each of said changing conditions is detected for measuring each of said uniform intervals of time, means for preventing the operation of said relay during a fractional portion of each of said intervals of time after each changing condition of the magnetic field has been detected, means controlled by said counting means for effecting the registration of said predetermined number of changing magnetic conditions within said field respectively detected within said uniform intervals of time, means for preventing the registration of said predetermined number of changing magnetic conditions when the interval between two of said predetermined number of changing magnetic conditions exceeds one of said uniform intervals of time, and means for counting on said counting means more than said predetermined number of changing magnetic conditions within said field detected by said detecting means during respective uniform intervals of time without registering more than said predetermined number of changing magnetic conditions.

24. In a submarine mine of the character disclosed arranged within a magnetic field, means for detecting in succession a plurality of changing magnetic conditions within said field, a relay adapted to be operated by said detecting means as each of said changing magnetic conditions is detected, means controlled by said relay for counting a predetermined number of changing conditions of the field detected by said detecting means, means for preventing the operation of said relay for a predetermined period of time after each changing condition of the magnetic field has been detected, means controlled by said counting means for effecting the registration of said predetermined number of changing magnetic conditions within said field respectively detected by said detecting means within predetermined intervals of time, means for preventing the registration of said predetermined number of changing magnetic conditions when the interval between two of said predetermined number of changing magnetic conditions exceeds one of said predetermined intervals of time, and means for counting on said counting means more than said predetermined number of changing magnetic conditions within said field detected by said detecting means during respective uniform intervals of time without registering more than said predetermined number of changing magnetic conditions.

25. In a submarine mine of the character disclosed, a coil for detecting changes in the ambient magnetic field, a polarized electrical relay operatively connected to said coil, a time delay device controlled by said relay, means controlled by the time delay device for partially disarming the mine for a predetermined time interval following each operation of the relay, electromechanical registering means constructed and arranged to count operations of the relay corresponding respectively to changes of predetermined order of polarity in the magnetic field, a time interval measuring device controlled by the time delay device and having means for restoring said count registering means to the initial counting position thereof at the expiration of each time interval measured thereby, acoustic means for detecting vibrations through the water surrounding the mine, a slow release relay controlled by said acoustic means and having circuit closing means thereon, a second electromechanical count registering means operatively connected for actuation in response to actuation of the first said registering means to a preselected count when said circuit closing means is operated, an electroresponsive detonator, and means on said second count registering means operatively connected to said detonator for firing the mine when the second count registering means has made a predetermined number of actuations.

26. In a submarine mine of the character disclosed, an electrical relay selectively operable to two contact positions in accordance with the polarity of a signal impulse received thereby, means operatively connected to said relay for detecting changes in the ambient magnetic field caused by movement of a vessel within the vicinity of the mine and adapted to generate signal impulses having polarities controlled by the polarities of the respective changes in the field, electromechanical time delay switching means under control of said relay for resetting the relay and preventing further actuation of the relay for a predetermined interval of time after each operation thereof, electromechanical counting means for registering the number of operations of the relay occurring in time spaced relation and in a predetermined order, means operatively connected to said relay for operating the counting means, a time delay switching device under control of said time delay switching means and constructed and arranged to restore said counting means to an initial unoperated condition at a predetermined time interval after the counting means has been operated, acoustic detecting means including a circuit closing element and responsive to vibrations within the water surrounding the mine, a slow release control relay operated by said element as vibrations are detected by the acoustic detecting means, electroresponsive stepping switch means constructed and arranged for successive actuation to different switch settings in response to respective operations of said control relay when the counting means registers a predetermined count, electroresponsive detonating means, and means for establishing an electrical connection between the detonating means and a selected contact of the stepping switch means whereby the mine is fired when the stepping switch has been actuated to a setting corresponding to said contact.

27. In a system of the character disclosed for firing a mine adapted to be planted within a body of water, means for detecting changes of either polarity in the terrestrial magnetic field adjacent the mine, a relay operatively con-

nected to said detecting means and having a movable contact element operable selectively in either direction from an initial position in accordance with the polarity of the magnetic changes of the field detected by said field detecting means, a pair of contacts on said relay adapted to be engaged by said movable contact element selectively in accordance with the direction of movement of the contact element from said initial position, a pair of slow releasing relays respectively connected to said contacts and selectively operative in response to engagement of said contacts by said movable contact element respectively corresponding to changes of magnetic field of alternate polarity, a time delay device adapted to be operated by either of said slow release relays, means controlled by said time delay device for causing said movable contact element to be restored to said initial position as the time delay device operates, a stepping switch mechanism for counting the number of alternate polarity operations of said relay, means including a plurality of electrical circuit connections to said slow release relays for causing the switch stepping mechanism to be stepped ahead to successive settings as said slow releasing relays operate in alternate order, a registering device, means for operating said registering device when the stepping mechanism has been stepped ahead to a preselected setting, means controlled by said time delay device for measuring predetermined intervals of time respectively corresponding to the operations of the time delay device, and means for restoring said switch stepping mechanism to an initial starting position when the movable contact element of said relay is not operated to a predetermined contact during one of said predetermined intervals of time.

28. In a submarine mine of the character disclosed arranged within a magnetic field, means for detecting in succession a plurality of changing magnetic conditions within said field, a relay operatively connected to said detecting means and adapted to be actuated selectively to opposite contact positions when changing magnetic conditions of opposite polarity corresponding thereto are respectively detected, means controlled by said relay for counting the actuations of the relay when successive actuations thereof are to said opposite contact positions respectively, means for preventing counting of a relay actuation when successive actuations thereof are to the same contact position, means effective when each of said actuations of the relay occurs for measuring a predetermined interval of time, and means for restoring said counting means to an initial counting position when a changing magnetic condition of opposite polarity is not detected within one of said predetermined intervals of time.

29. In a submarine mine of the character disclosed arranged within the magnetic field, means for detecting in succession a plurality of changing magnetic conditions within said field, a relay connected to said detecting means and adapted to be operated alternately thereby to opposite contact positions thereof respectively corresponding to changing magnetic conditions of alternate polarity detected by said detecting means, acoustic detecting means responsive to vibrations in the water surrounding said mine, a normally open electromagnetic switch constructed and arranged to be actuated to a closed position by the acoustic detecting means while said vibrations are being detected, means controlled by said relay for counting in succession operations of the relay to said opposite positions thereof, means effective when each of said operations of the relay occurs for measuring a predetermined interval of time, means for restoring said counting means to an initial counting position when the counting means is not actuated within one of said predetermined intervals of time, and means for firing the mine when said electromagnetic switch is closed within one of the predetermined intervals of time after a predetermined number of operations of the relay have been counted.

30. In a device for detecting and counting successive changes of predetermined character in the ambient field surrounding a detector, the combination of an ambient field-change detector, a relay connected to said detector and adapted to be operated thereby as a change in the field is detected, means including a pair of stepping switches for registering the number of field changes of predetermined character detected, means for operating one of said switches in response to the successive operations of said relay, and acoustically controlled means for operating the other of said switches when the intensity of the acoustic vibrations at the acoustically controlled means has reached a predetermined value within a predetermined interval of time after the first switch has registered a predetermined number of operations of said relay.

31. In a mine firing mechanism disposed within a magnetic field, means for detecting in succession a plurality of changing magnetic conditions of the field said changing conditions being of either polarity, means for measuring uniform intervals of time respectively corresponding to each changing magnetic condition of the field detected by said detecting means, electroresponsive counting means, and means for selectively operating said counting means in accordance with the number of said changing magnetic conditions of preselected polarity successively detected by said detecting means within said predetermined intervals of time respectively.

32. In a device for detecting successive signals, the combination of means for detecting in succession a plurality of signals, means controlled by said detecting means for measuring a predetermined interval of time after each signal, means actuated by said detecting means for counting a number of successive signals detected by said detecting means each of which occurs within said predetermined interval, and means including said time interval measuring means for resetting said counting means to an initial counting position when the interval between successive signals exceeds said predetermined interval.

33. In a device for detecting successive signals, the combination of means for detecting in succession a plurality of signals, means controlled by said detecting means for measuring a predetermined interval of time after each signal, means actuated by said detecting means for counting a predetermined number of successive signals each of which occurs within said predetermined interval, means controlled by said detecting means for rendering said counting means unresponsive to signals for a portion of said predetermined time interval after each signal detected by said detecting means, means including said time interval measuring means for resetting said counting means to an initial counting position when the interval between successive signals exceeds said predetermined interval, and electroresponsive means actuated by said counting means for giving a signal indication when said predetermined number of signals has been successively counted within a corresponding number of said predetermined time intervals.

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