

May 8, 1962

E. L. LOWE ETAL

3,033,113

SUBMARINE MINE CONTROL SYSTEM

Filed March 12, 1946

5 Sheets-Sheet 1

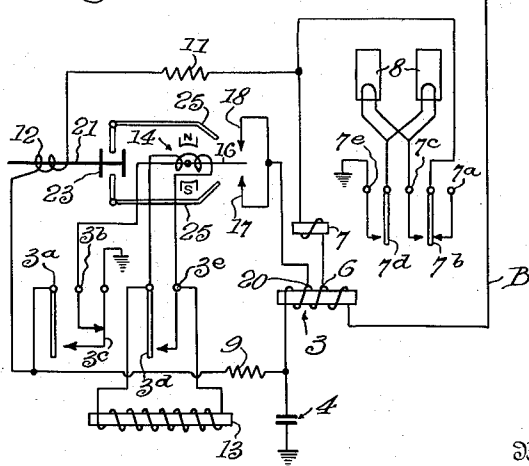
Fig. 1.

10 GROUPS
19 MINES IN EACH GROUP

GROUP NO.2

GROUP NO.1

Fig. 2.



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5 Sheets-Sheet 2

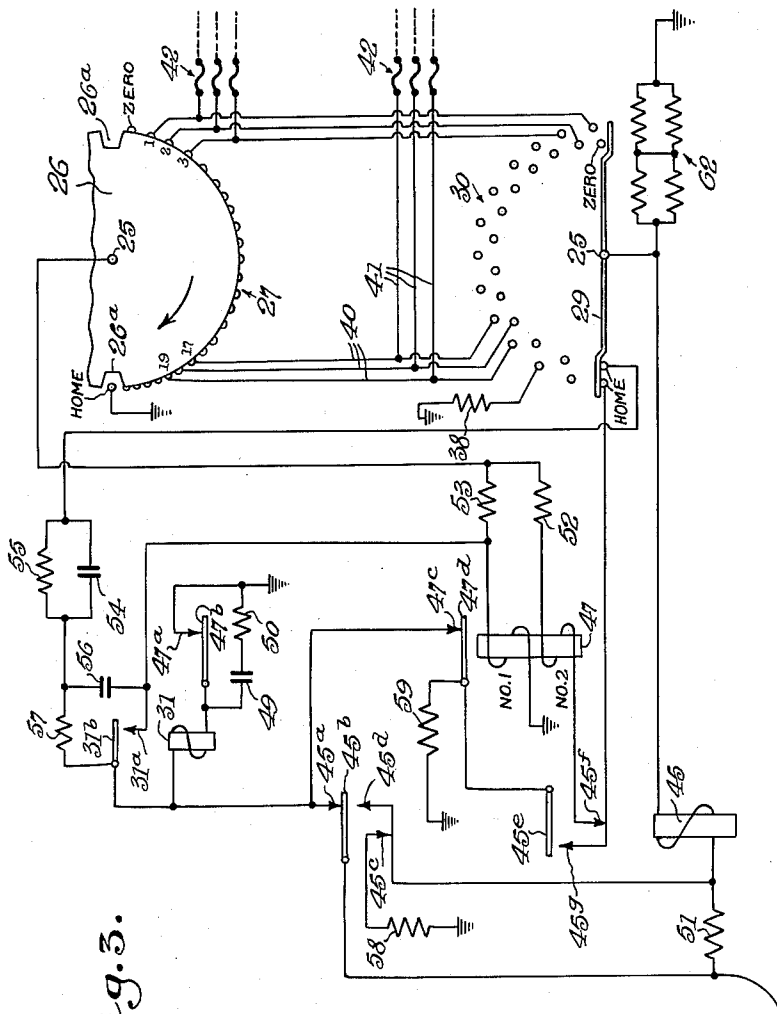


Fig. 3.

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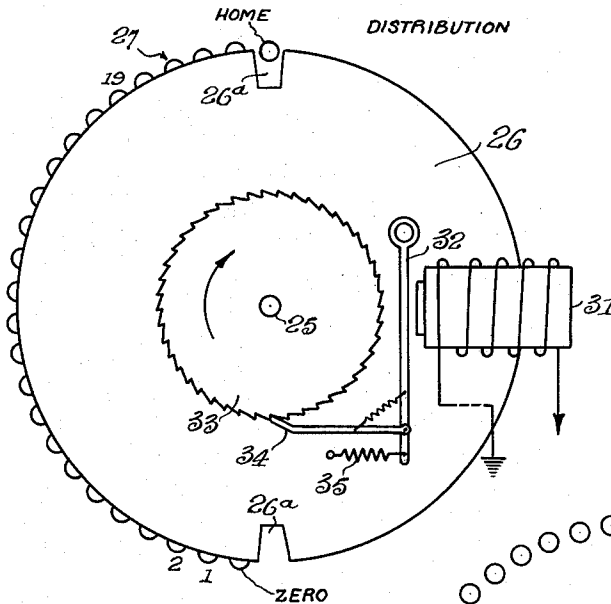


Fig. 4.

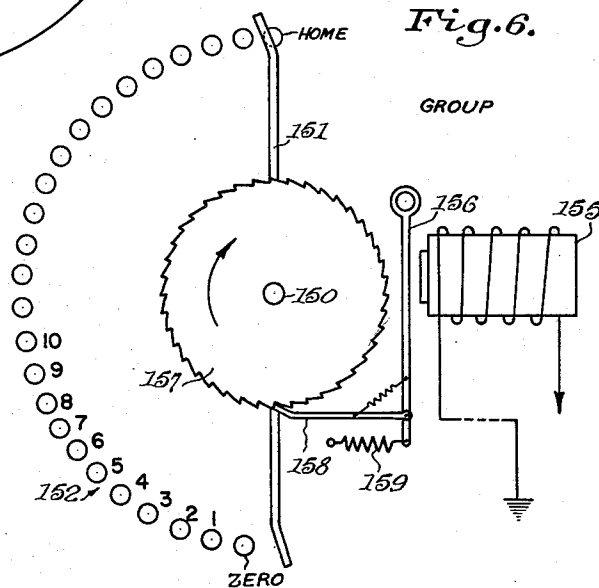


Fig. 6.

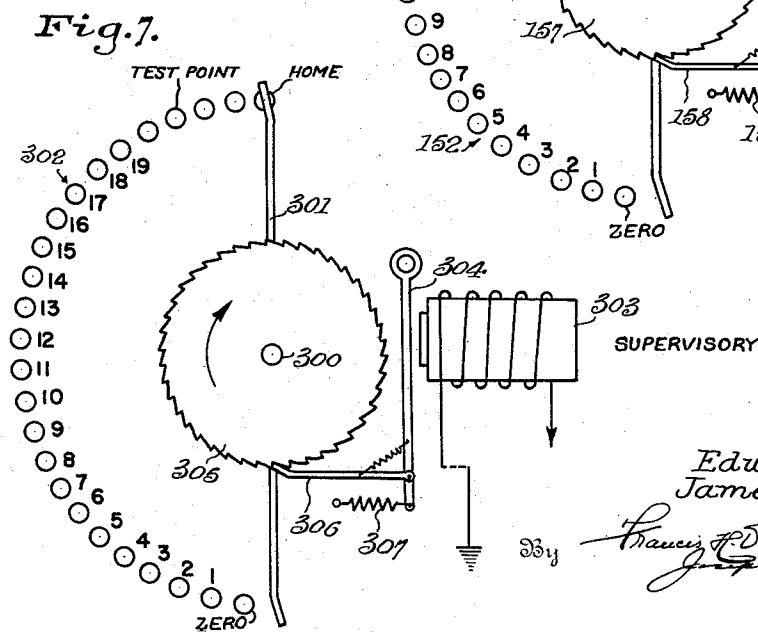


Fig. 7.

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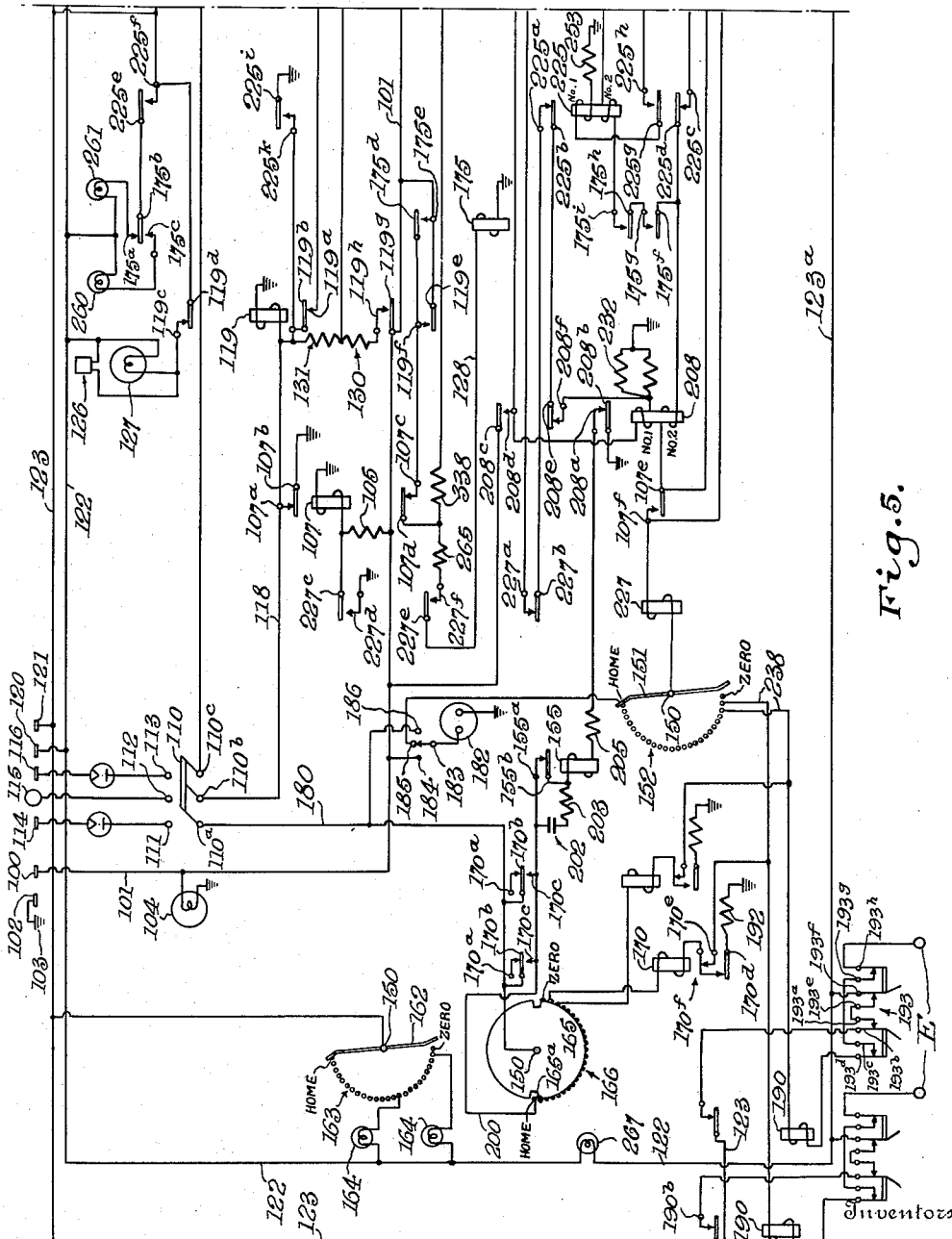
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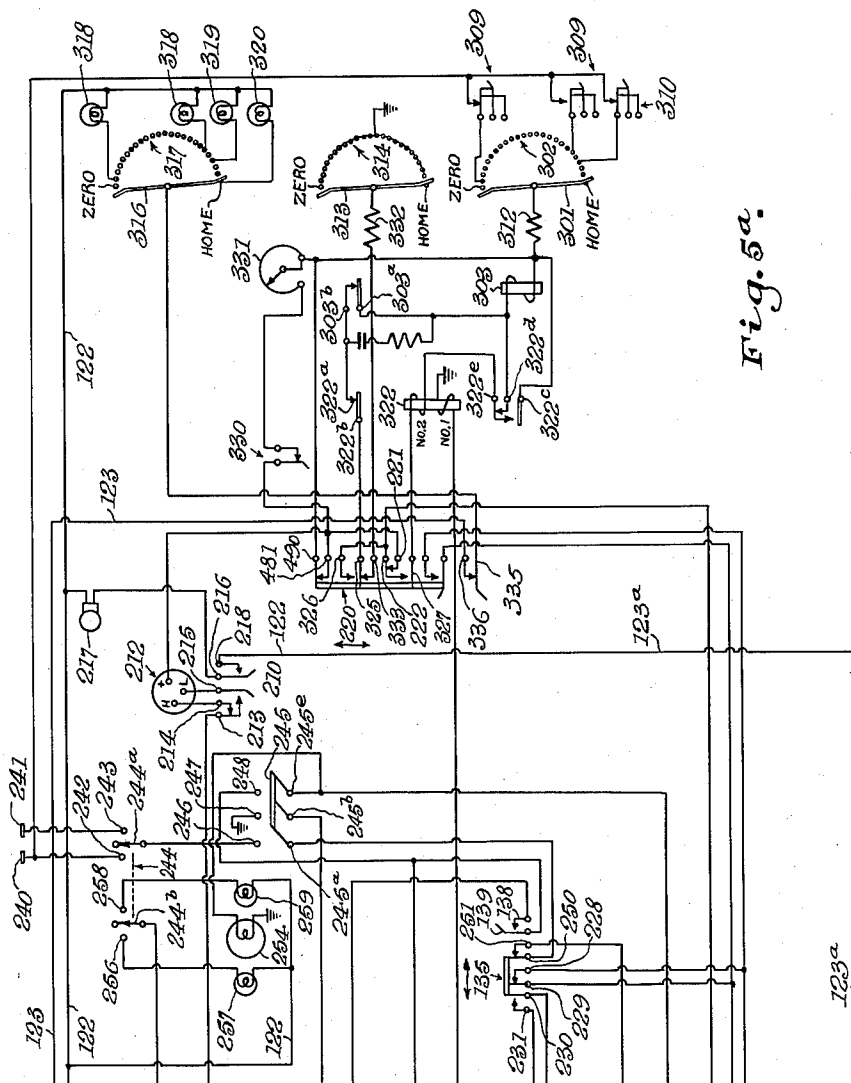


Fig. 5a.

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SUBMARINE MINE CONTROL SYSTEM

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Filed Mar. 12, 1946, Ser. No. 653,930

15 Claims. (Cl. 102-11)

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

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without payment to us of any royalty thereon.

This invention relates to submarine mines, and more particularly to controlling the operation thereof.

A submarine or underwater mine of the controlled type usually comprises a watertight case containing an explosive and an arming-and-firing device, and has associated therewith an electrical cable extending to a shore control station (commonly called a "casemate") and through which the arming-and-firing devices are controlled and/or operated. From the casemate, or shore control station, the operator has manual or automatic control over the firing or disarming of a mine which has been influenced by a passing vessel, as will appear more fully hereinafter. By such control the mine field can be made safe for the passage of friendly shipping or can be closed to all shipping if an enemy attack is imminent. By appropriately applying power from the shore control station, the operator can test or detonate a controlled submarine mine without the mines being influenced by a vessel.

These submarine mines may be of either the "ground" or the "buoyant" type. A ground mine is so designed that when its case is loaded it rests on the floor of the ocean or other area to be protected, while a buoyant mine is anchored at a predetermined depth. In either case, the mine is usually susceptible to arming by certain types of influence imposed by a marine vessel in proximity thereto; the devices for accomplishing the same being known as "detection devices," and include, for example, those which are magnetically operated. Depending on the tactical situation, and the manner in which power is applied, the mine can be: (1) fired instantly upon selection; (2) fired after a time delay; or (3) be disarmed.

Modern fields usually comprise a number of parallel lines of mines, the individual lines being arranged in groups. For example, high efficiency may be obtained with say 10 groups of mines, each group of which comprises nineteen (19) ground mines.

The teachings of the present invention are especially concerned with a system of submarine mine control in which a group of mine (of either of the two basic types described) submerged offshore and constituting a distant station is connected through a single conductor to a casemate, or shore control station, the respective mines of each of the groups being remotely controlled from the casemate through the instrumentality of a normally inactive automatic selector situated at the distant station, the mines being fired selectively from the casemate; or if desired, automatically by the use of the detection devices previously referred to. According to such a system the automatic selector mechanism is situated in the midst of the mine field at the distant station and functions to establish a path for the passage of electrical energy from the casemate through the control elements at a mine. The arrangement is such that the components of the submerged mine field may be selectively fired from the casemate through the conjoint action of the automatic selector situated at the distant station in the midst of the mine field and a series of devices controlled from the casemate and functioning when energized to cause the automatic selector to step-to and lock-on a selected mine for the purpose of establishing the electrical path aforesaid.

Such a system utilizes a pair of automatic selectors, one of the selectors being included in an operating panel which is located at the casemate, the other being disposed at the distant station in the midst of the submerged mine field, the two selectors, which are normally at rest on the "Home" position, being adapted to step in coordinated sequence to, and to stop on, a mine circuit which has been armed, the operating circuits for the respective automatic selectors embodying means for restoring the proper sequence to the selectors should their order of stepping relation be disrupted.

A system of the type to which the present invention relates is so designed that the operator at the operating panel may be informed at any time which mine in the group is operatively connected to the mine control system; and when rendered alert by application of the operating power, the system is mechanically and electrically silent (i.e., its operation will not produce disturbances of either a mechanical or electrical nature which could be easily discovered by detecting apparatus employed for the purpose of locating the mine field).

In such a system, electro-mechanically controlled units normally disrupt the firing circuit, and preclude the application of firing power to the shore cable, until the selector at the distant station has definitely locked on the mine selected for firing. After firing the mine automatically controlled, interacting electromechanical means remove all power from the shore cable and maintain the system in this condition until circuits of relatively high potential energy have been broken and the electro-mechanical components of the system restored to their normal positions, whereby to preclude accidental firing of another mine.

Another advantage of a system of the type described is that one or more mine groups may be controlled, or supervised, from a single supervisory system in the operating panel located at the casemate. The electrical characteristics of the entire system, and of any mine circuit in the system, may be readily ascertained at the shore station; and all of the mines of the submerged mine group may be successively fired while restricting application of the relatively high potential firing power to each mine in the order in which the respective mines have been conditioned for firing.

The control equipment ashore cooperates with a distribution box which is planted in the mine field and comprises the "distant station" referred to hereinbefore. A single conductor shore cable extends from the control equipment ashore to the distribution box; and from the latter an individual mine cable extends to each of the mines in the group. Within the distribution box is a selector assembly in the form of a distribution rotary stepping switch. This assembly is the junction for the individual mine circuits of a group with the single conductor shore cable; and through the said assembly any mine in a group may be connected with the control equipment ashore. Thus, any mine in the group may be selected, tested, fired, cleared, etc. through the medium of this selector assembly. By its action, a mine is automatically connected to the single shore cable when that mine has become armed by the influence of a passing vessel. Over this circuit, the control equipment ashore receives the signal that the mine has been armed, and the mine may then be fired or disarmed, as desired.

Within the distribution box is a time delay fuse for each of the individual mine cable circuits. This fuse provides a means for electrically disconnecting a faulty (or grounded) mine circuit from the group, an operation which will hereinafter be specifically described and referred to as "clearing" the mine, and for disconnecting a mine which has been fired.

For illustrative purposes only, the system of the present

invention is shown as associated with submerged mines of the ground type, the same comprising the usual mine case, explosive, detonators and primer charge, together with a firing device for detecting and signalling the presence of a vessel, and for arming and firing the mine. Briefly stated, the firing device of the illustrative form is armed (i.e. made operative) by magnetic influence.

It is among the objects of the present invention to attain the advantages of a system of the type described with a combination of instrumentalities or elements which is relatively simple and inexpensive to manufacture, install and operate.

Another object is to provide a shore station for controlling a system of the class described which is readily portable.

Still another object of the present invention is the provision of a submarine mine control system employing at the casemate, or shore station, an operating panel comprising a group rotary stepping switch and a supervisory rotary stepping switch, both of which are fundamentally similar in construction and operation to the previously described distribution rotary stepping switch at each of the distant stations of the mine field; and it is through these elements that there is applied the power necessary to operate the system.

The invention, then, comprises the features hereafter fully described, and as particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative of but a few of a number of ways in which the principles of the invention may be successfully employed.

In the drawings:

FIGURE 1 is a schematic plan of a marine area with two groups of mines each shown in full lines, together with the mine cables leading to the distant station from which each group is connected and controlled, and the shore cables which connect the distant stations to the shore-disposed casemate or control station;

FIGURE 2 is a schematic diagram of the electrical elements and control circuits at one of the individual mines;

FIGURE 3 is a schematic diagram of the electrical elements and control circuits at one of the ten distant stations from which each group of mines is controlled;

FIGURE 4 is a diagram of a portion of the distribution rotary stepping switch at the representative distant station of FIGURE 3;

FIGURES 5 and 5a collectively represent a schematic diagram of the electrical elements and control circuits of the operating panel, when it is assumed that the fragmented conductors illustrated at the top of FIGURE 5 are connected to the fragmented conductors illustrated at the bottom of FIGURE 5a;

FIGURE 6 is a diagram of a portion of the group rotary stepping switch which, as before stated, connects the control circuits with the desired group of mines through the appropriate distant station; and

FIGURE 7 is a diagram of a portion of the supervisory rotary stepping switch, previously referred to, which forms part of the operating panel.

Power

The mine control system of the present invention is shown, in the illustrative embodiment, as utilizing five (5) classes of electrical power, the same being substantially as follows and obtainable in any suitable manner:

110-volt direct current operating power,
250-volt direct current selection and clearing power,
550-volt direct current firing power,
6.3-volt alternating current signalling power,
2.5-volt alternating current filament power.

The 110-volt direct current is used to operate the selective apparatus, i.e. to move the rotary stepping switches

from circuit to circuit. The operating circuits have telephone-type relays which are adjusted to operate on specified current values, usually in the order of milliamperes.

The 250-volt direct current selection and clearing power is used for selecting any mine circuit from the control station for testing the mine, or firing by observation, and for clearing a mine. "Selection" is the action of stopping the distribution rotary stepping switch at a distant station on a particular mine circuit for testing the circuit or for firing the mine by observation. As before stated, "clearing" a mine is the action of electrically disconnecting a grounded mine circuit from the system. A partially grounded mine will interfere with the normal control and supervision of the entire group of mines of which it is a part. It is therefore necessary to provide some means of electrically eliminating such a mine from the group so that the operator can maintain proper control of the remaining serviceable mines. When selecting a mine, the full amount of 250-volt direct current selection power is reduced to approximately 190 volts by a resistor in order to prevent the occurrence of the clearing function when the selection feature is desired. Using the resistor to decrease the voltage to 190 volts for selection purposes obviates the necessity of providing a separate voltage supply between the 110-volt direct current selection power and the 250-volt direct current clearing power. Selection power at full value of 250 volts is used for cleaning a mine.

The 6.3-volt alternating current mine signalling power is used at the operating panel for illumination of the pilot lights and actuation of a signalling buzzer and a signalling bell for purposes which will later appear. Referring to FIGURE 1, the letter A designates the individual submerged mines, each of which comprises a mine case, explosive, detonators, priming charge etc.; and the firing device (for detecting and signalling the presence of a vessel, and for arming and firing the mine). These mines A are shown as being arranged in groups of nineteen (19), two of these groups being graphically represented in full lines and labelled "Group No. 1" and "Group No. 2." As previously stated, the teachings of the invention contemplate ten (10) groups each comprising nineteen (19) ground mines; but in the interests of simplicity, the complete system and its modes of operation may be thoroughly understood from the illustration and description of the two groups aforesaid.

Each of the mines of a single group is connected by a submerged single-conductor mine cable B to a submerged distant station C. Each of these submerged distant stations C contains in a water-tight housing a selective switching device, preferably of the rotary stepping type to which reference was previously made, the same being designated the "distribution rotary stepping switches." Each of these distribution rotary stepping switches (one at each of the distant stations C) is connected by a single-conductor shore cable D to a cable terminal E disposed ashore. It will be understood by those skilled in the art that the teachings of the invention are in no way limited by or to this exact number of mines, or groups, the same having been selected as suitable for illustrative purposes and as readily conforming to a large number of present day frequently encountered tactical situations.

In the following description certain relays and, specifically the operating coils thereof, are represented by certain numbers, while the contacts of the same relay are identified by lettered exponents. In the drawings all relays are shown in the deenergized or released condition, with the contacts of the relays being in alignment with the axes of the respective operating coils thereof, the stationary contacts being represented by an arrow and the movable contacts by a pivoted arm which is adapted, upon actuation, to move toward its respective operating coil.

The Firing Devices at the Individual Mines

In FIGURE 2 of the drawings there is illustrated in schematic diagram the electrical elements and circuits of the firing device of a representative mine. In this view there is indicated at B the mine cable which extends from the distribution rotary stepping switch at the associated distant station C. The mine cable B leads into the mine casing and connects through the entire winding (555.5 ohms) of the operating coil of a mine latch relay 3, and a capacitor 4 (2 mfd.) to ground. The function of this mine latch relay 3 is to set up, and hold closed, a normal mine circuit by transferring the path to ground from one of low resistance to high resistance when the control system is set for automatic fire. When the 250-volt direct current selection power is applied to the mine, in a manner which will later appear the mine latch relay 3 operates on the charging current of the capacitor 4.

At a point 6 (of 0.5 ohm resistance) on the winding of the operating coil of the mine latch relay 3 there is connected in series the operating coil (5 ohms) of a slow-operated firing relay 7, and a movable contact 7b of the said firing relay. This movable contact 7b cooperates with a stationary blank or rest contact 7a when the operating coil of the firing relay 7 is deenergized. When the operating coil of the firing relay 7 is energized the movable contact 7b cooperates with a stationary contact 7c which is connected in series to a pair of conventional detonators generally indicated at 8. The two detonators 8 are connected in parallel to insure that the mine will fire when the need arises, and each may acceptably require 400 milliamperes to fire it. A movable contact 7d is also connected in series to the said detonators 8; and when the operating coil of the firing relay 7 is energized this movable contact cooperates with a stationary contact 7e which is connected to ground. Thus, the firing relay 7 closes to ground the firing circuit of the detonators 8, the two-contact arrangement being provided to double the safety factor for the air gap when 250-volt direct current selection power is applied to the mine circuit through the mine cable B.

When the mine relay 3 is operated by the application of the 250-volt direct current selection power the following circuits are established:

Entire winding (555.5 ohms resistance) of the operating coil of the mine latch relay 3, resistor 9 (3200 ohms) through contacts 3a and 3c to ground. Point 6 (0.5 ohm) on the operating coil of the mine latch relay 3, resistor 11 (1500 ohms), reset solenoid 12 and through contacts 3a and 3c to ground.

Thus, the resistor 9 establishes sufficient potential on the operating coil of the firing relay 7 to insure that it will be energized when the 550-volt direct current firing power is applied. In addition, the resistor 9 (3200 ohms) limits current through the operating coil of the mine latch relay 3 to a value such that it will not damage the windings thereof. This resistor 9 also aids in limiting the current for the operating coil of the firing relay to a non-operative value when 250-volt direct current selection power or 250-volt clearing power is applied.

The resistor 11 (1500 ohms) which is in series with the operating coil of the firing relay 7 also assists in limiting the current flow through the said firing relay to a non-operative value when 250-volt direct current selection power or 250-volt clearing power is applied. This resistor 11 also assures sufficient potential across the detonators 8 for firing after the firing relay has operated.

As before stated, the invention contemplates the provision of means at the individual mines A for detecting the proximity of a vessel; and from this function to automatically arm the particular mine in order that it may, if desired, be fired either automatically, or otherwise. According to the form of the embodiment illustrated in FIGURE 2, the arming of a representative mine may be

accomplished automatically through detection of the magnetic field of a proximate vessel. In this embodiment, there is provided a coil rod 13 which may comprise a cylindrical iron core with a winding which is rubber-covered, the ends of the winding connecting with the ends of the operating coil of a sensitive relay generally indicated at 14. The magnetic influence of a proximate vessel will induce a voltage in the coil rod 13 which causes a minute current to flow in the windings of the coil rod.

The sensitive relay 14 has two components, i.e. the solenoid 12 which was previously referred to, and a galvanometer movement. The sensitive relay responds to the currents induced in the coil rod to detect the presence of the vessel and arm the mine.

The operating coil of the sensitive relay 14 has associated therewith a movable contact arm 16 which corresponds to the pointer of a commercial galvanometric indicating instrument. Associated with the movable contact arm 16, which is adapted for deflection in either of two directions, is a pair of contacts 17 and 18 both of which connect with the operating coil of the mine latch relay 3 at a point 20 (of 30 ohms resistance). Extending through the solenoid 12 of the reset device is a plunger 21, carrying a yoke 23 which engages the ends of a pair of pivoted galvanometer reset fingers 25, the function of which is to center the movable contact arm 16 when the operating coil of the reset solenoid is energized. The movable contact arm 16 of the sensitive relay 14 is connected to a stationary contact 3b which is engaged by the displaceable contact 3c which connects to ground. The contact 3c is displaced from its engagement with the stationary contact 3b by the previously mentioned movable contact 3a which is actuated by the mine latch relay 3. This movable contact 3a is connected between the series-connected ends of the resistor 9 and the solenoid 12; and when at rest remains out of contact with the grounded displaceable contact 3c. According to the foregoing arrangement, when the movable contact arm 16 of the sensitive relay 14 is deflected, a new circuit is established through either contact 17 or contact 18 to complete the following low resistance path to ground after which the flow of current will cause the distribution rotary stepping switch (at the associated distant station C) to step off and select the mine:

Mine cable B; operating coil of the mine latch relay 3 to point 20 (of 30.5 ohms resistance); contact 17 or 18 of the sensitive relay 14; movable contact arm 16; contacts 3b and 3c to ground.

The distribution rotary stepping switch and its manner of stepping will later appear.

When the mine has been selected, the additional flow of current to ground through the operating coil of the mine latch relay to the point 20 (of 30.5 ohms resistance) of its winding will energize and operate the mine latch relay whereupon the contacts 3b and 3c open and the contacts 3a and 3c close. This transfers the path to ground from one of low resistance to one of high resistance in the following circuit:

Mine cable B; through the entire winding (555.5 ohms) of the operating coil of the mine latch relay 3; resistor 9; contacts 3a and 3c to ground.

A parallel path is as follows:

Mine cable B; operating coil of the mine latch relay to point 6 (0.5 ohms); operating coil of the firing relay 7; resistor 11 (1500 ohms); the solenoid 12; contacts 3a and 3c to ground.

When the last-mentioned path is energized, the solenoid 12 resets the sensitive relay 14 (i.e. the pivoted arms 25 push the movable contact arm 16 back to the center position).

The make contacts 3d and 3e of the mine latch relay 3 short-circuit the high impedance feed-back of the coil rod 13 at the time of selection. If the coil rod is not short-circuited when the sensitive relay 14 is reset (through the energization of the solenoid 12), the sensitive relay

acts as a generator feeding the circuit of the coil rod, which is highly inductive. The generated current induces a magnetic field which, when it collapses, generates and feeds back current which would again deflect the movable contact arm 16 of the sensitive relay. The mine would thus be rearmed.

If the selected mine is to be fired, the operator at the shore-based operating panel applies firing power to the appropriate shore cable terminal E. The increase in voltage causes the firing relay 7 to fully energize and operate. At this time the current has the following very low resistance path to ground through the detonators 8:

Mine cable B; point 6 (0.5 ohms) of the winding of the operating coil of the mine latch relay 3; operating coil (5 ohms) of the firing relay 7; firing relay contacts 7b and 7c; detonators 8; and firing relay contacts 7d and 7e to ground.

In order to disarm the firing device at the mine A, the operator interrupts the flow of current to the shore cable terminal E; thereby deenergizing and releasing the mine latch relay 3 whereby the contacts 3a and 3c open, and the contacts 3b and 3c close.

The Distribution Rotary Stepping Switches

In FIGURE 3 of the drawings there is illustrated in schematic diagram the electrical elements and wiring circuits at each of the ten (10) distant stations of which two (2) are indicated at C in FIGURE 1. As before stated, at each of these submerged distant stations C there is a distribution rotary stepping switch which provides the means through which any mine in its group may be selected, tested, fired, etc.

Broadly stated, each of the distribution rotary stepping switches is a rotary stepping switch which is operated in step-by-step fashion by a motor magnet. In a commercially obtainable form, it comprises three banks of twenty-five stationary contacts each, each bank being in the form of a half-cylinder, the said banks being served by three (3) wiping instrumentalities which are secured to a common rotatable shaft. Such a switch comprises three wiping instrumentalities in the form of electrically conductive double-ended wiper-arms having their wiping-ends arranged 180° apart so that when one of the wiping-ends of a wiper-arm steps off the last contact in its respective bank of contacts, the other wiping-end of said wiper-arm will engage the first contact in said bank.

In the case of the distribution rotary stepping switch of the system of the present invention, it comprises two double-ended wiper-arms of the type described; the third wiping instrumentality taking the form of an electrically conductive disk for a purpose which will later appear.

The three sets of wiping instrumentalities and their associated contacts are designated as "levels"; the two comprising the two wiper-arms aforesaid being "mine levels," and the third being a "fan level." The wiper-arms of the two mine levels are electrically connected together, aligned with respect to each other, and operated in unison. In the interests of clarity, the banks of the stationary contacts of these two mine levels are illustrated in FIGURE 3 as being concentrically disposed, with the wiring arrangement such that one level (i.e. the inner one) has a "zero" contact and carries all of the even-numbered contacts; while the other of the mine levels has no "zero" contact and carries all of the odd-numbered contacts. Both levels have a "Home" contact as indicated. The wiping-ends of these two wiper-arms do not bridge across between any two of the adjacent stationary contacts of their respective banks.

In FIGURE 4, there is schematically illustrated a part of a representative distribution rotary stepping switch, the same comprising a shaft 25 on which there is mounted the wiping instrumentalities previously mentioned. The fan level of the representative distribution rotary stepping switch comprises a disk 26 having two diametrically opposite notches 26a, and a bank of twenty-five (25) sta-

tionary contacts 27 of which the first is a "zero" contact and the next succeeding nineteen (19) contacts (see FIGURE 3) are ultimately connected to the cables B of nineteen mines A which are controlled through that particular distribution rotary stepping switch. The last of the series is used for a "Home" contact which is grounded as shown in FIGURE 3.

The two diametrically opposite notches 26a in the periphery of the disk 26 exempt each contact as the disk rotates. All other contacts are connected in parallel to ground by the disk 26 (FIG. 3). If the disk 26 is connected to the cable when it is in the "Home" position, all mine cables in the group are connected in parallel by the disk. In the "Home" position, one of the notches 26a in the disk opposes the "Home" ground contact, and therefore, no mine can be grounded when the system is at "Home." When the notches of the disk are away from the "Home" position, all mine contacts except the one opposed by the then active notch are tied together in parallel and grounded so that firing power cannot be applied to more than one mine at a time. The disk 26 drops its wipers just before the non-bridging wipers of the other levels make connection with the corresponding contact in one of the other banks. In other words, the disk and the wiping end of a wiper-arm should never make simultaneous contact with corresponding contacts in their respective banks.

Behind the disk 26 of FIGURE 3 is the pair of double-ended wiper-arms of the two mine levels, the same being considered for present purposes as a single unit, and indicated in FIGURE 3 at 29. The two banks of stationary contacts served by these wiper-arms 29 are collectively indicated at 30. Although the disk 26 and the unitary double-ended wiper-arms 29 are shown in the composite representation of FIGURE 3 in side-by-side relationship, these wiping instrumentalities are secured to, and rotate on, the shaft 25 as aforesaid. Accordingly, while the disk 26 is shown as rotatable in clockwise fashion, the unitary wiper-arms 29 appear reversed in the composite showing of FIGURE 3, whereby they are rotatable in the opposite (or counter-clockwise) direction.

Referring again to FIGURE 4, disposed adjacent the shaft 25 of the representative distribution rotary stepping switch is a motor magnet 31, the latter being connected between circuits which ultimately include the shore cable D on the one hand and a suitable ground on the other. A description of these circuits for one of the distribution rotary stepping switches will shortly follow.

Associated with the motor magnet 31, and disposed between it and the shaft 25 is a pivotally mounted armature 32. The shaft 25 has secured thereto a ratchet wheel 33 which is engaged by a stepping pawl 34, the latter being pivotally mounted on, and extending in right-angular relationship from, the armature 32. The stepping pawl 34 is resiliently held against the ratchet wheel 33 in any suitable fashion; and is biased tangentially of the said ratchet wheel and with sufficient force to rotate the same in a clockwise direction (as seen in FIGURE 4), by a pawl spring 35. Thus, the coercion of the motor magnet 31 of the representative distribution rotary stepping switch and the pawl spring 35 will effectively cause the stepping pawl 34 to rotate the ratchet wheel 33 in step-by-step relationship whereby the unitary wiper-arms 29 (as seen in FIG. 3) will advance from the "zero" contact to, and through, the next succeeding nineteen (19) contacts (which connect with the mine cables B), and with other contacts whose functions will shortly appear. As the ratchet wheel 33 (FIG. 4) rotates, the ends of the unitary wiper-arms 29 (FIG. 3) and the diametrically opposite notches 26a of the fan disk 26, oppose each individual contact of their respective cooperating banks of stationary contacts. The disk 26 of the distribution rotary stepping switch (at the representative distant station C) drops contact with its bank of stationary contacts just before the non-bridging wiper-ends of the unitary wiper-

arms 29 engage their corresponding contacts. In other words, a disk and a wiper-arm never make simultaneous contact with corresponding contacts of their respective stationary banks.

Referring back to FIGURE 3, wherein the fan level and the mine levels of a representative distribution rotary stepping switch are compositely illustrated in back-to-back relationship with the mine level therefore operating in counter-clockwise relationship, the nineteen mine contacts of the two mine levels are connected to correspondingly arranged contacts of the bank of stationary contacts 27 of the fan level. In the composite mine level, the next succeeding contact after the one which is numbered 19 is left blank; and the next, which is numbered 21 is connected through a resistor 38 (1500 ohms), to ground, the same being used as an artificial mine level, for test purposes as will appear more fully hereinafter. The next two contacts, after the one which is numbered 21, are left blank; the two next succeeding contacts of the two levels are designated as "Home." These last two contacts of the composite mine level are radially aligned with respect to the shaft 25 of the distribution rotary stepping switch, whereby both of them are simultaneously contacted by the unitary double-ended wiper-arms 29 in their rotative movement.

As will be readily understood from FIGURE 3 the corresponding stationary contacts of the two mine levels and the single fan level are connected through suitable conductors collectively indicated at 40. Through conductors collectively indicated at 41 the conductors 40 each connects with a mine cable B (see FIG. 1), each of the said conductors 41 including a fuse 42 (0.15 ampere, 20 ohm fuse). The fuses 42 are of the time-delay type, being rated, for example, to carry 150 milliamperes continuously but to rupture in 15 seconds minimum (40 seconds maximum time) at 250 milliamperes. They provide a means of electrically disconnecting a faulty mine circuit from the group; the operation which is referred to as "clearing" the mine. The last or "Home" contact of the fan level is connected to ground as shown. Before any voltage is applied to the shore cable all relays of the distribution rotary stepping switch are in the deenergized or released position shown in FIGURE 3.

The motor magnet 31 (170 ohms) of the representative distribution rotary stepping switch receives current from the shore cable D (see FIG. 1) through movable and stationary contacts 45b and 45a, respectively, of a locking relay 45, and the current thus received flows through movable and stationary contacts 47b and 47a respectively, of a timing relay 47 to ground. The motor magnet 31 is also grounded through a capacitor 49 (1 mfd.) and a resistor 50 (150 ohms). The timing relay, which will later be more specifically described, is a slow-acting relay, and the current surge through its windings will not cause it to operate ahead of the motor magnet 31. In addition, it operates through a series of resistors (as will later appear) which impose too much resistance to permit it to operate at this time. The motor magnet 31 has its own contacts 31a and 31b which when closed by energization of the motor magnet establish the following low resistance current circuit:

Shore cable D, contacts 31b and 31a of the motor magnet, No. 1 winding (500 ohms) of the operating coil of the timing relay 47, to ground. This energizes the timing relay 47, causing it to open its contacts 47a and 47b and 47c and 47d. The opening of the contacts 47a and 47b breaks the circuit for the motor magnet 31 which when deenergized permits the pawl spring to advance the stepping pawl 34 (FIGURE 4) one notch. This moves the unitary double-ended wiper-arms 29 (counterclockwise as viewed in FIGURE 3) off "Home" and onto the "zero" contact shown. When the motor magnet 31 was deenergized, its contacts 31a and 31b open and interrupt the low resistance circuit to the No. 1 winding (500 ohms) of the operating coil of the timing relay 47.

In moving off "Home," the unitary double-ended wiper-arms 29 breaks the following high resistance circuit which up until then had also energized both the No. 1 (500 ohms) and the No. 2 (40 ohms) windings of the operating coil of the timing relay 47:

From the shore cable D through a resistor 51 (2300 ohms), and the operating coil (75 ohms) of the locking relay 45, through unitary double-ended wiper-arms 29, the "Home" contact of the mine level of the distribution rotary stepping switch; contacts 45f and 45g of the locking relay 45, No. 2 winding (40 ohms) of the operating coil of the timing relay 47, resistor 52 (100 ohms), resistor 53 (4500 ohms), No. 1 winding (500 ohms) of the operating coil of the timing relay 47, to ground. (The reason for breaking the foregoing circuit, by the movement of the unitary double-ended wiper-arms 29 off the "Home" contact, is because the current flow through it is in excess of the holding value of the timing relay 47 and will not permit the latter to release.)

Since the foregoing circuit is interrupted by the movement off "Home" of the wiper-arms 29, the deenergized timing relay 47 now releases, and the motor magnet is again energized and the stepping cycle will repeat itself. As the flow of current through the No. 1 winding (500 ohms) of the operating coil of the timing relay 47 is sufficient to operate that relay it is not necessary to re-establish the current flow through the No. 2 winding (40 ohms).

Stepping the double-ended wiper-arms 29 of the mine level of the distribution rotary stepping switch to the "zero" contact (moving counterclockwise as shown) grounds the fan level, since the operative one of the notches 26a no longer exempts the "Home" contact which is grounded. The capacitor 4 at the mine discharges to ground through the fan disk 26 of the distribution rotary stepping switch any time the disk is rotated away from the "Home" contact.

When the unitary wiper-arms 29 are contacting the "Home" contacts of the two mine levels, the inner "Home" contact connects with a capacitor 54 (16 mfd.) which is open when the wiper-arm is away from the "Home" contact, and its charge is dissipated through a resistor 55 of high resistance (250,000 ohms). If there are no armed or grounded mine circuits, the unitary wiper-arms 29 of the distribution rotary stepping switch will step from contact-to-contact and arrive at the "Home" position.

The capacitor 49 (1 mfd.) and resistor 50 (150 ohms), suppress arcing between the contacts 47a and 47b of the timing relay; and a capacitor 56 (1 mfd.) and resistor 57 (150 ohms) perform the same function between the contacts 31a and 31b of the motor magnet.

Stepping to "Home" Position

When the motor magnet 31 of the representative distribution rotary stepping switch is deenergized or released it drives the said distribution rotary stepping switch from the contact numbered 23 to the "Home" position, where it will stop. The motor magnet 31 will remain in the deenergized position because current is passing through both of the windings of the operating coil of the timing relay 47. The holding circuit is as follows:

Shore cable D; resistor 51 (2300 ohms); operating coil of the locking relay 45; unitary wiper-arms 29, "Home" contacts; contacts 45f and 45g of the locking relay; No. 2 winding (40 ohms) of the operating coil of the timing relay 47; resistor 52 (100 ohms); resistor 53 (4500 ohms); No. 1 winding (500 ohms) of the operating coil of the timing relay to ground.

With the contacts 47a and 47b of the timing relay 47 held open, the motor magnet 31 has no circuit, and the distribution rotary stepping switch cannot step off "Home" until the current supply is removed from the timing relay to make it release. Since the capacitors 4 of each of the mines controlled by the representative distribution rotary stepping switch are again placed in parallel, and

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the grounded "Home" contact of the fan level is again exempted by the proximate notch 26a, a current surge again charges each of the capacitors 4.

The capacitor 54 (16 mfd.) in parallel with the operating coil of the locking relay 45 holds the charging current for the capacitors 4 at the mines below the operating current required by the said locking relay. If the locking relay 45 were to operate on the surge its contacts 45f and 45g would open and release the timing relay 47, whereupon the unitary double-ended wiper-arms 29 would automatically step off the "Home" contacts and continue to rotate. As the "Home" contact of the fan level is connected to ground, and the unitary wiper-arms 29 of the mine selection levels are connected through their axes to the shore cable D, all mines in the group are connected in parallel to the said shore cable when the said unitary wiper-arms are standing on the "Home" contacts.

Stepping to An Armed Mine

Let it be assumed that the distribution rotary stepping switch is at the "Home" position and a mine has become armed (as through the influence of a proximate marine vessel); then a low resistance path to ground will be created at the firing device of the mine, and enough current will flow through the operating coil (75 ohms) of the locking relay 45 to operate it. The circuit of the current will then be as follows:

Shore cable D; resistor 51 (2300 ohms); operating coil of the locking relay 45; unitary wiper-arms 29; "Home" contacts; contacts 45g and 45f of the locking relay; No. 2 winding (40 ohms) of the operating coil of the timing relay 47; resistor 52 (100 ohms); disk 26 of the fan level; conductors 40 and 41; fuse 42; mine cable B; operating coil of the mine latch relay 3 to the point 20 (of 30.5 ohms resistance); through either of the contacts 17 or 18 to the deflected movable arm 16; contacts 3b and 3c to ground.

Thus, the locking relay 45 at the distant station C is energized, whereupon the contacts 45a and 45b are opened and the contacts 45b and 45d are closed. This shunts the resistor 51 (2300 ohms) and increases the flow of current through the operating coil of the locking relay 45; and the opening of the contacts 45a and 45b opens the circuit of the motor magnet 31 at a second place. It also opens the contacts 45c and 45d, which removes a bleeder resistor 58 (5500 ohms), closes contacts 45e and 45g, and opens contacts 45f and 45g, thus opening the holding circuit for the timing relay 47. At this time the circuit is as follows:

Shore cable D; contacts 45b and 45d of the locking relay; operating coil of the locking relay 45; unitary wiper-arms 29 and "Home" contacts; contacts 45g and 45e; resistor 59 (5000 ohms) to ground.

The slow-release timing relay 47 releases, but the locking relay 45 holds in the operated position because of the path to ground through the resistor network 62 (20,000 ohms); and also through the contacts 45e and 45g of the locking relay and the resistor 59 (5000 ohms). When the timing relay 47 finally releases, it closes its contacts 47a and 47b and 47c and 47d, thereby completing the following circuit to the motor magnet 31 of the distribution rotary stepping switch:

Shore cable D; contacts 45b and 45d of the locking relay; operating coil of the locking relay; unitary wiper-arms 29; "Home" contacts; contacts 45e and 45g; contacts 47c and 47d of the timing relay; motor magnet 31; contacts 47a and 47b of the timing relay to ground.

When the motor magnet 31 operates, the timing relay 47 operates, and when the contacts 47c and 47d of the timing relay open, the locking relay 45 is held operated by current bled to ground through the resistor 59 (5000 ohms). The motor magnet 31 releases, and the unitary wiper-arms 29 step from the "Home" contacts to the "zero" contact, thereby breaking the holding circuit for the locking relay 45. The small amount of current bled

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through the resistor network 62 (20,000 ohms) is not enough to hold the locking relay 45 in the operated position, and it releases. Upon release, the locking relay 45 closes its contacts 45a and 45b, thereby completing the circuit to the motor magnet 31. It also opens its contacts 45b and 45d, thereby removing the by-pass on the resistor 51 (2,300 ohms). At the same time, the release of the locking relay 45 opens its contacts 45e and 45g (no current) and closes its contacts 45f and 45g (no current). It also closes its contacts 45c and 45d, thereby completing the path to ground through the bleeder resistor 58 (5500 ohms).

The stepping cycle continues in the manner described hereinbefore until the mine circuit is contacted. At the moment the unitary wiper-arms 29 engage the armed mine's contact, the circuit is as follows:

Shore cable D; resistor 51 (2300 ohms); operating coil of the locking relay 45; unitary wiper-arms 29; conductors 40 and 41; fuse 42; mine cable B; operating coil of the mine latch relay 3 to point 20 (of 30.5 ohms resistance) to contact 17 or 18 of the sensitive relay 14; the deflected movable contact arm 16; contacts 3b and 3c to ground.

This current path causes the locking relay 45 to operate and open its contacts 45a and 45b, thereby releasing the timing relay 47. It also closes its contacts 45b and 45d, to by-pass the resistor 51 (2300 ohms) and thus increase the flow of current through the operating coil of the locking relay 45; and opens its contacts 45c and 45d to remove the path to ground through the bleeder resistor 58 (5500 ohms).

By-passing the resistor 51 (2300 ohms) in the manner described, permits the mine latch relay 3 to operate and close its contacts 3a and 3c. This transfers the path to ground in the firing device from one of low resistance to one of high resistance. The system will stay locked on the mine until the mine is fired or disarmed, and the locking relay 45 caused to release and re-establish the stepping circuits earlier described. While locked on the mine, the circuit is as follows:

Shore cable D; contacts 45b and 45d of the locking relay; operating coil of the locking relay; unitary wiper-arms 29; conductors 40 and 41; fuse 42; mine cable B; operating coil of the mine latch relay 3 to the point 6 (of 0.5 ohm resistance); operating coil of the firing relay; resistor 11 (1500 ohms); reset solenoid 12 (500 ohms); and contacts 3a and 3c of the mine latch relay to ground.

At the firing device, the following parallel circuit path also exists:

Mine cable B; entire winding (555.5 ohms) of the operating coil of the mine latch relay 3; resistor 9 (3200 ohms); contacts 3a and 3c of the mine latch relay to ground.

Disarming a Mine

With the circuits in the condition set forth immediately hereinbefore, the mine may be either disarmed or fired. To disarm the mine and start the system stepping, the locking relay 45 must be made to release and close its contacts 45a and 45b, to thereby complete a circuit through the motor magnet 31. In the operation of the control system of the present invention, the locking relay 45 is made to release by the removal of power from the shore cable D, the manner of which will shortly be described.

Firing a Mine

The application of firing power at 550 volts will cause the firing relay 7 to operate to thereby complete a circuit to ground through the detonators 8. When the mine is fired, the end of the mine cable B drops into the water and becomes grounded. The firing power ruptures the fuse 42 (0.15 ampere) and eliminates the circuit of that mine from the system. The only path to ground for firing power is now through the resistor network 62 (20,000 ohms) at the distribution rotary stepping switch. This current is sufficient to hold operated the locking

relay 45. Removing the firing power (550 volts direct current) from the shore cable D will permit the locking relay 45 to release and close its contacts 45a and 45b, thus completing the path for 110-volt direct current operating power to the motor magnet 31, whereby the unitary wiper-arms 29 will step to the "Home" position.

Selecting a Mine

This is initiated by opening the flow of 110-volt direct current operating power through the shore cable D, thus releasing the timing relay 47. The timing relay establishes the stepping circuit for the motor magnet 31 of the distribution rotary stepping switch so that when power is reapplied, the said switch will begin to step.

As the unitary wiper-arms 29 of the distribution rotary stepping switch steps through the field, it may be desired to stop it on a particular mine circuit. As the unitary wiper-arms 29 steps into engagement with the contact of the desired mine circuit, 250-volt direct current selection power is applied to the appropriate shore cable D, and the current flow is as follows:

Shore cable D; resistor 51 (2300 ohms); unitary wiper-arms 29; conductors 40 and 41; fuse 42; mine cable B; entire winding of the operating coil (555.5 ohms) of the mine latch relay 3; capacitor 4 (2 mfd.) to ground.

The current surge drawn in charging the capacitor 4 (2 mfd.) is enough to operate the locking relay 45 and the mine latch relay 3.

Operation of the locking relay 45 breaks the current path for the motor magnet at the contacts 45a and 45b of the locking relay, and the distribution rotary stepping switch locks on that particular mine circuit. To step the distribution rotary stepping switch from this mine circuit, it is only necessary to interrupt the supply of 110-volt direct current operating power from the shore cable D. This releases both the mine latch relay 3 and the locking relay 45. The locking relay 45 establishes the operating circuit to the motor magnet 31 so that when power is reapplied, the distribution rotary stepping switch will begin stepping. If there are no armed or grounded mine circuits, the unitary wiper-arms 29 will return to the "Home" position. Any mine circuit or the Test Point may be selected in the manner hereinbefore stated.

The Operating Panel

As before stated, FIGURES 5 and 5a collectively represent a schematic diagram of the electric elements and control circuits of the operating panel. This operating panel controls the individual mines A through the distribution rotary stepping switches and connects with the latter through the shore cable terminals E in a manner which will shortly appear.

Referring more particularly to FIG. 5, 110-volt direct current is supplied from a suitable source, to the input terminal 100 of the operating panel. From this input power terminal 100 of the operating panel there extends into the operating circuit the 110-volt direct current power lead 101. The other side of the operating circuit is connected to a common ground, as shown at 103. So long as power is being supplied to the power lead 101 there is illuminated a pilot light 104 (Operating Power), which is connected between the said power lead and a suitable ground, as shown.

The power lead 101 supplies current through a resistor 105 (of 1500 ohms resistance) the operating coil (450 ohms) of a slow-acting type of holding relay 107 and from the latter to ground.

The control system is put into operation by a triple-pole single-throw switch 110 which is shown in FIGURE 5 in the open position. The three poles of this operation switch, indicated at 110a, 110b and 110c are adapted to engage and cooperate with contacts 111, 112 and 113, respectively, the latter being respectively connected to input terminals 114, 115 and 116. The input terminals 114 and 116 are designated the "fan" and "wiper" input terminals,

for purposes which will be later described; while the input terminal 115 (Interlock Bus) is employed when it is desired to operate (through the control system of the invention) more than the previously described ten groups of mines. In such a case the desired additional group or groups (each group of which may acceptably be composed of nineteen submerged ground mines as described hereinbefore) are bussed to the interlock common input terminal 115. When the operation switch 110 is in closed position, its middle pole (i.e. 110b) carries the bussed interlock common circuits to a line 118 which connects through the operating coil (650 ohms) of a limiting relay 119 to ground.

A pair of input terminals 120 and 121 are connected to a suitable source of 6.3 volts alternating current and supply signal power to the circuits of the operating panel through the signal power leads 122 and 123, respectively. To the power lead 122 there is connected one side of the circuit of a buzzer 126 and one side of the circuit of a pilot light 127 (Interlock), the other side of the circuit of each of these instrumentalities being through contacts 119c and 119d of the limiting relay 119 to the signal power lead 123.

Between the power lead 101 (for supplying 110-volt direct current to the circuits of the operating panel) and the line 118 (which connects the middle pole 110b of the triple-pole single-throw operation switch 110 with the operating coil of the limiting relay 119) is a pair of aligned and connected resistors 130 (3500 ohms) and 131 (1500 ohms). The power lead 101 carries a movable contact 119g which is actuated by the operation of the limiting relay 119 to close with a stationary contact 119h on the outside end of the resistor 130. The outside end of the resistor 131 is connected directly to the line 118.

Referring to FIGURE 5a, the numeral 135 generally indicates a horizontally movable three-position key-type switch (Disarm-Interlock Reset Key). Among other elements which will be later described, the switch 135 comprises a stationary contact 138 and a movable contact 139, the same being in closed relationship when the said key is moved into the right-hand position, and open when the said switch is in either the center position or the left-hand position. The stationary contact 138 of the switch 135 (Disarm-Interlock Reset Key) is connected to the inner (and connected) ends of the resistors 130 and 131, while the movable contact 139 of the said switch (i.e. 135) is connected to the power lead 101 which supplies the 110-volt direct current. Thus, when the switch 135 is in the right-hand position and the contacts 138 and 139 are closed, and energizing circuit to the operating coil of the limiting relay 119 is completed, unless at that time the line 118 (Interlock) is grounded through the contacts 107a and 107b of the holding relay 107.

At this point in the description of the electrical elements of the circuits of the operating panel and the manner in which the same are operated, the group rotary stepping switch will be considered. As previously mentioned, the principal functions of this switch are to connect the group control and signal circuits in series with any selected distant station C and its contained distribution rotary stepping switch which selects the desired individual mine (of that particular group).

The Group Rotary Stepping Switch

Structurally, the group rotary stepping switch is similar in many respects to the distribution rotary stepping switches at the distant stations C. That is, the group rotary stepping switch comprises three banks of twenty-five stationary contacts each, each bank being in the form of a half-cylinder, the said banks being served by three wiping instrumentalities which are secured to a common rotatable shaft. Two of these wiping instrumentalities are in the form of individual double-ended wiper-arms having their wiping arranged 180° apart so that when one of the wiping-ends of a wiper-arm steps off the last contact in its

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respective bank of contacts, the other wiping-end of said wiper-arm will engage the first contact in said bank.

The third wiping instrumentality is disk-shaped as in the case of the disk 26 of the distribution rotary stepping switches. The three sets of wiping instrumentalities and their associated contacts are designated as "levels"; one being a "group selection level"; another being a "signal level"; and the third, which comprises the disk-shaped wiping instrumentality, being the "fan level." In the showing of FIGURE 6 the numeral 150 indicates the common rotatable shaft; and in this view only the outermost wiper-arm and its bank of contacts (which comprise the "group selection level") appear, the same being respectively indicated as 151 and 152. As to the series of contacts 152, it will be perceived that, moving in a clockwise direction, the first contact is identified as "zero"; the next ten contacts are mine group contacts, each ultimately connecting with one of the shore cables D; the next twelve contacts are left "blank"; and the last contact is designated "Home."

Disposed adjacent the shaft 150 of the group rotary stepping switch is a motor magnet 155, the latter being connected between circuits which ultimately include the power lead 110a (supplying 110-volt direct current operating power) and a suitable ground. A description of these circuits will shortly follow. Associated with the motor magnet 155, and disposed between it and the shaft 150 of the group rotary stepping switch, is a pivotally mounted armature 156. The shaft 150 has secured thereto a ratchet wheel 157 which is engaged by a stepping pawl 158, the latter being pivotally mounted on, and extending in right-angular relationship from, the armature 156. The stepping pawl is resiliently held against the periphery of the ratchet wheel 157 in any suitable manner; and is biased tangentially of the said ratchet wheel 157, and with sufficient force to rotate the same in a clockwise direction, by a pawl spring 159. Thus, the coaction of the motor magnet 155 and the pawl spring 159 will effectively cause the stepping pawl 158 to rotate the ratchet wheel 157 in step-by-step relationship, whereby the wiper-arm 151 of the group selection level will advance from the "zero" contact to, and through, the contacts numbered 1 through 10; through the next succeeding twelve blank contacts; and onto the final or "Home" contact. As one end of the wiper-arm 151 leaves the "Home" contact, the opposite end moves onto the "zero" contact. At no time do the wiping-ends of the wiper-arms bridge across two adjoining contacts.

The double-ended wiper-arm of the signal level of the group rotary stepping switch is indicated in FIGURE 5 at 162, and its series of contacts at 163. The construction and arrangement of the wiper-arm and bank of stationary contacts of the signal level is exactly the same as those of the group selection level previously described, even to the numbering system of the contacts. The axis of the wiper-arm 162 of the group signal level is connected to the signal power lead 123; and the ten successively numbered contacts of the group signal level lead to a corresponding number of white pilot lights 164 which in turn connect with the power lead 122 whereby the said pilot lights 164 will be successively illuminated to indicate which group circuit the wiper-arm 162 is at the moment contacting.

The fan level of the group rotary stepping switch comprises a disk 165 having two diametrically opposite notches 165a, and a bank of twenty-five stationary contacts 166 of which the first ten after the "zero" contact are ultimately connected to the ten shore cables which connect with the distribution rotary stepping switches, at the distant stations C. A relay 170 (group relay) is included in each fan level circuit, the construction and arrangement being such that when the group rotary stepping switch is at the "Home" position the fan level disk 165 contacts all ten successively numbered fan level contacts 166 to connect all of the said group relays and shore cables in parallel with the power lead 110a which supplies

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the 110-volt direct current operating power. The currently active one of the two diametrically opposite notches 165a of the fan level disk 165 exempts the circuit of the operating coil of the motor magnet 155 of the group rotary stepping switch in such manner that the operation of one of the group relays 170 is required to initiate action of the stepping pawl 158. The arrangement of the wiper-arm 151 of the group selection level and the fan level disk 165 on the common shaft 150 (along with the wiper-arm 162 of the signal level) is such that as the shaft rotates the currently active notch 165a of the fan level disk exempts a shore cable circuit (leaving it no longer connected in parallel with all the others) the wiper-arm 151 of the group selection level contacts the same shore cable circuit, switching it in series with the control circuits. The fan disk 165 of the group rotary stepping switch drops contact with its bank of cooperating stationary contacts just before the non-bridging wiper-ends of the wiper-arms 151 (group selection level) and 162 (signal level) make connection with their respective contacts. In other words, the disk and the wiper-arms never make simultaneous contact with corresponding contacts in their respective stationary banks. Depending on certain circuit conditions, which will later appear, the group rotary stepping switch will lock on a particular group, or "step" by it.

From the foregoing it will be perceived that when 110-volt direct current operating power is supplied to the input terminal 100, and the operation switch 110 is in open position (see FIGURE 5), the pilot light 104 (Operating Power) comes on. The holding relay 107 operates, receiving power from the power lead 101 (110-volt direct current) through the resistor 105 (1500 ohms) and through the operating coil (450 ohms) of said relay to the ground. The energization of the holding relay opens contacts 107a and 107b to remove the ground from the line 118; and also opens its contacts 107c and 107d, thus opening the circuit of a firing-clearing relay 175. At the same time, the operation of the holding relay 107 closes its contacts 107e and 107f, but for reasons which will later appear this causes no circuit change.

In view of the fact that the limiting relay 119 has not yet been energized its contacts 119c and 119d are closed and there is completed a circuit across the power leads 122 and 123 (which supply 6.3-volt alternating current signal power), thereby energizing the buzzer 126 and the pilot light 127 (Interlock).

Now if the hereinbefore mentioned horizontally movable three-position key-type switch 135 (Disarm-Interlock Reset Key) is moved to the right-hand position it will close its contacts 138 and 139 and cause the operation of the limiting relay 119, the same receiving current from the power lead 101 (110-volt direct current) through the said contacts and the resistor 131 (1500 ohms) and through the operating coil of the said limiting relay to ground.

When the limiting relay 119 is operated, the contacts 119a and 119b are opened; causing no circuit change. The contacts 119c and 119d open, thereby deenergizing the buzzer 126 and extinguishing the pilot light 127 (Interlock). The contacts 119e and 119f are closed, thereby establishing a circuit through which the operating coil of the firing-clearing relay 175 may receive power to operate in the event the control system locks on a mine, as will later appear. The contacts 119g and 119h close to complete a holding circuit for the operating coil of the limiting relay 119.

At this time the key-type switch 135 (Disarm-Interlock Reset Key), which was previously moved into the right-hand position, should be released, or centered, thereby opening contacts 138 and 139 (FIGURE 5a).

Referring to FIGURE 5, when the operating switch 110 is closed, direct current at approximately 97 volts flows from the contact 111 through the pole 110a, and line 180, to the electrically conductive fan disk 165 and through it to the bank of stationary contacts 166 of the fan level. As previously mentioned, each of the fan level

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contacts numbered 1 through 10 connects with the operating coil of a group relay 170. In the interest of simplicity only two complete group relay circuits and their components are illustrated.

Referring to FIGURE 5, the potential of the 110-volt direct current circuits (i.e. power lead 101 and line 180) of the operating panel is measured by a voltmeter 182 which is grounded at one terminal and connected by the other to a single-pole three position switch 183. The stationary contacts of the switch 183 are designated at 184, 185 and 186, the same being respectively connected with the power lead 101, the "Home" contact of the group selection level, and the line 180 which connects the pole 110a of the operation switch 110 with the disk 165 of the fan level of the group rotary stepping switch.

One end of the operating coil of each of the group relays (collectively indicated at 170) is connected to one of the ten stationary contacts of the fan level which successively follow the "zero" contact. That is, the operating coil of the first group relay will connect with contact 1 of the series of ten stationary contacts aforesaid; the operating coil of the second group relay will connect with contact 2 of said series, and so on. The opposite end of the operating coil of each of the group relays 170 is connected through a displaceable contact 170f and a stationary contact 170e, to the ten corresponding contacts 152 (successively following the "zero" contact) of the group selection level. Each of the last mentioned contacts of the group selection level of the group rotary stepping switch is connected to one end of the operating coil (20 ohms) of a signal relay 190. When the operating coils of the group relays 170 are deenergized the displaceable contact 170f and the stationary contact 170e are closed, but when energized, the said operating coils actuate movable contacts 170d which displace the displaceable contacts 170f from engagement with the stationary contacts 170e and provide a circuit to ground through a resistor 192 (1500 ohms). The operating coil of each of the signal relays 170 is connected to one of ten horizontally movable three-position key-type switches 193 ("Group Selection Keys"). In one direction the switches 193 are spring returned and in the other they lock. When the key is in the center position the following contact pairs are connected: 193a—193b, 193c—193d, 193e—193f, and 193g—193h. The stationary contact 193g of each group selection key 193 cooperates with a movable contact 193h, the latter in turn being connected to the shore cable terminal E for that particular group of mines. When in either the left-hand or the right-hand position, each of these switches disconnects its group of mines from the control system.

To the "Home" contact of the bank of stationary contacts 166 of the fan level there is connected to a line 200 which carries a stationary contact 170c for each of the group relays 170 employed (ten in the illustrative embodiment with two appearing in the form illustrated in FIGURE 5). This line 200 also carries a stationary contact 155a, the latter cooperating with a movable contact 155b which is operated by, and connected to, the motor magnet 155 (330 ohms) of the group rotary stepping switch. Between the last of the aforesaid series of contacts 170c and the contact 155a, there is connected to the line 200 (in series relationship) a capacitor 202 (1 mfd.) and a resistor 203 (150 ohms), the latter being connected to the adjacent end of the motor magnet 155. The other end of the motor magnet 155 connects through a resistor 205 (300 ohms) and stationary and movable contacts 208a and 208b, respectively, of a stopping relay 208 to ground.

The operating coil of the stopping relay 208 is in two sections, as indicated at No. 1 (36 ohms) and No. 2 (35 ohms).

To the pole 110c of the operating switch 110 there is connected a horizontally movable three-position key-type switch generally indicated at 210 (250 ma. Scale—Bell

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On) for enabling the operator to alternatively read currents in the mine cables B and in the shore cable D; and to connect the circuit of an alarm bell which will be described. This switch 210 has associated therewith a milliammeter 212 the latter comprising three posts which are designated at "H" (High Scale—500 Milliampere); "L" (Low Scale—250 Milliampere); and "+" (i.e. positive post which is common to both "H" and "L"). The switch itself comprises a displaceable contact 213 to which the pole 110c of the operating switch 110 is directly connected; a stationary contact 214 which connects with the post "H" of the milliammeter 212; a movable contact 215 which is connected to the post "L" of the milliammeter; and which serves to displace the contact 213 from engagement with the stationary contact 214; a movable contact 216 which connects through the circuit of an alarm bell 217 with the power lead 122 (6.3-volt alternating current signal power), and a stationary contact 218 which ultimately connects with the signal power lead 123, after passing through the lead 123a; contacts 193f, 193e, 193a and 193b of the group selection key 193; and contacts 190a and 190b.

When moved into the left-hand position, the switch 210 (250 ma. Scale—Bell On) transfers the reading to the 250 milliamper scale of the milliammeter 212; and when moved into the right-hand position it connects the circuit of the alarm bell 217 with the signal power lead 123a.

Referring to the center of FIGURE 5a, the number 220 generally designates a vertically movable three-position key-type switch (Lamps Off-Supervisory) the full purpose of which will be later described in detail. This switch 220 comprises a stationary contact 221 to which the "+" post of the milliammeter 212 is connected. This stationary contact 221 is engaged by a displaceable contact 222 which connects through stationary and movable contacts 225c and 225d, respectively of a control relay 225, with the No. 2 winding (36 ohms) of the operating coil of the stopping relay 208, and from the latter through contacts 107e and 107f of the holding relay 107 through the operating coil (8 ohms) of a guide relay 227 to the wiper-arm 151 of the group selection level of the group rotary stepping switch.

Referring to FIGURE 5a, the previously referred to key-type switch 135 (Disarm-Interlock Reset Key) comprises a stationary contact 228 and a movable contact 229, the same being closed when the switch is in the center position, as illustrated. These contacts 228 and 229 respectively connect with contacts 107f and 107e of the holding relay 107. The switch 135 also comprises a movable contact 230 and a stationary contact 231, which are open when the switch 135 is in either the center position or the right-hand position, but are closed when the said switch is in the left-hand position. The contact 230 connects through stationary and movable contacts 227a and 227b, respectively, of the guide relay 227; stationary and movable contacts 225a and 225b, respectively, of the control relay 225; and movable and stationary contacts 208e and 208f, respectively, of the stopping relay 208; to a resistor network 232 (1000 ohms) and through it to ground. The contact 231 of the switch 135 (Disarm-Interlock Reset Key) is connected to the stationary contact 208d of the stopping relay 208, which is connected through the No. 1 (36 ohms) winding of the operating coil of the stopping relay 208 to the resistor network 232 (1000 ohms total resistance) and through the latter to ground.

From the showing of FIGURES 5 and 5a, it will be seen that the movable and stationary contacts 230 and 231, respectively, will only connect through the No. 1 winding of the operating coil of the stopping relay when the guide relay 227 and the stopping relay 208 are energized and the control relay 225 deenergized.

When the stopping relay 208 is energized its contacts 208a and 208b open, thereby opening the circuit from ground through the resistor 205 (300 ohms) to the oper-

ating coil of the motor magnet 155 of the group rotary stepping switch, whereby the group rotary stepping switch is locked on the group "No. 1." The energization of the stopping relay 208 completes the following circuit through which the said stopping relay holds itself operated:

110-volt direct current power lead 101, contacts 208c and 208d, No. 1 winding (36 ohms resistance) of the operating coil of the stopping relay, resistor network 232 (1000 ohms total resistance) to ground.

This holding circuit is necessary to enable the deenergization of the stopping relay 208 each time the timing relay 47 associated with the distribution rotary stepping switch at each of the distant stations operates to cause the current through the No. 1 winding (36 ohms) of the operating coil of the stopping relay to drop below its holding value. At the same time, the energization of the stopping relay 208 closes its contacts 208e and 208f, establishing a circuit from the latter to the resistor network 232 and thus to the ground as previously described. Through this last-mentioned circuit, the holding circuit of the stopping relay 208 may be short-circuited to cause the said stopping relay to deenergize and release when the operator desires to step the group rotary stepping switch off the group. This shorting circuit is completed by closing the contacts 230 and 231 of the switch 135 (Disarm-Interlock Reset Key).

When the guide relay 227 is energized it opens its contacts 227a and 227b. This opens the "disarm circuit" so that the stopping relay 208 will not be short-circuited and made to release if the operator should be holding the switch 135 in the left-hand position at the very moment the group is selected. At the same time, the energization of the guide relay 227 closes the contacts 227c and 227d, thus short-circuiting the slow-release holding relay 107 to the ground. However, the guide relay 227 is energized for so short a period that the slow-release holding relay 107 does not drop out. The energization of the guide relay 227 closes the contacts 227e and 227f, but this causes no circuit change at this time because the contacts 107c and 107d are still open.

The disarm circuit is wired through contacts 208e and 208f of the stopping relay for the reason that otherwise if the operator should move the switch 135 (Disarm-Interlock Reset Key Switch) to the left-hand position (thereby closing contacts 230 and 231) with the expectation of stepping the group rotary stepping switch from one group and stop on the next group, he would find that the group rotary stepping switch would continue to rotate instead of stopping on the next group contact as desired. The reason for this is that the guide relay 227 being deenergized and released and its contacts 227a and 227b closed, the No. 1 winding of the stopping relay 208 would be shunted by virtue of the operator's holding closed the contacts 230 and 231 of switch 135. This winding being shunted, the stopping relay 208 would be slow to operate and its contacts 208a and 208b would not open and break the circuit for the motor magnet 155 of the group rotary stepping switch before it again operated and stepped the group rotary stepping switch onto the next group.

As soon as the operation switch 110 closes current flows through the operating coils of all ten of the group relays 170 in parallel; their closed contacts 170e and 170f, the ten successively numbered group contacts of the group selection level of the group rotary stepping switch, the operating coils of all ten of the signal relays 190, and from the latter to each of the ten key-type switches 193 (Group Selection Keys), their respective movable contacts 193d, stationary contacts 193c, stationary contacts 193g and movable contacts 193h to the ten shore cable terminals E. At this point each of the ten group selection keys 193 is in the position shown in FIGURE 5 of the drawings, whereby the contacts 193d and 193c,

and 193g and 193h are closed and there is no circuit interruption. Accordingly, current flows into each of the ten shore cables D to the distribution rotary stepping switch at each of the distant stations represented at C in FIGURE 1. For reasons which will later appear, the operate value of each of the distribution rotary stepping switches at the distant stations C is 165 milliamperes, whereas the operate value of the group relays 170 is only 125 milliamperes. Since the circuits are inductive, each group relay 170 operates ahead of its associated distribution rotary stepping switch at the distant stations C. The energization of the group relays 170 closes the contacts 170b and 170c, thus causing the flow of current from the line 180 (at approximately 97 volts direct current) into the line 200, the closed contacts 155a and 155b of the motor magnet 155 (330 ohms) of the group rotary stepping switch through the resistor 205 (300 ohms) and closed contacts 208a and 208b of the stepping relay 208 to ground. At the same time the contacts 170e and 170f of the group relays 170 open, and the contacts 170d and 170f close, to complete a new circuit to ground through the resistor 192 (1500 ohms); and the ten group relays 170 are thus held energized, each being sealed into the circuit through its own movable contact 170d and displaceable contact 170f.

Since a circuit to the motor magnet 155 of the group rotary stepping switch is completed, in the manner explained hereinbefore, the said motor magnet operates and breaks its own circuit at its contacts 155a and 155b. Accordingly, the deenergization of the motor magnet 155 permits the spring 159 (FIG. 6) to advance the stepping pawl 158 one position on the ratchet wheel 157, thus stepping the group fan level disk 165 and the wiper-arm 151 (group selection level) and 162 (group signal level) to the initial or "zero" position. If at this time the voltmeter switch 183 is on the contact 184 (or "Wiper Home" position), the voltmeter 182 will cease to indicate since the wiper-arm 151 of the group selection level has stepped off the "Home" contact. The active notch 165a of the fan disk 165 has taken one step and a second circuit is established through the said fan disk to energize the motor magnet 155 of the group rotary stepping switch. Thus, the motor magnet 155 is again energized, the circuit broken and released in the manner aforesaid to permit the spring 159 to advance the stepping pawl 158 and the ratchet wheel 157 one position. Accordingly, the wiper-arm 151 (group selection level) and the wiper-arm 162 (group signal level) and the group fan level disk 165 step to the "No. 1" group position. The notch 165a in the fan level 165 now exempts the circuit of the No. 1 group relay whereupon the No. 1 group relay is deenergized. However, the wiper-arm 151 of the group selection level has contacted the "No. 1" group position and established a circuit from the wiper-arm 151 and through the No. 1 contact of the group selection level to the operating coil of the No. 1 signal relay 190 and from the latter to the switch 193 (Group Selection Key) for group "No. 1," and thus to the shore cable terminal E for the No. 1 group. As before stated, while the circuit is in this condition current will flow through the associated shore cable D to the distribution rotary stepping switch for the No. 1 group (at the appropriate distant station C) and from the motor magnet of said distribution rotary stepping switch 31 to ground in the manner previously described. Since the above current path has low resistance enough current will flow to energize the stopping relay 208, the guide relay 227, and the motor magnet 31 of the distribution rotary stepping switch at the distant station C.

Firing-Clearing Power

The 250-volt direct current clearing power and the 550-volt direct current firing power are supplied to the circuits of the operating panel through the input terminals 240 and 241, respectively. These terminals 240 and

241 are associated with a three-circuit tandem tap switch generally indicated at 244. In effect the tandem tap switch 244 provides a "selection level" and a "signal level." The selection level comprises a switch arm 244a which selectively engages contacts 242 and 243 which are respectively connected to the input terminals 240 (250-volt direct current clearing power) and 241 (550-volt direct current firing power).

Cooperating with the selection arm 244a of the tandem switch 244 is a triple-pole single-throw switch 245 (Firing-Clearing Power). The poles of this triple-pole single-throw switch 245 are indicated at 245a, 245b and 245c, and the contacts which they engage are respectively indicated at 246, 247 and 248. The contact 246 is connected to the selection arm 244a of the tandem switch 244; the contact 247 is grounded and the contact 248 is connected to the previously described movable contact 139 of the switch 135 (Disarm-Interlock Reset Key).

The pole 245a of the triple-pole single-throw switch 245 (Firing-Clearing Power) is connected to a movable contact 250 of the switch 135 (Disarm-Interlock Reset Key) which cooperates with a stationary contact 251, the latter connecting through the No. 2 winding (10 ohms) of the operating coil of the control relay 225; and through the following contacts of the firing-clearing relay 175: stationary contact 175i, movable contact 175h, stationary contact 175g and movable contact 175f; to the movable contact 225d of the control relay 225; the said movable contact 225d as before stated being connected through the No. 2 winding (36 ohms) of the operating coil of the stopping relay 208 and movable and stationary contacts 107e and 107f respectively of the holding relay 107 through the operating coil (8 ohms) of the guide relay 227 to the wiper-arm 151 of the group selection level of the group rotary stepping switch.

The pole 245b of the triple-pole single-throw switch 245 (Firing-Clearing Power) is connected through stationary and movable contacts 119a and 119b respectively of the limiting relay 119 to the line 118 (Interlock Bus) which, as before stated connects to ground through the operating coil of the limiting relay 119, and also to a shunting ground through stationary and movable contacts 225k and 225i, respectively, of the control relay 225.

The pole 245c of the triple-pole single-throw switch 245 is connected through stationary and movable contacts 225h and 225g respectively to the No. 1 winding (500 ohms) of the operating coil of the control relay 225 and through the said coil and a resistor 253 (2300 ohms) to ground.

The pole 245c of the triple-pole single-throw switch 245 is also connected through a pilot light 254 (Switch On) to ground.

To return to the "signal level" of the three-circuit tandem tap switch 244, the contact 256 connects through a pilot light 257 (250 volts) to the signal power lead 122 while the contact 258 is connected to the said signal power lead 122 through a pilot light 259 (550 volts). The arm 244b of the three-circuit tandem tap switch 244 is connected to the signal power lead 123. The arms 244a and 244b of the said tandem tap switch are provided with non-operative center positions, wherein neither the 250-volt direct current clearing power nor the 550-volt direct current firing power are supplied to the circuits of the operating panel.

Referring to FIGURE 5, a pilot light 260 (Mine Firing) and a pilot light 261 (Mine Fired) are connected between the signal power lead 122 and a pair of spaced stationary contacts 175c and 175a, respectively, of the firing-clearing relay 175. Between this pair of spaced stationary contacts 175c and 175a there extends a movable contact 175b which when at rest engages the stationary contact 175a but moves into engagement with the stationary contact 175c when the firing-clearing relay is energized.

From the foregoing it will be understood that when the

tandem tap switch 244 is turned to the "clearing voltage" position (i.e. with the switch arm 244a engaging the contact 241) the pilot light 257 (250 volts) is illuminated; and when the said switch is turned to the "firing voltage" position (i.e. with the switch arm 244a engaging the contact 242) the pilot light 259 (550 volts) is illuminated.

When the control system locks on a mine, the firing-clearing relay 175 is energized to establish the circuits through which the 250-volt direct current clearing power or the 550-volt direct current firing power can be applied to the selected shore cable terminal E and from it to and through the appropriate distant station C to the selected mine upon the closing of the switch 245 (Firing-Clearing Power). The pilot light 261 (Mine Fired) is illuminated after the firing-clearing relay 175 has released to close the contacts 175a and 175b after firing or clearing the mine. While the firing-clearing relay 175 is energized, the contacts 175b and 175c are closed, thereby illuminating the pilot light 260 (Mine Firing), to indicate that firing or clearing power is going out either to a mine, or to a distant test point as will appear more fully hereinafter.

The control relay 225 operates when 250-volt direct current clearing power or 550-volt direct current firing power flows through the No. 2 winding (10 ohms) of its operating coil. Through its contacts 225c and 225d the control 225 removes 110-volt direct current operating power from the shore cable to prevent further stepping. As before stated, this control relay 225 has its own holding circuit through the No. 1 winding (500 ohms) of its operating coil and its contacts 225g and 225h. The resistor 130 (3500 ohms) limits the flow of current through the operating coil of the limiting relay 119 while the latter is held operated by its own holding circuit. Through its contacts 225i and 225k the control relay puts a shunt on the limiting relay 119 which prevents the resetting of the limiting relay 119 while the control relay 225 is energized.

When the control relay 225 is energized its contacts 225a and 225b open the shunting circuit of the stopping relay 208, thus making it impossible for the operator to step the group rotary switch off a group while the 250-volt clearing power or the 550-volt firing power are being applied to a mine through one of the shore cables D.

The holding relay 107 controls the circuit of the firing-clearing relay 175; and the shunting circuit of the limiting relay 119. Through its contacts 107e and 107f the holding relay 107 controls the mine disarming circuit when the switch 135 is in the left-hand position. This slow-operate slow-release holding relay 107 is independent of the operations switch 110 and operates as soon as the 110-volt direct current is applied to the circuits of the operating panel at the input terminal 100.

As before stated, the limiting relay 119 controls the pilot light 127 (Interlock) which illuminates as soon as the said limiting relay 119 is deenergized; and it also controls the warning buzzer 126 which when energized, warns the operator that one of the distribution rotary stepping switches (at a distant station C) is locked on a mine, or grounded mine circuit, and that the limiting relay 119 has deenergized and released. If control equipment for groups of mines in addition to the ten described hereinbefore is connected to the input terminal 115 (Interlock Bus), and if a mine becomes armed, the limiting relay 119 functions to open the circuit to power for the firing-clearing relay of each additional group so connected. Thus, the limiting relay 119 prevents the firing of mines whose detection circuits have been actuated by the shock of detonation of nearby mines when the control system is set for automatic fire. The circuit of the limiting relay 119 is independent of the operation switch 110, and is operated by moving switch 135 (Disarm-Interlock Reset Key) into the right-hand position to close the contacts 138 and 139. In the event the operator attempts to reset the limiting relay 119 at such time as it is shunted, a

short circuit on the 110-volt direct current source is prevented by the resistor 131 (1500 ohms).

Stepping to an Armed Mine

When a mine becomes armed, the following circuit from the operating panel is established:

Line 180; fan disk 165 of the group rotary stepping switch; operating coil of the group relay 170 of the group comprising the armed mines; contacts 170f and 170e; operating coil of the appropriate signal relay 190; appropriate group selection key 193; appropriate shore cable D; resistor 51 (2300 ohms) at the appropriate distant station C; operating coil of the locking relay 45; unitary wiper-arms 29; contacts 45g and 45f; operating coil (40 ohms) of the timing relay 47; resistor 52 (100 ohms); fan disk 26; conductors 40 and 41, and fuse 42; mine cable B; point 20 (30.5 ohms) on the operating coil of the mine latch relay 3; contact 17 or 18 of the sensitive relay 14; deflected movable arm 19; and contacts 3b and 3c of the mine latch relay 3 to ground.

The flow of current through the operating coil of the locking relay 45 is approximately 34 milliamperes. Since the operate value of the locking relay is 28 milliamperes, it operates, breaks its contacts 45f and 45g, and causes the timing relay 47 to release. When the timing relay releases it closes its contacts 47a and 47b and current flows to ground through the motor magnet 31 of the distribution rotary stepping switch. As before stated, the operate value of the group relay 170 being only 100 milliamperes, is lower than that of the motor magnet 31 of the distribution rotary stepping switch (i.e. 165 milliamperes); whereby the group relay operates first. This removes power from the shore cable when the contacts 170e and 170f of the group relay open. A circuit to the motor magnet 155 of the group rotary stepping switch is now complete through its contacts 170b and 170c; and it steps to the contact of the group of the armed mine in the manner hereinbefore stated. As soon as the wiper-arm 151 of the group selection level of the group rotary stepping switch engages the contact of the circuit of the armed group, the following circuit is completed:

"+" contact of the milliammeter 212; contacts 221 and 222 of the switch 220 (Lamps Off-Supervisory Key); contacts 225c and 225d of the control relay; No. 2 winding (36 ohms) of the operating coil of the stopping relay 208; contacts 107e and 107f of the holding relay 107; wiper-arm 151 of the group selection level of the group rotary stepping switch; operating coil (20 ohms) of the appropriate signal relay 190; appropriate group selection key 193; appropriate shore cable D; and motor magnet 31 at the appropriate distant station C to ground.

As hereinbefore stated the current flow through this circuit causes the stopping relay 208 to operate and lock the group rotary stepping switch on the appropriate group contact. The distribution rotary stepping switch now selects and locks up on the armed mine, thereby disarming it in the manner previously described. When the distribution rotary stepping switch locks up, the flow of current is enough to hold the guide relay 227 in operated position, and it opens its contacts 227a and 227b. This opens the shunting circuit of the stopping relay 208 so that if the operator moves the switch 135 (Disarm-Interlock Reset Key) in to the left-hand position, the stopping relay 208 will not be caused to release and let the group rotary stepping switch step off the group before the unitary wiper-arms 29 of the distribution rotary stepping switch have returned to the "Home" position. When the contacts 227c and 227d close, the operating coil of the slow-release holding relay 107 is shunted, thereby causing the said holding relay to release. When the contacts 227e and 227f close there is initiated the first step toward establishing the operating circuit for the firing-clearing relay 175.

When the holding relay 107 releases, it closes its contacts 107a and 107b, thereby grounding the line 113 (Interlock Bus), and releasing the limiting relays (which

correspond to the limiting relay 119 of the operating panel of the present invention) of all interlocked operating panels. The closing of the contacts 107c and 107d of the holding relay establishes the following circuit for the firing-clearance relay 175:

Line 101; contact 119g of the limiting relay 119; contact 175e of the firing-clearing relay 175; contacts 119e and 119f of the limiting relay; contacts 107c and 107d of the holding relay 107; resistor 265 (1500 ohms); contacts 227f and 227e of the guide relay 227; operating coil (650 ohms) of the firing-clearing relay 175 to ground.

The opening of the contacts 107e and 107f of the holding relay shunts the flow of short cable current through the contacts 228 and 229 of the switch 135.

When the firing-clearing relay 175 operates, it breaks its contacts 175a and 175b and closes its contacts 175b and 175c, but at this time no circuit change is caused thereby. When the contacts 175d and 175e are closed the firing-clearing relay 175 completes its own holding circuit before the limiting relay 119 released and opens its contacts 119e and 119f. At the same time, there is caused the closing of the contacts 175f and 175g and 175h and 175i, thereby completing the circuits for firing or clearing power except for the manual closing of the appropriate switches.

When the limiting relay releases, it closes its contacts 119a and 119b, but this causes no circuit change at this time. When the contacts 119c and 119d close, there is energized the buzzer 126 and the pilot light 127 (Interlock). The opening of the contacts 119e and 119f causes no circuit change; but the opening of the contacts 119g and 119h removes power from the operating coil of the limiting relay 119.

When the control system of the present invention as hereinbefore described is locked on an armed mine, the following is the status of certain of the operating and signalling instrumentalities:

Firing relay 7-----	Not operated.
Mine latch relay 3-----	Operated.
Sensitive relay 14-----	Reset.
Distribution rotary stepping switch -----	Locked on circuit of the armed mine, with its motor magnet not operated.
Locking relay 45-----	Operated.
Timing relay 47-----	Not operated.
Signal relay 190-----	Operated.
Group relay 170-----	Not operated.
Group rotary stepping switch -----	Locked on group having the armed mine with its motor magnet not operated.
Guide relay 227-----	Operated.
Holding relay 107-----	Not operated.
Stopping relay 208-----	Operated.
Limiting relay 119-----	Not operated.
Firing-clearing relay 175---	Operated.
Control relay 225-----	Not operated.
Pilot light 164 (of the effect- ed group)-----	On.
Pilot light 127 (Interlock)---	On.
Buzzer 126 -----	Energized.

Manual Selection of a Group

The foregoing relationships exist when the group rotary stepping switch and all of the distribution rotary stepping switches are in their respective "Home" positions. In order to initiate stepping it is necessary to break the holding circuit of the timing relay 47 and make it release. This establishes a circuit for the motor magnet 31 of the appropriate distribution rotary stepping switch. An armed mine accomplishes this by causing the locking relay 45 to operate in the manner earlier described. The

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operator at the operating panel may accomplish the same result by opening the circuit at the group selection key 193 of the group it is desired to select. The opening of this circuit interrupts the flow of 110-volt direct current operating power to the distribution rotary stepping switch at the distant station, and timing relay 47 releases. When the group selection key 193 is permitted to assume its center position wherein its contacts are closed, the following circuit exists:

Line 180; fan disk 165 of the group rotary stepping switch; operating coil of the group relay 170 of the affected group; contacts 170e and 170f; operating coil of the appropriate signal relay 190; appropriate group selection key 193; appropriate shore cable D; contacts 45a and 45b of the locking relay 45; motor magnet 31; contacts 47a and 47b of the timing relay to ground.

However, the operate value of the group relay 170 (i.e. 100 milliamperes) is lower than that of the motor magnet 31 of the distribution rotary stepping switch (i.e. 165 milliamperes), as before stated. Therefore, the group relay operates first and removes power again from the shore cable when the contacts 170e and 170f of the group relay open. A circuit to the motor magnet 31 of the distribution rotary stepping switch is now complete through contacts 170b and 170c of the group relay, and the group rotary stepping switch steps to the contact of the desired group. When the group has been selected, the distribution rotary stepping switch will step through the group and leave the system locked on the group with the distribution rotary stepping switch at its "Home" position.

Disarming a Mine

The mine may be disarmed by either of the following two methods of operating the control system as it has been thus far described:

(1) Move the switch 135 (Disarm-Interlock Reset Key) into the left-hand position and retain it there; and by this method send both the distribution rotary stepping switch and the group rotary stepping switch to their "Home" positions. If the operator were to promptly restore the switch 135 to its previous position, the distribution rotary stepping switch would return "Home," but the group rotary stepping switch would remain locked on the group; and it would then be necessary to again move the switch 135 into the left-hand position in order to return the group rotary stepping switch to its "Home" position.

(2) Break the circuit at the appropriate group selection key 193, thus causing only the distribution rotary stepping switch to go "Home," and leaving the group rotary stepping switch locked on the group. In order to send the group rotary stepping switch "Home," it is necessary to move the switch 135 into the left-hand position. If the switch 135 is maintained in this position, power is interrupted from the shore cable D and the guide relay 227. Taking power off the shore cable D causes the locking relay 45 at the distant station C to release and re-establish the stepping circuits for the distribution rotary stepping switch to return "Home."

Removing power from the guide relay 227 causes it to release and thereby close its contacts 227a and 227b, to thereby re-establish the disarm circuit so that when the distribution rotary stepping switch reaches "Home" and the operator moves the switch 135 into the center position, the shunting circuit of the stopping relay 208 will be completed and cause it to release and allow the group rotary stepping switch to stop. The deenergization of the guide relay in the manner set forth, opens its contacts 227c and 227d, thereby removing the shunt from the holding relay 107 which will again operate. It also opens contacts 227e and 227f of the guide relay, thereby opening the holding circuit of the firing-clearing relay 175, causing the latter to release.

When the holding relay operates it opens its contacts 107a and 107b, thereby removing the ground from the

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line 118 (Interlock Bus) and the limiting relays (which correspond to the limiting relay 119 of the operating panel of the present invention) of all interlocked operating panels. All of these relays (including the limiting relay 119) can be reoperated if the switch 135 is moved into the right-hand position. At the same time, the contacts 107c and 107d of the holding relay open, but this causes no circuit change. The contacts 107e and 107f close, and reestablish the original stepping circuit which is independent of the switch 135.

As the motor magnet of the distribution rotary stepping switch steps toward its "Home" position, the guide relay 227 operates and releases with the said motor magnet. The guide relay remains in the unoperated position when the distribution rotary stepping switch reaches "Home." Since the guide relay is released, its contacts 227a and 227b are closed, and, if the switch 135 is moved into its left-hand position, the holding circuit for the stopping relay 208 is shunted. The stopping relay releases and closes its contacts 208a and 208b, thus establishing the stepping circuit for the group rotary stepping switch which will then return "Home," as earlier described.

From the foregoing it is believed apparent that either of the two methods of removing power from the shore cable will cause the appropriate distribution rotary stepping switch to return "Home," but in either case, the switch 135 must be moved into the left-hand position after the distribution rotary stepping switch has returned "Home" in order to return the group rotary stepping switch to its "Home" position.

Detonation of a Mine by Automatic Fire

When the system is set for automatic fire, the tap switch 244 is moved into the right-hand position, whereupon the pilot light 259 becomes illuminated; and the switch 245 (Firing-Clearing Power) is closed. When a mine becomes armed, the group rotary stepping switch selects the proper group and the associated distribution rotary stepping switch selects the armed mine.

When firing power (550-volt direct current) is applied, it flows through the following circuit:

Pole 245a of the switch 245 (Firing-Clearing Power); contacts 250 and 251 of the switch 135; No. 2 winding (10 ohms) of the operating coil of the control relay 225; contacts 175i and 175h and 175g and 175f of the firing-clearing relay 175; No. 2 winding (36 ohms) of the operating coil of the stopping relay 208; operating coil (8 ohms) of the guide relay 227; wiper-arm 151 of the group selection level of the group rotary stepping switch; operating coil (20 ohms) of the appropriate signal relay coil 190; appropriate group selection key 193; appropriate shore cable D contacts 45b and 45c of the locking relay 45; operating coil (75 ohms) of the locking relay 45; unitary wiper-arms 29 of the distribution rotary stepping switch; conductors 40 and 41 and fuse 42; appropriate mine cable B; point 6 (0.5 ohm) on the operating coil of the mine latch relay 3; operating coil (5 ohms) of the firing relay 7; contacts 7b and 7c; detonators 8; and contacts 7d and 7e to ground.

When 550-volt direct current firing power flows through the operating coil of the control relay 225, it operates and opens its contacts 225a and 225b, thereby eliminating the possibility of stepping the group rotary stepping switch if the switch 135 should be moved into the left-hand position. The contacts 225a and 225b of the control relay open the shunting circuit of the stopping relay 208. The operation of the control relay opens its contacts 225c and 225d, thereby preventing the 550-volt direct current firing power from being fed back through the milliammeter 212 and the 110-volt direct current operating power circuit. At the same time, the contacts 225e and 225f close, thereby illuminating the pilot light 260 (Mine Firing or Clearing). The contacts 225g and 225h close

and complete the following holding circuit for the control relay 225:

Line 101; contact 119g of the limiting relay; contact 248 and pole 245c of the switch 245 (Firing-Clearing Power); contacts 225g and 225h of the control relay; No. 1 winding (500 ohms) of the operating coil of the control relay; and resistor 253 (2300 ohms) to ground.

When the control relay operates, it also closes its contacts 225i and 225k, thereby putting a second ground on the line 118 (Interlock Bus).

Firing power detonates the mine and the exposed end of the ruptured mine cable B becomes grounded in the water. The fuse 42 ruptures. The only path to ground for the 550-volt direct current firing power is through the resistor network 62 (20,000 ohms) at the distant station C. The flow of current is approximately 30 milliamperes, which is sufficient to hold operated the locking relay 45 and prevent stepping. But the guide relay 227 releases and closes its contacts 227a and 227b, thereby reestablishing the disarm circuit so that when the control relay 225 has been released, as hereinafter explained and the distribution rotary stepping switch reaches "Home" the operator may move the switch 135 into the left-hand position, and the shunting circuit of the stopping relay 208 will be completed and cause it to release and allow the group rotary stepping switch to step. At the same time, the contacts 227c and 227d of the guide relay open, and remove the shunt from the holding relay 107, which will again operate. The contacts 227e and 227f of the guide relay also open, thereby opening the holding circuit of the firing-clearing relay 175, causing the latter to release.

When the holding relay 107 operates, it opens its contacts 107a and 107b, thereby removing one of the grounds from the line 118 (Interlock Bus) and the limiting relay 119 (and all corresponding relays of any interlocked panels) may be operated if the switch 135 is moved into the right-hand position (after the switch 245 has been opened and the second ground removed from the line 118). The contacts 107c and 107d of the holding relay also open, but cause no circuit change. The contacts 107e and 107f close and reestablish the original stepping circuit, which is independent of the switch 135.

When the firing-clearing relay 175 releases, it opens its contacts 175b and 175c and closes its contacts 175a and 175b. The pilot light 260 (Mine Firing or Clearing) is disconnected and the pilot light 261 (Mine Fired or Cleared) is illuminated. Contacts 175d and 175e open, but cause no circuit change. The contacts 175f and 175g and 175h and 175i all open, thereby taking power off the shore cable.

Since there is no longer any power on the shore cable circuit, the signal relay 190 for the appropriate group releases and closes its contacts completing the circuit to illuminate a pilot light 267 (Alarm). In addition, the bell 217 will also be energized if the switch 210 is in the right-hand position. The locking relay also releases since there is no power on the shore cable.

The control relay 225 is still held operated by the holding circuit through its own No. 1 winding (500 ohms) and the contact 245 and pole 245c of the switch 245 (Firing-Clearing Power). The system will remain locked in this condition, on the circuit of the fired mine, until the switch 245 is opened. At this time the following is the status of certain of the operating and signalling instrumentalities:

Firing relay 7	Blown up with mine.
Mine latch relay 3	Do.
Sensitive relay 14	Do.
Distribution rotary stepping switch	Locked on circuit of blown mine with its motor magnet not operated.
Locking relay 45	Not operated.
Timing relay 47	Do.
Signal relay 190	Do.

Group rotary stepping switch

	switch -----	Locked on the appropriate group with its motor magnet not operated.
5	Group relay 170 -----	Not operated.
	Guide relay 227 -----	Do.
	Holding relay 107 -----	Operated.
	Stopping relay 208 -----	Do.
	Firing-clearing relay 175 ---	Not operated.
10	Control relay 225 -----	Operated.
	Limiting relay 119 -----	Not operated.
	Pilot light 259 (Firing Power On) -----	Illuminated.
	Appropriate group pilot light 164 -----	Do.
15	Pilot light 267 (Alarm) ---	Do.
	Pilot light 127 (Interlock) --	Do.
	Buzzer 126 -----	Energized.
	Pilot light 261 (Mine Fired or Cleared) -----	Illuminated.
20	Bell 217 -----	Audible if switch 210 in right-hand position.
	Pilot light 104 (Operating Power) -----	Illuminated.

When the switch 245 (Firing-Clearing Power) is opened, its pole 245a separates from the contact 246, but no circuit change takes place since the firing power circuit is already open at the contacts 175f and 175g and 175h and 175i of the firing-clearing relay. The pole 245b separates from the contact 247, thereby removing one of the grounds that was placed on the line 118 (Interlock Bus); but the line 118 is still grounded at the contacts 225i and 225k of the control relay. When the pole 245e and contact 248 of the firing-clearing power switch (245) open, the holding circuit of the control relay is broken, thereby releasing the latter.

When the control relay releases, its contacts 225a and 225b close, thereby setting up the shunting circuit of the stopping relay. Its contacts 225c and 225d close, and thereby re-establish the normal 110-volt direct current operating circuit. The contacts 225e and 225f open, thereby extinguishing the pilot light 261 (Mine Fired or Cleared). The contacts 225g and 225h also open, but there is no circuit change. The contacts 225i and 225k open, and remove another ground from the line 118 (Interlock Bus). The following circuit is now established: position illustrated in FIGURE 5a.

Contact 113 and pole 110c of the switch 110 (Operation); milliammeter 212; contacts 221 and 222 of the switch 220 (Lamps Off-Supervisory); contacts 225c and 225d of the control relay; No. 2 winding (36 ohms) of the operating coil of the stopping relay 208; contacts 107e and 107f of the holding relay; operating coil (8 ohms) of the guide relay 227; wiper-arm 151 of the group selection level of the group rotary stepping switch; operating coil of the proper signal relay 190; associated group selection key 193; associated shore cable D; contacts 45a and 45b of the locking relay at the distant station; motor magnet 31; contacts 47a and 47b of the timing relay to ground.

The distribution rotary stepping switch will now step "Home." The first surge of 110-volt direct current operating power to the distant station C causes the guide relay 227 (at the operating panel) to operate and open its contacts 227a and 227b, thereby opening the disarm circuit and making it impossible for the operator to step the group rotary stepping switch if he should move the switch 135 (Disarm-Interlock Reset Key) into the left-hand position before the distribution rotary stepping switch reaches home. The guide relay also closes its contacts 227e and 227f, but no circuit change takes place.

The holding relay 107 will hold operated as the guide relay pulses with the steps of the distribution rotary stepping switch. If the switch 135 is in the left-hand

position, other mines armed by "countermining" will be disarmed as the distribution rotary stepping switch steps toward "Home," in the manner described. Since the last ground was removed from the line 118 (Interlock Bus) when the control relay 225 released, the limiting relay 119 may be reoperated if the switch 135 is in the right-hand position.

The Supervisory Circuits

The supervisory circuits permit the operator to directly control the mines of any connected group for firing, clearing, or testing. After a group has been selected (through the wiper-arm 151 of the group selection level) the operator may cause the distribution rotary stepping switch and the supervisory rotary stepping switch (to be shortly described) to step in synchronism and lock-up on any desired mine circuit. In addition, supervisory mine lights indicate to the operator the tactical number of the mine circuit then being contacted by the wiper-arm (i.e. 29) of the selected distribution rotary stepping switch. Correspondingly, when a mine becomes armed while the supervisory circuits are switched in, the supervisory rotary stepping switch steps in synchronism with the selected distribution rotary stepping switch, and when the system locks up the supervisory mine lights indicate the tactical number of the armed mine. The mine may then be fired or disarmed and the system reset by returning all rotary stepping switches to the "Home" position.

The Supervisory Rotary Stepping Switch

As previously stated, the circuits of the operating panel include the supervisory rotary stepping switch whose function is to exercise supervision over the control system as it has thus far been described. Fundamentally, it is similar to the group rotary stepping switch and to the distribution rotary stepping switches (at the submerged distant stations C). That is, the supervisory rotary stepping switch comprises three banks of twenty-five stationary contacts each, each bank being in the form of a half-cylinder, the said banks being served by three wiping instrumentalities which are secured to a common rotatable shaft. In the case of the supervisory rotary stepping switch, the wiping instrumentalities comprise three aligned double-ended wiper-arms of the type previously described; and the three levels of the said switch are designated the "mine selection level," and "synchronizing level," and the "signal level."

Referring to FIGURE 7, the supervisory rotary stepping switch is shown schematically as comprising a rotatable shaft 300 to which there is secured the wiping instrumentalities aforesaid.

In the showing of FIGURE 7 only the outermost wiper-arm and its series of contacts (which comprise the "mine selection level") appear; and the same are respectively indicated at 301 and 302.

Disposed adjacent the shaft 300 of the supervisory rotary stepping switch is a motor magnet 303, the latter having associated with it a pivotally mounted armature 304. Secured to the shaft 300 is a ratchet wheel 305 which is engaged by a stepping pawl 306, the latter being pivotally mounted on, and extending in right-angular relationship from, the armature 304. The stepping pawl is resiliently held against the periphery of the ratchet wheel 305 in any suitable fashion; and is biased tangentially of the ratchet wheel 305, and with sufficient force to rotate the same in a clockwise direction (as seen in FIGURE 7), by a pawl spring 307. Thus, the coaction of the motor magnet 303 of the supervisory rotary stepping switch and the pawl spring 307 will effectively cause the stepping pawl 306 to rotate the ratchet wheel 305 in step-by-step relationship whereby all three of the wiper arms will advance from the "zero" contact to, and through, the contacts generally indicated at 302.

Each of the nineteen numbered contacts (after the initial "zero" contact) of the mine selection level is connected through a key-type switch 309 (Mine Keys) to the

input terminal 240 for the 250-volt direct current clearing power. Similarly, the contact numbered 21 of the mine selection level is connected through a key-type switch 310 (Test Point) to the input terminal 240.

5 The single contact between those which are numbered 19 and 21, and the two contacts between the contact numbered 21 and the "Home" contact, are left blank in the mine selection level.

The nineteen mine keys 309 supply 250-volt selection 10 power to the mine selection level when selecting any of the nineteen mines in any group. That is, the mine selection level of the supervisory rotary stepping switch provides the means for switching 250-volt selection power out to the distribution rotary stepping switch (at the selected 15 distant station C) for the purpose of locking the system on a particular mine of that group. The 250-volt selection power is limited by a resistor 312 (300 ohms) to such an extent that it will not rupture the fuse 42 (0.15 amperes, time-delay type) at the distant station C.

20 The double-ended wiper-arm of the synchronizing level of the supervisory rotary stepping switch is indicated in FIGURE 5a at 313 and its series of contacts at 314. As to the series of contacts 314 they are successively identified as "zero" and numbers 1 through 19 (moving clock- 25 wise), with the contact numbered 13 connected directly to ground, as shown. The last contact is designated as the "Home" contact. All of the numbered contacts of the synchronizing level are bussed together with the exception of the "Home" contact. In the case of the synchronizing level of the supervisory rotary stepping switch, the wiping-ends of its wiper-arm 313 bridge across respec- 30 tively adjacent contacts of its stationary bank without interrupting the circuit in passing from one contact to another.

35 The double-ended wiper-arm of the signal level of the supervisory rotary stepping switch is indicated in FIGURE 5a at 316 and its contacts at 317. Each of the nineteen numbered contacts of the signal level is connected to the signal power lead 122 through a pilot light, as shown 40 at 318. Similarly, the contact numbered 21 of the signal level of the supervisory rotary stepping switch is connected to the signal power lead 122 through a pilot light 319 (Test Point); and the last or "Home" contact is connected to the said lead 122 through a pilot light 320 ("Home").

45 Referring still to FIGURE 5a, the wiper-arm 301 of the supervisory rotary stepping switch is connected to one end of the motor magnet 303 through the resistor 312 (300 ohms), which was previously referred to. The other end of the motor magnet 303 is connected through 50 its own contacts 303a and 303b, and contacts 322a and 322b of a stepping relay 322, to a movable contact 325 of the switch 220 (Lamps-Off-Supervisory). When the switch 220 is in the upper position, the movable contact 325 engages a stationary contact 326 which is connected 55 to the stationary contact 225c of the control relay (FIGURE 5).

Referring to FIGURE 5a, the numeral 330 indicates a key-type switch (Start Key), connects the "+" terminal of the milliammeter 212 and one of the terminals 60 of a ballast resistance rheostat 331 (200 ohms). The other terminal of the ballast resistance rheostat 331 is connected to one end of the motor magnet 303 (330 ohms) of the supervisory rotary stepping switch. The purpose of this ballast resistance rheostat 331 is to enable the adjustment of the current of the shore cables D to a standard value 65 for reference and testing purposes after the groups of mines A have been planted. During normal operation the setting of the ballast resistance is left at the "zero" position.

70 The wiper-arm 313 of the synchronizing level connects through a resistor 332 (300 ohms) with a stationary contact 333 of the switch 220 (Lamps-Off-Supervisory). This stationary contact 333 is engaged by the previously described movable contact 325 when the latter is in the 75 position illustrated in FIGURE 5a.

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The wiper-arm 316 of the signal level of the supervisory rotary stepping switch is connected to a movable contact 335 of the switch 220 (Lamps Off-Supervisory). When in the position shown this movable contact 335 engages a stationary contact 336 which is directly connected to the signal power lead 123.

In regard to the Test Point of the mine selection level, this may be utilized by closing and opening the contacts of the switch 330 (Start Key) or any of the group selection keys 193. At the same time the switch 310 (Test Point) is closed. Opening the switch 330 (Start Key) breaks the flow of 110-volt direct current to the shore cable D, causing the deenergization of the slow-operating timing relay 47 at the selected distribution rotary stepping switch, thus setting up the stepping circuits of the latter. Releasing the switch 330 (Start Key) (or, in the alternative, the group selection key 193) restores 110-volt direct current to the appropriate shore cable D.

Referring to FIGURE 5, the group selection key 193 for any desired group of mines may be moved to the right into the position illustrated and then released; and the group rotary stepping switch will select that group and lock-up on it through the agency of the following circuit from the stationary contact 225c of the control relay:

Pole 110c of the operation switch 110; through the milliammeter 212; start key 330; ballast resistance rheostat 331; motor magnet 303 of the supervisory rotary stepping switch; contacts 303a and 303b; contacts 322a and 322b of the stepping relay 322; switch 220; contacts 225c and 225d of the control relay; through the No. 2 winding (36 ohms) of the stopping relay 203; contacts 107e and 107f of the holding relay 107; operating coil (8 ohms) of the guide relay; wiper-arm 151 (group selection level) of the group rotary stepping switch and through it to the appropriate group contact; operating coil of the appropriate signal relay 190; associated group selection key 193; shore cable D; contacts 45a and 45b of the locking relay 45; motor magnet 31 of the distribution rotary stepping switch; contacts 47a and 47b of the timing relay 47; to ground.

As previously pointed out, the operate value of the group relays is 100 milliamperes; while the operate value of the distribution rotary stepping switches is 165 milliamperes. Therefore, the group relay operates first and removes power again from the shore cable D when contacts 170e and 170f of the group relay open. A circuit to the motor magnet 31 of the distribution rotary stepping switch is now complete through contacts 170b and 170c of the group relay; and the wiper-arm 151 of the group rotary stepping switch will step through the group contacts and leave the system locked on the group with the distribution rotary stepping switch at the "Home" position.

Since current is now flowing through the circuits of the supervisory rotary stepping switch, the motor magnet 303 is energized and opens its contacts 303a and 303b, and thus shunts the current through contacts 322d and 322e of the stepping relay 322, and from the latter through the No. 2 winding (10 ohms) of the operating coil of the stepping relay to a movable contact 327 of the switch 220 (Lamps Off-Supervisory). The No. 1 winding (500 ohms) of the operating coil of the stepping relay 322 connects through a resistor 338 (2300 ohms) with the contact 107d of the holding relay 107. When the switch 220 is in the raised position, the movable contact 327 engages a contact 222 which, as before stated is connected to the contact 225c of the control relay 225. The operation of the stepping relay 322 opens the contacts 322a and 322b, but no circuit change takes place, since this current path was already broken by the separation of the contacts 303a and 303b of the motor magnet. Contacts 322c and 322e are closed, thus opening contacts 322d and 322e, and this circuit change shunts out the motor magnet 303. The shunting out and deenergization of the motor magnet 303 steps the wipers

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301, 313 and 316 to the "zero" position, the circuit path at this time being through the No. 2 winding (10 ohms) of the operating coil of the stepping relay 322 and through contacts 327 and 222 of the switch 220 to contact 225c of the control relay 225 and from the latter to and through the group selection level of the group rotary stepping switch, et cetera, to the distribution rotary stepping switch at the appropriate distant station C.

Until this moment, the current flow is insufficient to energize the operating coil of the motor magnet 31 of the distribution rotary stepping switch. The rise in current through the shore cable D caused by shunting the operating coil of the motor magnet 303 of the supervisory rotary stepping switch energizes the motor magnet 31. When the motor magnet 31 is energized, the contacts 31a and 31b are closed and a circuit is created to cause the energization of the No. 1 winding (500 ohms) of the operating coil of the timing relay 47. This causes the opening of the contacts 47a and 47b of the timing relay which in turn causes the deenergization of the motor magnet 31, whereupon said motor magnet releases and permits the distribution rotary stepping switch to step to the "zero" contact. The opening of the contacts 31a and 31b of the motor magnet breaks the circuit to the timing relay. There is a moment when the said contacts 31a and 31b and the contacts 47a and 47b of the timing relay are simultaneously open. During that brief interval, the remaining paths to ground through the resistor network 62 (20,000 ohms) and the resistor 58 (5500 ohms) all have high resistance and do not pass sufficient current to hold energized the operating coil of the stepping relay 322 at the supervisory rotary stepping switch. Thus, the stepping relay releases and its contacts 322a and 322b close, thus reestablishing the original current circuit to the motor magnet 303 of the supervisory rotary stepping switch. The contacts 322c and 322e are opened and the contacts 322d and 322e are closed, thus breaking the shunting circuit around the motor magnet 303; and through contacts 322d and 322e of the stepping relay there is set up a circuit for the next operation of the said stepping relay. Both the distribution rotary stepping switch and the supervisory rotary stepping switch have stopped on one point; and the stepping relay 322 and the motor magnet 303 of the supervisory rotary stepping switch are both deenergized and made ready to repeat the stepping cycle.

So long as selection power is not applied, there is no circuit through the wiper-arm 301 of the mine selection level of the supervisory rotary stepping switch. The wiper-arm 316 of the signal level, in its clockwise rotative movement, causes each of the mine pilot lights 318 to flash in succession as the supervisory rotary stepping switch steps from point to point. Since the contacts 333 and 325 of the switch 220 are open, there is no current path to the wiper-arm 313 of the synchronizing level.

As indicated before, when the switch 220 is depressed it switches the supervisory circuits in series with the group control circuits (operating panel and selector assembly) making possible the selection of individual mines for testing or for observation fire; when the key 220 is in the centered position the supervisory circuits are inactive and there is no control over the system. When the switch 220 is in the raised (or "Lamps Off" position), all supervisory lamps are cut off, thereby indicating positively to the operator that there is no supervision over the groups of mines.

The pilot light 267 (Alarm) becomes illuminated when a shore cable D is open, or when more than one group has armed mines, or when the 110-volt direct current power supply has been interrupted.

Aside from the operation of the supervisory rotary stepping switch, the circuit changes and functions of the electrical instrumentalities of the operating panel during stepping is identical with that previously described.

Any time the Test Point key 310 is closed, the 250-

volt selection power is applied to the following circuit when the wiper-arm 301 of the mine selection level engages the Test Point contact:

From 250-volt direct current terminal 240 to and through the Test Point key 310 to the Test Point contact of the mine selection level through the wiper-arm 301; resistor 312 (300 ohms); contacts 322c and 322e and No. 2 winding (10 ohms) of the operating coil of the stepping relay 322 to the contacts 327 and 222 of the switch 220 to the stationary contact 225c of the control relay 225 (see FIG. 5) and from it to and through distant station C; and finally through the resistor 38 (1500 ohms) to ground.

The surge of 250-volt D.C. selection power through the resistor 38 (1500 ohms) at the distant station C causes the energization of the locking relay 45 to thereby stop the unitary wiper-arms 29 of the mine level of the distribution rotary stepping switch on the number 21, or Test Point, contact. When the distribution rotary stepping switch locks up the circuits and electrical instrumentalities of the operating panel function in a manner similar to that previously described in connection with the application of 250-volt direct current selection power to the stationary contact 225c of the control relay 225.

While locked on the Test Point the status of the relays and signal devices is as follows:

Locking relay 45	Operated.
Timing relay 47	Not operated.
Distribution rotary stepping switch	Locked on Test Point (contact No. 21) with its motor magnet 31 not operated.
Signal relay 190	Operated.
Guide relay 227	Do.
Holding relay 107	Not operated.
Limiting relay 119	Do.
Firing-clearing relay 175	Operated.
Control relay 225	Not operated.
Stepping relay 322	Operated.
Group relay 170	Not operated.
Group rotary stepping switch	Locked on the selected group with its motor magnet 155 not operated.
Supervisory rotary stepping switch	Locked on Test Point (contact No. 21) with its motor magnet 303 not operated.
Pilot light 319	Illuminated.
Pilot light 164 (of the selected group)	Do.
Pilot light 104	Do.

When the operator opens the contacts of the switch 310 (Test Point) there is broken the circuit for the 250-volt direct current selection power. The flow of 110-volt direct current over the circuit of the shore cable D is of sufficient value to hold energized the locking relay 45 at the distant station C, the appropriate signal relay 190, the guide relay 227, and the stepping relay 322.

Having selected the Test Point of the supervisory rotary stepping switch, the operating hand of the ballast resistance rheostat 331 may be adjusted until there is an appropriate indication on the milliammeter 212 (i.e. in the present case an indication of 58 milliamperes should appear on the milliammeter 212). When the ballast resistance has been properly adjusted, the index setting of the rheostat knob is observed and recorded for that particular shore cable D and the ballast resistance rheostat is then reset to the recorded index for all future testing of that group of mines. After the recording of the indi-

cation and setting of the ballast resistance rheostat 331, the said rheostat is returned to zero.

When the supervisory system is in operation there are two ways in which the operator may interrupt the flow of power to cause the locking relay 45 (at the appropriate distant station C) to release and thereby enable the supervisory system to step off the Test Point or a mine circuit. One method is to open the contacts of the switch 330 (Start Key) to thereby break the circuit of the current to the distribution rotary stepping switch; and the other way is to open the contacts of the concerned group selection key 193. The deenergization of the locking relay 45 at the distant station C sets up the normal stepping circuits of the distribution rotary stepping switch, as earlier described. In the operating panel the signal relay 190, the guide relay 227, and the stepping relay 322 are all deenergized and release, and the holding relay 107 is again energized. Upon release of the key aforesaid (i.e. either the start key 330 or the group selection key 193), the distribution rotary stepping switch and the supervisory stepping switch step in synchronism back to their respective "Home" positions where they lock up in the manner previously described. At this point the group rotary stepping switch is still locked on the selected group and will remain there until the key-type switch 135 (Disarm-Interlock Reset Key) is moved into the left-hand position to short-circuit the holding circuit of the stopping relay, whereby it is caused to release. Since the flow of current to ground through the circuit of the shore cable D and the bleeder resistors at the distant stations C is now approximately 20 milliamperes, the condition of certain relays and signal devices of the system is as follows:

All firing relays 7 are deenergized; all mine latch relays 3 are deenergized; each of the sensitive relays 14 is reset; all of the locking relays 45 at the distant stations C are deenergized; each of the timing relays 47 is energized; all distribution rotary stepping switches are on "Home" position; the motor magnet 31 of each of the distribution rotary stepping switches is deenergized; each of the signal relays 190 is energized; each of the group relays 170 is deenergized; the group rotary stepping switch is on the "Home" position; the motor magnet 155 of the group rotary stepping switch is deenergized; the guide relay 227 is deenergized; the holding relay 107 is energized; the stopping relay 208 is deenergized; the limiting relay 119 is deenergized (and can be operated by moving the key-type switch 135 into the right-hand position); the firing-clearing relay 175 is deenergized; the control relay 225 is deenergized; the stepping relay 322 is deenergized; the supervisory stepping switch is on the "Home" position; the motor magnet 303 of the supervisory rotary stepping switch is deenergized; the pilot light 320 ("Home") is illuminated; and the white pilot light 104 (D.C. Power) is illuminated.

Manual Selection of a Mine With Supervisory Control

To select an individual mine for testing or observation fire, the desired group of mines must have first been selected. The method of selecting a mine is exactly the same as that for a Test Point as previously described, except that the desired mine key 309 is operated to close its contacts and the supervisory circuits and the group control circuits will operate to step. When the distribution rotary stepping switch contacts the circuit of the desired mine the surge of 250-volt direct current selection power charges the capacitor 4 for the firing device at the mine; and the locking relay 45 at the distant station C and the mine latch relay 3 at the mine operate to stop the distribution rotary stepping switch on the desired mine. The circuit for selection power is similar to that previously described except that the current flows from the mine level of the distribution rotary stepping switch,

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through the appropriate mine cable B, the entire winding (555.5 ohms) of the mine latch relay 3, through the firing device capacitor 4 to ground. The flow of firing power is the same as previously described. When clearing, the switch 244 (Voltage Selection Tap Switch) is placed in the "clearing voltage" position and the switch 245 (Firing-Clearing Power) turned on after the mine has been selected.

In order to step off the mine when the supervisory circuits are in operation, the switch 330 (Start Key) or the appropriate group selection key 193 is opened and closed. The unitary wiper-arms 29 of the distribution rotary stepping switch will step off, and if there are no other armed mines in the group it will return to its "Home" position. The group rotary stepping switch will remain locked on the group until the switch 135 (Disarm-Interlock Reset Key) is moved to the left.

When the supervisory circuits are switched on, the automatic disarm feature is not in operation. Thus, if the control system locks on an armed mine while the supervisory circuits are in operation, the movement of the key-type switch 135 into the left-hand position will have no effect. In such a case disarming is accomplished by opening and closing the switch 330 (Start Key) or the appropriate group selection key 193.

The Supervisory Holding Circuit

When the control system is locked on a mine or Test Point with the supervisory control in operation, the supervisory rotary stepping switch will not go "Home" if the switch 220 (Lamps Off-Supervisory) is raised. This prevents the supervisory control from getting out of synchronism when a mine is fired. When locked on a mine, the stepping relay 322 is held operated through the following circuit:

Contacts 175d and 175e of the firing-clearing relay contact; power lead 101; contact 119g of the limiting relay; contacts 175d and 175e of the firing-clearing relay; contacts 107c and 107d of the holding relay; resistor 338 (2300 ohms); and No. 1 winding (500 ohms) of the operating coil of the stepping relay 322 to ground.

Since the stepping relay is in the energized and operated position, its contacts 322a and 322b are open and there is no circuit for the motor magnet 303 of the supervisory rotary stepping switch if the operator raises the switch 220 (Lamps Off-Supervisory). However, if a mine is selected without the interlock having first been reset, the supervisory does not become sealed in through the No. 1 winding (500 ohms) of the operating coil of the stepping relay. The reason is that the contacts 119e and 119f of the released limiting relay 119 are open and there is no circuit through which current can flow to energize and operate the firing-clearing relay 175. Since the firing-clearing relay does not become operated, the holding circuit for the No. 1 winding (500 ohms) of the stepping relay 322 is open at contacts 175d and 175e of the firing-clearing relay.

The Supervisory Synchronizing Circuit

If the supervisory rotary stepping switch should be out of synchronism when the selected distribution rotary stepping switch returns to the "Home" position, the supervisory rotary stepping switch can be made to synchronize automatically if the switch 220 (Lamps Off-Supervisory) is raised. This is true regardless of the status of the limiting relay 119. The self-stepping circuit for the motor magnet 303 of the supervisory rotary stepping switch is as follows: "+" terminal of the milliammeter 212; contacts 481 and 490 to switch 220 (Lamps Off-Supervisory) through the operating coil of the motor magnet 303; through contacts 303a and 303b of the motor magnet 303; through contacts 322a and 322b of the stepping re-

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lay 322; through contacts 325 and 333 of the switch 220 (Lamps Off-Supervisory); and through the resistor 332 (300 ohms), wiper-arm 313 of the synchronizing level of the supervisory rotary stepping switch, and the contacts 314 to ground.

When the motor magnet 303 operates it breaks its own circuit at its contacts 303a and 303b and reoperates. It is self-stepping until the stepping circuit is broken when the wiper-arm 313 of the synchronizing level steps to the "Home" contact.

Other modes of applying the principles of the invention may be employed, changes being made as regards the details described, providing the features stated in any of the following claims, or the equivalent of such be employed.

Having thus described our invention what we claim as new and wish to secure by Letters Patent is:

1. A submarine mine system comprising a casemate control assembly, a distant station assembly including a series of submerged mines and means in electrical relationship with the mines for controlling their detonation, said means including a normally disrupted path to ground, a detector assembly responsive to an electrical field produced by a vessel in the immediate vicinity of the mine and adapted to complete said path to ground, a single path of electrical distribution between the casemate and distant station assemblies, and means for automatically firing any one of the mines of the said series, said means including a distant station selector having a series of selected positions and a home position, means for maintaining the selector normally inoperative and on its home position until said normally disrupted path to ground has been established and additional means controlled by the proximity of a vessel for stepping the selector to one of its selected positions, said selective position being determined by the establishment of said ground on one of the mines.

2. A submarine mine system comprising a casemate control assembly, a distant station assembly including a series of submerged mines and means in electrical relationship with said mines for controlling their detonation, said means including a normally open high resistance path to ground adapted to be closed in the presence of an electrical field produced by a vessel located in the immediate vicinity of the mine, a single path of electrical distribution between casemate and distant station assemblies and means for firing any one of said mines, said means including a distant station selector having a series of selective positions and a home position, means for maintaining the selector normally inoperative and on its home position until said normally disrupted path to ground has been established and additional means in connection with said path to ground and responsive to the presence of an electrical field produced by a vessel to close said path to ground, whereby to cause the selector to step to one of its selective positions, said selective position being determined by the establishment of a ground on one of the mines.

3. A submarine mine system comprising a casemate control assembly, a distant station assembly including a series of submerged mines and means in electrical relationship with the mines for controlling their detonation, said means including normally disrupted high and low resistance paths to ground adapted to be successively established in the presence of an electrical field produced by a vessel in the immediate vicinity of the mine, a single path of electrical distribution between the casemate and distant station assemblies and means for automatically firing any one of the mines of said series after the normally open paths to ground have been successively closed, said means including a distant station selector having a series of selective positions and a home position, means for maintaining the selector normally inoperative and on its home position until the normally open high and low resistance paths to ground have been closed and additional

means in connection with said paths to ground and responsive to an electrical field induced by a vessel in the immediate vicinity of the mines for stepping the selector to one of its selective positions, said selective position being determined by the establishment of said path to ground on one of the mines.

4. A submarine mine system comprising a casemate control assembly, a distant station assembly including a series of submerged mines, each mine embodying a normally open circuit to ground and means in said circuit controlled by a vessel in the immediate vicinity of the mine for closing said normally open circuit to ground, said means including a detector circuit means for energizing said circuit, said means being responsive to the electrical field produced by a vessel in the vicinity of the mine and means operated by said detector circuit when the latter is energized to close said normally open path to ground, a single conductor extending between the assemblies and providing a path of electrical distribution therebetween, means at the casemate assembly for impressing an operating power and a high potential firing power on said interconnecting conductor, a firing circuit and an operating circuit at the distant station assembly, said circuit being supplied with operating and firing power from said conductor, an automatic selector at the distant station comprising a stepping mechanism the latter being included in said operating circuit, a pair of wipers and a rotatable metallic disc simultaneously operated by said stepping machine, means for normally connecting the mine circuits of the respective mines in parallel with the operating circuit through said disc and wipers and means controlled by the detector mechanisms in the respective mine circuits whereby the parallel connections of the mine circuits will be broken and said circuits selectively connected with the firing circuit to fire the mine.

5. A submarine mine control system comprising a distant station including a group of submerged mines, a distributing assembly situated in the midst of the mines and controlling the distribution of electrical energy thereto, a mine circuit and a ground in connection with each mine, means responsive to the presence of a vessel in the immediate vicinity of the mine for connecting the mine circuit with the ground, an automatic selector in the distributing assembly, said selector having a home position and a series of selective positions corresponding in number to the number of mines in the mine group, means connecting said positions with the mine circuits of the respective mines, an operating circuit for said selector, means included in said circuit and coacting with the selector for normally maintaining the latter on its home position, additional means in said operating circuit to step said selector from its home position when a ground has been formed on one of the mine circuits, a stepping circuit in connection with the operating circuit and said selector to step said selector to a selective position after it has been stepped from the home position, a firing circuit, means in connection with the selector and controlled by the operating circuit for connecting the firing circuit with the grounded mine circuit when said selector has reached a selective position connected with the ground circuit, a casemate control assembly, a single conductor extending between the casemate control assembly and the distributing assembly at the distant station, said conductor providing a path of electrical distribution for the operating and firing circuits and means at the casemate assembly for impressing operating power and high potential firing power on said conductor.

6. A submarine mine control system comprising a distant station including submerged distributing assemblies, a series of submerged mines connected therewith, a mine circuit in connection with each of said mines, the respective mine circuits including a ground and means responsive to an electrical field produced by a vessel in the immediate vicinity of the mine, said means including a closed detector circuit, a detector coil energized by the presence of a vessel and adapted to produce a current in said detec-

tor circuit, instrumentalities operated when the detector circuit is energized to connect the ground with the mine circuit, an operating circuit and a firing circuit, an automatic selector comprising a contact bank including upper, lower and intermediate rows of mine contacts, the mine contacts in the upper and intermediate rows being connected to the contacts in the lower rows and to the mine circuits, a stepping mechanism in the operating circuit, said mechanism being non-responsive to the current normally flowing through said circuit but operable by an increase in current flow produced when a ground has been established on a mine circuit, a pair of interconnecting wipers and a metallic disc, said wipers serving the upper and intermediate rows and said disc energizing the lower row of contacts, said wipers and disc being simultaneously responsive to the energization and de-energization of the stepping mechanism whereby when a ground has been formed on one of the mine circuits, the wipers and disc will be rotated until one of said wipers engages the contact connected to the grounded mine circuit, means in connection with the operating circuit and operable when one of the wipers has engaged a contact to disrupt the circuit of the stepping mechanism and to lock the wiper on the engaged contact, a casemate control assembly, a single conductor extending between the casemate control assembly and the distributing assembly at the distant station, said conductor being connected to said operating and said firing circuits, means at the casemate control assembly for impressing operating and firing power upon said interconnecting conductor and additional means in connection with the casemate assembly and the distant station assembly to connect the firing circuit with the grounded mine circuit.

7. A submarine mine system comprising a casemate control assembly, a plurality of distant station assemblies each including a submerged mine field, means in electrical relation with the respective mines of each distant station for controlling the detonation of said mines, said means including a disrupted path to ground adapted to be established by the electrical field of a vessel in the immediate vicinity of the mine, means for automatically establishing a single path of electrical distribution between the casemate assembly and a selected distant station assembly and means for automatically firing any of the mines of the respective mine fields when a vessel is in the immediate vicinity of a mine in such mine field, said means including an automatic selector at each distant station, said selector having selective positions and a home position and means in connection with the selector for maintaining the latter non-operable and on its home position until said path to ground has been established and additional means responsive to an electrical field set up by a vessel in the immediate vicinity of the mines for stepping said selector to one of its selective positions.

8. A submarine mine control system comprising a plurality of distant stations, each station including a group of submerged mines, a distributing assembly situated in the midst of the mine group and controlling the distribution of electrical energy thereto, mine circuits for each mine and a ground in connection with each of said mine circuits, means responsive to the proximity of a vessel for connecting the mine circuits with the ground, an automatic selector, said selector having a home position and a series of selective positions corresponding in number to the number of mines in the mine group controlled by a distant station, conductors interconnecting said positions with the mine circuits, an operating circuit for said selector, means included in the operating circuit and coacting with the selector for normally maintaining the latter on its home position, additional means in said operating circuit to step said selector from its home position when a ground has been formed on one of the mine circuits, a stepping circuit in connection with the operating circuit and said selector to step said selector to a

selective position after it has been stepped from the home position, a firing circuit, means in connection with the selector and controlled by the operating circuit for connecting the firing circuit with the grounded mine circuit when said selector has reached a selective position connected with a grounded mine circuit, a casemate control assembly common to the distant stations and including operating and firing circuits, conductors extending between the casemate control assembly and the distributing assemblies of the distant stations, said conductors providing paths of electrical distribution between the casemate assemblies and the distributing assemblies of the distant stations for the operating and firing circuits thereof and means at the casemate assembly for automatically connecting its operating and firing circuits with the conductor of a distant station, the selector of which is on a selective position connected with a grounded mine and additional means at the casemate for impressing operating power and high potential power on said conductor.

9. A submarine mine control system comprising a plurality of distant stations, each distant station embodying a group of submerged mines, a distributing assembly in the midst of said mines and controlling the distribution of electrical energy thereto, an automatic selector in said distributing assembly, said selector having a home position and a series of selective positions, a plurality of mine circuits, conductors connecting the selective positions of the selector with the respective mine circuits, each mine circuit including a ground connection and mechanism responsive to and operated when a vessel is in the immediate vicinity of a mine to connect the ground connection with the mine circuits, means for maintaining the selector normally inoperative and in its home position until said mine circuit has been connected to ground, an operating circuit in electrical relation with said mine circuit, a stepping mechanism in said operating circuit and nonresponsive to the current normally flowing into said circuit but operable by an increase in current flow produced by the establishment of said ground connection, said stepping mechanism being energized and de-energized by the flow of current through the operating circuit to step said selector from its home position to a selective position, a firing circuit and means in connection with the selector to complete the firing circuit through a ground mine circuit when the selector has stopped upon one of its said positions connected with a ground connection, a casemate control assembly common to the distant stations, conductors extending between the casemate control assembly and the distant station assemblies, said conductor being connected to the operating and firing circuits thereof, operating and firing circuits at the casemate and instrumentalities controlled by said circuits for automatically placing the latter in electrical relation with the operating and firing circuits of a distant station the selector of which is on a selective position connected with a grounded mine, and an additional means at the casemate control assembly for impressing operating power and high potential firing power upon said interconnecting conductor.

10. A submarine mine control system comprising a plurality of distant stations, each distant station including a group of submerged mines and a distributing assembly in the midst of the mine group and controlling the distribution of electrical energy thereto, a mine circuit for each mine and a ground connection for each of said mine circuits, mechanism in each mine circuit and operable when a vessel is in the immediate vicinity of a mine to connect the mine circuit with the ground, an automatic selector having a home position and a series of selective positions each of which is connected with one of the mine circuits, an operating circuit, means in the operating circuit and coacting with the selector for normally maintaining the latter on its home position, means controlled by said operating circuit and effective when a mine circuit has been grounded to step the selector from its home position and to lock it on the selective position connected with the

grounded mine circuit, a firing circuit, means for connecting said firing circuit with the grounded mine circuit when a selector has stopped on a selective position connected with said grounded mine circuit, a casemate control assembly common to the distant stations, conductors extending between the casemate control assembly and the assemblies of the distant stations, said conductors being connected at the distant stations to the operating and firing circuits thereof, operating and firing circuits in the casemate control assembly, means in connection with said casemate control assembly for automatically connecting its operating and firing circuits with the conductor of a distant station, the automatic selector of which is on a selective position, connected with a grounded mine circuit, and additional means in the casemate control assembly for impressing operating power and firing power on the last mentioned conductor.

11. A submarine mine control system comprising a plurality of distant stations, each station including a group of submerged mines, a distributing assembly in the midst of the mine group and controlling the distribution of electrical energy thereto, a mine circuit in connection with each of said mines, said mine circuits including a ground, electro-magnetically controlled means in the mine circuit of each mine and operated by a vessel when the latter is in the immediate vicinity of the mine to connect the ground of such mine with the mine circuit, a firing circuit at each distant station, an automatic selector comprising a contact bank including upper, lower and intermediate rows of mine contacts, the mine contacts in the upper and intermediate rows being connected to the contacts in the lower row and to the mine circuits, a stepping mechanism in the operating circuit, said mechanism being non-responsive to the current normally flowing through said circuit but operable by an increase in current flow produced when a ground has been established on a mine circuit, a pair of interconnected wipers and a metallic disc, said wipers serving the upper and intermediate rows and said disc engaging the lower row of said contacts, said wipers and disc being simultaneously responsive to the energization and de-energization of the stepping mechanism whereby when a ground has been formed on one of the mine circuits the wipers and discs will be rotated until one of said wipers engage the contact connected to the grounded mine circuit, means in connection with the operating circuit and operable when one of the wipers has engaged a contact to disrupt the circuit of the stepping mechanism and to lock the wiper on the engaged contact, a casemate control assembly common to the distant stations, conductors extending between the casemate assembly and the assemblies of the distant station, said conductors being connected to the operating and firing circuits of said stations, operating and firing circuits in connection with the casemate control assembly, means for connecting said operating and firing circuits of the casemate assembly with the conductor of a distant station the automatic selector of which is locked on a grounded mine and additional means at the casemate control assembly for impressing operating and firing power upon said interconnecting conductor.

12. A submarine mine control system comprising a plurality of distant stations, each distant station including a normally inactive automatic distributor, a plurality of submerged mines controlled by said distributor, means in connection with each mine to establish a ground, said means including a normally open ground circuit and means responsive to the electrical field of a vessel in the immediate vicinity of the mine to close said ground circuit, each of said automatic distributors having a home position and a series of selective positions corresponding in number to the number of mines controlled by said distributors, means for interconnecting the selective positions of said distributor with the mine circuits of the mines which it controls, means for normally retaining

said distributor on its home position until said ground has been established, an operating station, means for selectively firing any of said mines from the operating station said means including a device responsive to the proximity of a vessel, and a normally inactive automatic selector at the operating station, said automatic selector having a home position connected with a ground and a series of selective positions corresponding in number to the number of distant stations, means including a plurality of conductors for connecting the selective positions of said automatic selector with the distributors of the distant stations, means for normally retaining said automatic selector on its home position until one of the mine circuits of a distant station has been grounded, means for stepping the automatic distributor and the automatic selector at a distant station in coordinated relation, means associated with the distributor and selector to stop and lock the same on a selected position, means at the operating station to visually indicate the selective position upon which said distributor and automatic selector have stopped, operating, locking and firing circuits in electrical relation with the operating and distant stations and means for applying operating, locking and firing power through the locked distributor and selector.

13. A submarine mine control system comprising a plurality of distant stations, each distant station including a normally inactive automatic distributor and a plurality of submerged mines controlled by said selector, each of said mines having a normally open ground, means in connection with each of said mines for closing the normally open ground circuit, said means being operated by the proximity of a vessel, each of the distributors at the distant stations having a home position and a series of selective positions corresponding in number to the number of mines controlled by said station, means for interconnecting said selective positions with the mine circuits of the mines controlled by the distant station, means for normally retaining said distributor on its home position until a mine circuit has been grounded, an operating station, means for selectively firing any of said mines from the operating station and by the proximity of a vessel, said means including a normally inactive automatic selector at the operating station, said automatic selector having a home position and a series of selective positions corresponding in number to the number of distant stations, means interconnecting the selective positions of said automatic selector with the distributors at the distant stations, means for normally retaining said automatic selector inoperative and on its home position until the normally open circuit between the mine and its ground has been closed, means for stepping said last named automatic selector and an active automatic selector at a distant station in coordinated relation, means associated with said automatic selector to stop the same on a selected position, means at the operating station to visibly indicate the position upon which the automatic selectors have stopped, operating, locking and firing circuits in connection with the operating and distant stations, means in connection with said circuits for successively effecting their connection with the circuits of the respective mines, means for applying operating, locking and firing power through said last named automatic selector.

14. A submarine mine control system comprising a plurality of distant stations, each distant station including a plurality of submerged mines in electrical relation therewith, a normally open mine circuit and a ground in connection with each mine, means at each of said mines for closing the normally open mine circuit to ground, said means being operated by the proximity of a vessel, a normally inactive automatic distributor at each of said distant stations, each of said distributors having a home position and a series of selective positions, means for interconnecting the selective positions of the distributor with the mine circuits of the respective mines, an operat-

ing circuit for said distributor means included in said circuit and coacting with the selector for normally maintaining the latter on its home position, additional means in said operating circuit to step said selector from its home position when a ground has been formed on one of the mine circuits, a stepping circuit in connection with the operating circuit and said distributor to step said distributor to a selective position after it has been stepped from the home position, an operating station, means for selectively firing any of said mines from the operating station and by the proximity of a vessel, said means including a normally inactive automatic selector at the operating station, said automatic selector having a home position and a series of selective positions corresponding in number to the number of distant stations, means connecting the selective positions of said automatic selector with the distributors of the distant stations, means in connection with said operating circuit for normally retaining said automatic selector on its home position, additional means in said operating circuit for stepping an automatic selector and a distributor at a distant station in coordinated relation when a mine controlled by said station has been grounded, means associated with said automatic selector and said distributor to stop and lock the same on a selective position, means at the operating station to visually indicate the selective position on which an automatic selector and a distributor have stopped and locked, a locking circuit and means in said circuit for locking the automatic selector on a selective position, a firing circuit and means in connection with the distributors and selectors at the distant and operating stations to complete the firing circuit of a grounded mine circuit when the automatic selector and distributor have stopped on a selective position connected with ground, means for applying operating, locking and firing power to said operating, locking and firing circuits through said automatic selector.

15. A submarine mine control system comprising a plurality of distant stations, each station including a plurality of submerged mines controlled by said station, a normally inactive automatic distributor having a home position and a series of selective positions, a plurality of mine circuits, conductors connecting the selective positions of the selector with the respective mines, each mine circuit including a normally open ground connection and mechanism operable by the proximity of a vessel to close said ground connection, an operating circuit, means in the operating circuit and coacting with the distributor for normally maintaining the latter on its home position, additional means in said operating circuit to step said distributor from its home position when a ground has been connected to one of the normally open mine circuits, a stepping circuit in connection with the operating circuit and said distributor to step the latter to a selective position after it has been stepped from the home position, an operating station, means for selectively firing any of said mines from the operating station and by the proximity of a vessel, said means including a normally inactive automatic selector at the operating station, said automatic selector having a home position and a series of selective positions corresponding in number to the number of distant stations, means interconnecting the selective positions of the automatic selector with the automatic distributors of the distant stations, means in connection with said operating circuit for normally retaining said automatic selector on its home position, means for stepping said automatic selector and an automatic distributor at a distant station in coordinated relation, means associated with said automatic selector and said distributor to stop and lock the same on a selective position, means at the operating station to visibly indicate the selective position which the automatic selector and distributor at the distant station have stopped, a locking circuit and means controlled by said locking circuit for locking the selector on a selec-

tive position, a firing circuit, means operated by said firing circuit to fire the mine connected with the position upon which the automatic selector and a distributor have stopped and locked, means for successively connecting the operating, locking and firing circuits with a grounded mine through the automatic selector and distributor locked on said mine, means for applying operating, locking and firing power to said operating, locking and firing circuits.

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