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FIRING CONTROL CIRCUIT
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[Diagram of firing control circuit with various electronic components and connections labeled with numbers and symbols.]
This invention relates generally to firing control systems for depth charges. More specifically, the invention relates to an electronically controlled depth charge firing system adapted to respond to the gradient of the magnetic field generated by a submarine and to explode the depth charge when a predetermined gradient is received thereby; and wherein the system operates to prevent the explosion of the depth charge in response to countermining shocks received thereby.

In certain of the prior art devices such, for example, as the system described and claimed in the copending application of W. S. Macdonald et al. for Firing Control Mechanism For A Depth Charge, Serial No. 453,550, filed August 4, 1942, it has been the usual practice to employ a condenser which is adapted to be discharged by the firing of a gas tube operatively connected thereto in response to a predetermined magnetic gradient. The condenser is caused to discharge through a slow-make relay which, when operated, completes a circuit to an electro-responsive detonator to fire the depth charge. A countermining network further is provided and comprises a vacuum tube adapted to respond to shocks received thereby and fire another gas tube. The firing of this second gas tube causes the firing condenser to discharge through the second gas tube thus preventing the relay from operating.

The foregoing arrangement, however, has not been found to be entirely satisfactory in practice for the reason that relays of the type employed therein are particularly delicate in structure and susceptible to damage as a result of sudden shocks received thereby such, for example, as the shock received upon striking the water. In the event that a countermine signal is received by this system, each of the gas tubes is caused to fire substantially concurrently whereby it is necessary that the firing relay operate in a proper manner to introduce a sufficient delay in the closure of the firing circuit to allow the charge on the firing condenser to be dissipated through the second gas tube. This disadvantage is overcome in the system of the present invention for the reason that the signal which results from a countermine shock received by the system does not concurrently appear at the gas tubes which control the firing condenser. Such signal appears first at the tube in the countermining network whereby the charge on the firing condenser is dissipated a predetermined amount before the signal appears at the other tube. By means of the foregoing arrangement, no firing relay is required and the detonator is arranged common to both discharge paths of the condenser, one of such paths being of considerably higher resistance than the other whereby the current caused to flow therethrough is of insufficient magnitude to operate the detonator.

Another object is to provide a new and improved system for firing a depth charge in which the firing circuit thereof is prevented from becoming effective until a predetermined interval has elapsed after a countermining signal has been received thereby.

Another object of the invention is to prevent the firing and protective circuits from being actuated simultaneously.

Another object is to interpose a delay in the application to the firing circuit of signals adapted to cause an actuation thereof whereby the protective system is caused to operate first if a similar signal concurrently is applied thereto.

Another object is the provision of a new and improved system for firing a depth charge having a firing circuit and a protective circuit and wherein the protective circuit is rendered effective in response to countermining shocks to prevent the operation of the firing circuit for a predetermined interval.

Another object is the provision of a new and improved system for firing a depth charge having a firing circuit adapted to be rendered effective in response to signals of predetermined character and a protective circuit responsive to countermine signals and wherein the firing circuit is adapted to render the firing circuit ineffective for a predetermined interval when a signal adapted to operate the firing circuit and a countermine signal are received concurrently.

Another object is to provide an improved firing system for a depth charge which is economical to manufacture, reliable in operation and which possesses all the qualities of compactness, ruggedness and durability.

Still other objects, advantages and improvements will be apparent from the following description taken in connection with the accompanying drawings which illustrate in diagrammatic form the complete electrical system of the present invention according to the preferred embodiment thereof.

The system of the present invention comprises a pair of gradient coils L1 and L2 adapted to apply an input signal through a suitable chopper 10 and an air core transformer 11 to an amplifying network variably in accordance with the gradient of the magnetic field with which the coils are linked as the coils are moved through the field. An air core transformer is employed herein rather than an iron or other high permeability material core transformer in order to prevent spurious signals from being generated by the transformer in response to shocks or vibrations received thereby. In addition, an air core transformer provides for a substantially larger gain in the signal applied thereto than an iron or other high permeability material core transformer. The aforesaid arrangement is similar to that described and claimed in the aforesaid application of W. S. Macdonald et al. and for a more detailed description of this arrangement reference is made thereto.

The amplifying network of the instant system comprises three similar vacuum tubes 12, 13, and 14, each having a plate 15, cathode 16, control grid 17 and screen grid 18. Operating potential is applied to the plates 15 of tubes 12, 13 and 14 from a battery BA1 through resistors 19, 21 and 22 respectively, cathode voltage being supplied thereto from a battery BA2 through cathode resistors 23, 24 and 25 respectively. It will be noted that potential is not applied to the plates and cathodes of these tubes until the depth charge has descended a sufficient distance in the water to close the contacts of the hydrostat switch 26, as described in the aforesaid copending application of W. S. Macdonald. Potential is applied to the screen grid 18 of each of the tubes from battery BA1 through a voltage divider network comprising resistors 63 and 64, a condenser 65 also being provided to maintain the screen grids at a substantially constant potential.
The control grids 17 of tubes 12, 13 and 14 are connected through grid resistors 27, 28 and 29 respectively to ground, the resistor cell 26 being in parallel in order that a portion of the output of tube 12 may be selected for amplification by tubes 13 and 14. The input signal to the amplifying network is applied through a suitable coupling condenser 31 to the control grid of tube 12, additional coupling condensers 30 being provided in the output circuits of tubes 12 and 13 in the unamplifying network.

Two gas tubes 32 and 33 are further provided, each comprising a plate 34, cathode 35 and control grid 36. Operating potential is applied to the plates of tubes 32 and 33 from battery BA through resistors 37 and 38 respectively and potential is applied to the cathodes thereof from battery BA through control resistors 39 and 41. Biasing voltage is applied to the control grids of tubes 32 and 33 from battery BA through grid resistors 42 and 43 respectively. The output of the last tube in the amplifying network is applied to the control grid of tube 32 through a suitable coupling condenser 44 and the output of tube 32 is applied to the control grid of tube 33 through an R-C network comprising condenser 45 and resistor 46 and through a suitable coupling condenser 47.

A condenser 48 is arranged in the output circuit of tube 33 and is connected in series with a suitable electroresponsive detonator 49, the condenser being caused to discharge through the tube and detonator when the tube is rendered conducting. As the depth charge travels downward into sufficiently close proximity with respect to a submarine, the gradient signal received by cells L1 and L2 increases, this signal being amplified by tubes 12, 13 and 14 and appearing at the control grid 36 of gas tube 32. When the depth charge has reached a position adjacent the submarine, the signal appearing at the control grid of tube 32 will be of sufficient magnitude to cause the power applied thereto to be the break-down voltage of the tube and thereby cause the tube to conduct.

When this occurs, condenser 45 is caused to discharge through tube 32, the grounded filament lead and resistor 46, the rate of discharge being controlled by resistor 46. The discharge of condenser 45 causes the voltage at point 51 in the circuit to go negative by an amount equal to the drop in the voltage applied to the plate of tube 32 caused by the firing thereof. The change in voltage polarity produced at point 51 produces a corresponding change at point 52 in the grid circuit of tube 33 such that a large negative voltage appears at the grid and the tube is non-conducting. If the negative voltage now appears at point 53 causes current to flow from battery BA through resistor 43 to condenser 47 which tends to restore the initial charge on condenser 47 and cause the voltage on the grid of tube 33 to increase in a positive direction, it being understood that condenser 45 is still discharging through tube 32.

When condenser 45 has substantially fully discharged, tube 32 is extinguished since the plate voltage thereof has fallen below the main gap sustaining voltage of the tube. When tube 32 is extinguished, condenser 45 is recharged very rapidly from battery BA through resistors 38 and 37, whereby the voltage on the grid of tube 33 increases rapidly to a value sufficient to cause the tube to conduct current. When this occurs, firing condenser 48 is caused to discharge through tube 33 and electroresponsive detonator 49, thereby to operate the detonator and explode the depth charge.

The protective circuit employed herein comprises any suitable electrical transducer 53 such, for example, as a piezoelectric crystal, arranged with a voltage or current changing so as to be shocked by a wave of hydrostatic pressure striking the depth charge and to generate an electro-motive force in accordance therewith. The protective circuit further comprises a gas tube 54 having a plate 55, cathode 56 and control grid 57. Static operating potentials are applied to the elements of tube 54 as follows: potential is applied to the control grid of tube 54 through resistor 58, to the control grid 57 from battery BA through resistor 38, to the control grid 57 from battery BA through resistor 58, and to the cathode 56 battery BA through resistor 49. The firing condenser 48 is also connected to the plate 55 of tube 54 through a resistor 61 adapted to limit the magnitude of current flow through tube 54 and detonator 49.

The operation of the protective circuit in response to a wave of hydrostatic pressure such, for example, as may be received by the depth charge as the result of an explosion of another depth charge or similar explosion within the vicinity thereof will now be described.

When such an explosion occurs, crystal 53 is stressed thereby causing an electro-motive force to be generated thereby. A condenser 62 is connected between the crystal and the control grid 57 of tube 54 and is adapted to be charged by the voltage generated by the crystal. As the charge on condenser 52 appears at the control grid of tube 54 increases to a value sufficient to cause the tube to break down and conduct current. When this occurs, firing condenser 48 is caused to discharge through resistor 61, tube 54, and electroresponsive detonator 49, the detonator being operated by reason of the small value of current flow there through controlled by the current limiting resistor 61. When condenser 48 has discharged sufficiently, the plate potential of tube 54 falls below the main gap sustaining voltage of the tube and the tube is extinguished, the condenser thereafter being recharged by battery BA. It will be noted that the discharge of the firing condenser through tube 54 also lowers the plate potential of tube 33 such that this tube is rendered ineffective until the firing condenser is recharged.

As is well known in the art, vacuum tubes such, for example, as the type employed in the amplifier stage of the instant case, are susceptible to sudden shocks and as a result thereof the plate voltages of the tubes is affected. Therefore, when commutating shocks are received by the firing system of the present invention, it is possible that tubes 12, 13 and 14 will react in such a manner as to cause a voltage to appear at the control grid of tube 32 which is of sufficient magnitude to cause the tube to break down and conduct current. At the same time, however, tube 54 will be rendered conductive by crystal 53, as heretofore described, and the firing condenser caused to discharge through the path which includes tube 54 and current from the discharge path for condenser 48 which includes tube 33 is not energized by reason of the delay provided by condensers 45 and 47 in applying potential of proper magnitude to the control grid of tube 33. This delay is of sufficient period to allow the plate potential of tube 33 to be reduced by the discharge of condenser 48 to a value less than that required to cause current to flow therein when the grid potential reaches the rated control grid breakdown voltage.

From the foregoing, it should now be apparent that a firing control circuit for a depth charge has been provided which is well adapted to fulfill the aforesaid objects of the invention.

While the invention has been described in particularity with reference to an example thereof which gives satisfactory results, it readily will be apparent to those skilled in the art to which the invention pertains, after understanding the invention, that further embodiments, modifications and changes may be made therein without departing from the spirit and scope thereof as defined by the claims appended hereto.

The present invention may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of any royalties thereon or therefor.
What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In a firing control system for a depth charge, the combination of means including an electron discharge device having a control grid and adapted to fire said depth charge when a predetermined value of voltage is applied to said control grid, means for detecting changes in the magnetic field adjacent said depth charge and for generating voltages in accordance therewith, said voltage generating means being subject to generating spurious voltages in response to pressure impulses received thereby, means including a transducer for disabling said firing means as said pressure impulses are received by the depth charge, and circuit means for preventing simultaneous actuation of said firing and said disabling means in response to said pressure impulses.

2. In a firing control system for a depth charge, the combination of means including an electron discharge device having a control grid and adapted to fire said depth charge when a predetermined value of voltage is applied to said control grid, means for detecting changes in the magnetic field adjacent said depth charge and for generating voltages in accordance therewith, means for applying said predetermined voltage to said discharge device, means for applying said predetermined voltage to said discharge device, means for applying said predetermined voltage to the control grid of said first mentioned discharge device, and means responsive to shocks received by said depth charge and including said second discharge device for reducing said voltage below the operative level thereof when the shocks are received concurrently with the application of voltage to said voltage applying means.

3. A device of the character disclosed for providing initial of current flow comprising, in combination, means including a first electron discharge device having a control grid and adapted to initiate said current flow when a voltage of predetermined value is applied to said control grid, means for generating voltage signals, a second electron discharge device, means for amplifying said voltage signals and applying the amplified voltages to the grid of said second discharge device, a source of potential, a resistance and a capacitance serially connected across said source of potential, means including said second discharge device for providing a discharge path for said capacitance through said resistance thereby effecting said discharge interval, and means interconnecting said discharge means and said second discharge device for interposing a delay in the application to the control grid of said first mentioned discharge device of voltages generated by the voltage generating means.

4. In a firing control system for a depth charge, the combination of means including an electron discharge device for firing said depth charge as said device operates, protective means including a transducer for disabling said firing means when pressure impulses are received by said depth charge, means responsive to changes in the magnetic field adjacent said depth charge, and circuit means controlled by said magnetic responsive means and adapted to operate said electron discharge device a predetermined time interval after a predetermined change in the magnetic field has been detected by the magnetic responsive means.

5. A firing control system of the character disclosed comprising, in combination, a normally charged condenser, a pair of discharge paths of different resistance values, said condenser, an electroresponsive detonating means common to said plurality of discharge paths, means for detecting changes in the magnetic field adjacent said depth charge and for generating electrical signals in accordance therewith, a first electron discharge device responsive to electrical signals of predetermined character and included in the discharge path of least resistance for causing said condenser to discharge therethrough as the device operates thereby to operate said detonator, a second electron discharge device responsive to electrical signals of said predetermined character and arranged in a discharge path of higher resistance for causing said condenser to discharge therethrough as the discharge device operates, said discharge path of higher resistance being adapted to control the discharge of said condenser in such a manner as to prevent the operation of said detonating means, means for initiating the operation of said second electron discharge device in response to pressure impulses received by said discharge device and means for delaying application of electrical signals of said predetermined character to said first discharge device.

6. In a depth charge, a firing circuit including an electron discharge device having a control grid, said firing circuit being rendered effective when a voltage of predetermined value is applied to said control grid, means for supplying operative anode voltage to said discharge device, means for applying said predetermined voltage to the control grid after a predetermined delay, a second discharge device operatively connected to the anode of said first mentioned discharge device, and means responsive to shocks received by said depth charge and including said second discharge device for reducing said voltage applied to said discharge device to a predetermined value subsequent to said predetermined time interval.

7. In a depth charge, a first trigger tube, a firing control circuit for said depth charge including said first trigger tube and operative to trigger said first tube after a predetermined time interval after the application of a predetermined voltage to the control grid of said first mentioned tube, a second trigger tube included in said circuit for receiving said predetermined voltage and constructed and arranged to be fired thereby, a delay network interconnecting said tubes for determining said predetermined interval of time the firing of said second tube causing the output voltage of said network to swing first in a negative direction and thereafter in a positive direction to trigger said second tube upon attaining a predetermined positive level, said predetermined interval of time being the time required for said output voltage to swing through said negative and positive directions to said predetermined positive level, a third trigger tube, and means responsive to countermeasure shocks received by said depth charge and including said third trigger tube for rendering said first trigger tube inoperative when said charge device is operated prior to the positive swing of said output voltage.

8. In a depth charge, means responsive to changes in a magnetic field and adapted to generate voltages proportional thereof, means for amplifying said voltages, a pair of gaseous discharge devices each having a plate and control grid and adapted to fire when a predetermined value of voltage is applied to the control grid thereof, means applying said amplified voltages to the grid and a capacitor connected to said grid between said capacitor across the main discharge path of said first of the devices, a second capacitor, means connecting said second capacitor between the junction of said capacitor and said grid and said capacitor and the control grid of the other of said devices and adapted when said first of the discharge devices is fired to cause said capacitor to charge and means for delaying application of electrical signals of said predetermined character to said second discharge device.

9. In a depth charge, a firing circuit including an electron discharge device having a control grid, said firing circuit being rendered effective when a voltage of predetermined value is applied to said control grid, means for applying said predetermined voltage to said control grid, means for generating voltage signals, a second electron discharge device, means for amplifying said voltage signals and applying the amplified voltages to the grid of said second discharge device, a source of potential, a resistance and a capacitance serially connected across said source of potential, means including said second discharge device for providing a discharge path for said capacitance through said resistance thereby effecting said discharge interval, and means interconnecting said discharge means and said second discharge device for interposing a delay in the application to the control grid of said first mentioned discharge device of voltages generated by the voltage generating means.

10. In a depth charge, a firing circuit including an electron discharge device having a control grid, said firing circuit being rendered effective when a voltage of predetermined value is applied to said control grid, means for applying said predetermined voltage to the control grid after a predetermined delay, a second discharge device operatively connected to the anode of said first mentioned discharge device, and means responsive to shocks received by said depth charge and including said second discharge device for reducing said voltage applied to said discharge device to a predetermined value subsequent to said predetermined time interval.
to discharge through said detonating means and said other one of the discharge devices when said other discharge device is fired.

9. In a firing control system for a depth charge, the combination of a firing circuit responsive to generated signal voltages and to electrical signals of predetermined character, said firing circuit including a first and second electron discharge devices, means responsive to changes in a magnetic field for generating said generated signal voltages in accordance with such changes, said generating means being subject to generating spurious electrical signals of said character in response to vibrations received thereby, a protective circuit coupled to said firing circuit and responsive to said electrical signals to render said firing circuit ineffective for a predetermined interval of time, vibration responsive means for applying said electrical signals to said protective circuit, and circuit means interconnecting said first and second electron discharge devices and coacting with said first electron discharge device to develop a time delay in the application to said second electron discharge device of said generated signal voltages and on said electrical signals whereby said protective circuit is enabled to render said firing circuit ineffective for said predetermined interval of time upon concurrent application to said generating means of magnetic field changes and vibrations.

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