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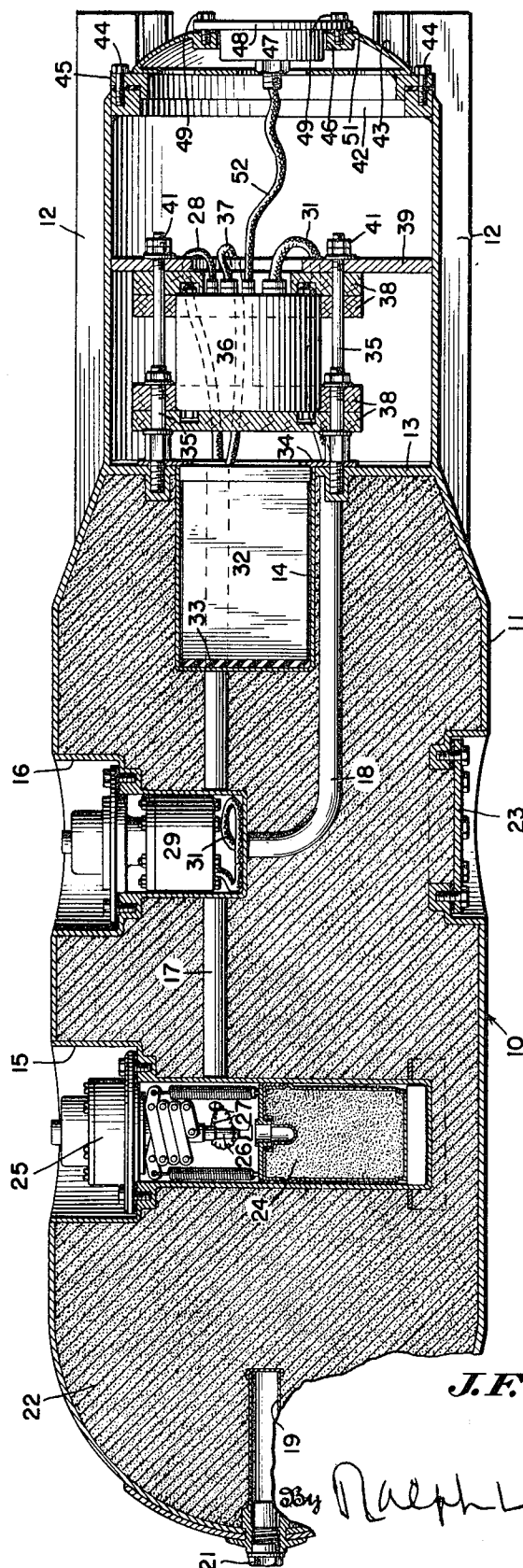
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ACOUSTIC MINE FIRING CONTROL SYSTEM

Filed May 15, 1945

2 Sheets-Sheet 1



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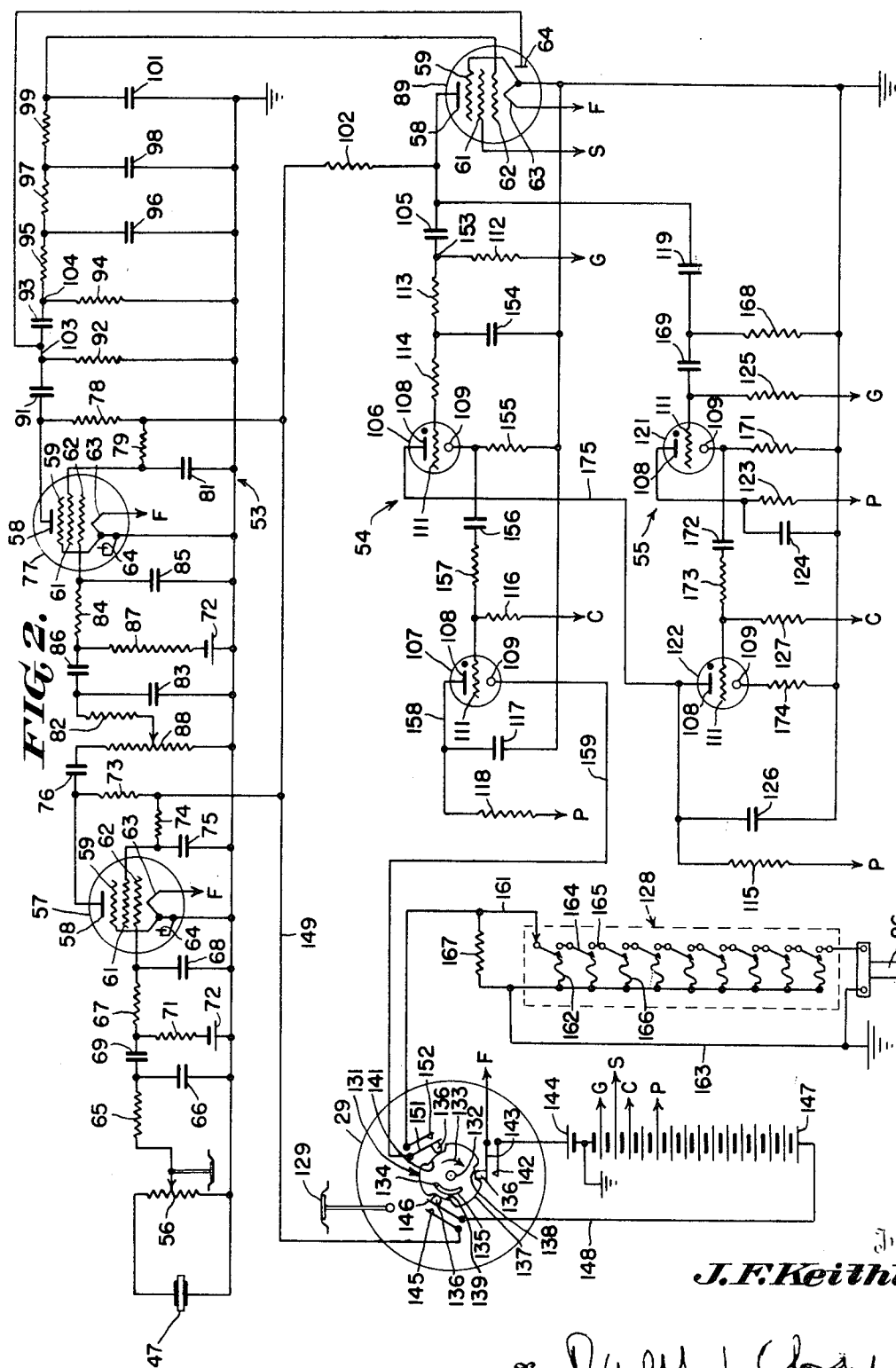
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ACOUSTIC MINE FIRING CONTROL SYSTEM

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21 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to firing control systems for marine mines and more specifically to an acoustic mine firing control system wherein the system operates to detonate and explode the mine associated therewith in response to sound signals transmitted through the surrounding water by sound emitting bodies such, for example, as a surface vessel, submarine or the like, and the system operates to prevent detonation of the mine in response to countermining explosions occurring within the vicinity thereof.

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

It is well known in the art that an acoustic underwater signal is extremely complex, the energy components thereof being distributed over a wide range of both frequency and amplitude. Moreover, a normal ship's sound is characterized by a gradual increase in intensity or strength while a signal resulting from a countermining explosion is characterized by a steep wave front or a very rapid increase in intensity or strength.

Tests have proved that the spatial energy distribution of ship's sound is such that the extremely low frequency components thereof, 5 to 50 cycles, for example, are concentrated below and adjacent the ship's hull, such low frequency sounds being greatly attenuated at a distance of substantially 150 feet athwartship due to the reflection of pressure waves at the surface of the water and to the destructive interference cause by out-of-phase vibration of the various sections of the ship's hull. On the other hand, the higher frequency components of a ship's sound present a much wider target area since these sounds are attenuated athwartship at a much lesser degree. Therefore a mine firing control system which is sensitive only to the low frequency components of a ship's sound provides an area of sensitivity which may be made to coincide substantially with the zone of destructivity of the mine employing the system, thereby increasing the probability of imparting severe damage to a target ship actuating the system.

In accordance with the principles set forth in the foregoing discussion, the mine firing control mechanism of the instant invention is adapted to be operated by the low frequency components of a ship's acoustic field included within the range of 5 to 50 cycles per second, for example, and utilizes the differences in the average values of signals received as a function of time to discriminate between a normal ship's sound and a sound produced by a countermining explosion.

In its broader aspects, the present invention comprises a microphone which is adapted to transduce pressure signals impinging against the surface thereof into electrical signals corresponding thereto. The output of the microphone is fed into a signal channel wherein the desired low frequency components of the signal are selected and amplified by a two-stage, band-pass amplifier. The amplified signal is then rectified to obtain a signal proportional to the average amplitude of the amplified signal;

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this rectified signal is further filtered, amplified by a one-stage, D.C. amplifier and thereafter fed into a firing channel and a protective channel. The firing channel comprises a cold-cathode, gas "glow" tube which, when operated, causes another gas tube to arc and discharge a condenser through a shipcounter or an electroresponsive detonator, as the case may be.

The protective channel also comprises two cold-cathode, gas tubes of the same character as those in the firing channel. The circuit constants of both the firing and protective channels are selected and arranged in such a manner to cause the firing channel to respond to slow rates of increase on signal amplitude characteristics of a normal ship's sound and the protective channel to respond to the more rapid increases in signal amplitude characteristics of countermining shocks. When the protective channel is actuated, it operates to discharge a condenser and remove the plate voltage from the "glow" tube in the firing circuit, thereby preventing the firing tube associated therewith from being operated. Such action renders the firing channel ineffective to operate the detonator for a predetermined period of time corresponding to the time required to recharge the condenser discharged by the actuation of the protective channel, such period of time being referred to hereinafter as the "dead period."

An object of the present invention is to provide an acoustic mine firing control system with an area of sensitivity which coincides substantially with the zone of destructivity of the mine employing the system.

Another object is the provision of a new and improved acoustic mine firing control system in which the system operates to produce a firing actuation thereof in response to sound signals of predetermined character and to prevent a firing actuation when sound signals of a different character are received thereby.

Another object is the provision of a new and improved acoustic mine firing control system in which the system operates to produce a firing actuation thereof only in response to sound signals which have a predetermined amplitude-time function.

Another object in a new and improved acoustic mine firing control system is the provision of a firing channel responsive to sound signals of predetermined character and a protective channel adapted to prevent the firing channel from operating when sound signals of a different character are received by the system.

Another object is to provide a new and improved acoustic mine firing control system in which the system operates to produce a firing actuation thereof in response to low frequency components of a ship's sound and to prevent a firing actuation when a plurality of countermining shocks are continually received by the system.

Still another object is to provide an acoustic mine firing control system in which the zero signal level of the system is adjusted to the background noise level, thereby eliminating the undesirable effect of background noise on the system.

A further object of the present invention is to provide an acoustic mine firing control system in which the sensitivity thereof is automatically adjusted in accordance with the depth to which a mine employing the system is submerged.

A still further object is the provision of a new and improved acoustic mine firing control system the component parts of which are rugged in construction, economical to manufacture and reliable in service.

Additional objects and advantages will be apparent from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a sectional view with certain parts in elevation of an underwater mine suitable for use with the

acoustic mine firing control system of the present invention; and

FIG. 2 illustrates in diagrammatic form a complete electrical system suitable for use with the mine of FIG. 1 according to a preferred embodiment of the invention.

Referring now to the drawings for a more detailed description of the invention and more particularly to FIG. 1 thereof, the numeral 10 generally designates an underwater mine adapted to be launched from an aircraft in flight and adapted to come to rest on the bed of a body of water in which the mine is launched. The mine comprises an outer casing 11 generally of cylindrical configuration and having a reduced end portion to which fins 12 or the like are secured to steer or guide the mine in flight.

The casing 11 is divided internally at the reduced end portion thereof by a bulkhead 13 which supports a well 14 for a purpose hereinafter to be disclosed. The casing 11 is also provided with inwardly extending wells 15 and 16 from which extend respectively, tubes or ducts 17 and 18 to the bulkhead 13. The casing is further provided with a well 19 in which a percussion detonator may be inserted, if desired, when the mine 10 is to be used for purposes other than those disclosed herein. Accordingly, for purposes herein, the well 19 is sealed as by the plug 21.

The remaining space within the main portion of the casing 11 is filled with an explosive charge 22 of TNT or the like sufficient to destroy or damage a vessel and to impart a negative degree of buoyancy to the mine whereby the mine is caused to sink through the water and come to rest on the bed thereof. The explosive charge conveniently may be admitted into the casing by way of a suitable watertight filler opening 23.

A booster charge 24 and the extender mechanism 25 usually associated therewith are arranged within the well 15 in watertight relation therein. The extender mechanism carries an electroresponsive detonator 26 for igniting the booster charge 24 and is adapted to move the detonator into operative relation with respect to the booster charge when the mine reaches a predetermined depth of submergence in the water, as is well known in the art to which the invention appertains. The leads 27 of the detonator comprise a cable 28 which is extended through the duct 17 to the reduced end portion of the casing 11.

Arranged within the well 16 in watertight relation therewith, is a clock mechanism 29 adapted to complete certain circuits of the electrical system within predetermined intervals of time after the mine has been launched within the water, as will appear more clearly as the description proceeds. For this purpose, a multi-conductor cable 31 connected to contacts comprising the clock mechanism is extended through the duct 18 into the reduced end portion of the casing.

The well 14 serves as a housing and support for a battery 32, the battery being clamped within the housing against a resilient support 33 therein by means of a retaining ring 34 secured to the bulkhead as by a plurality of studs 35. The battery 32 is arranged to supply electrical energy to a firing control mechanism 36 by way of a multi-conductor cable 37 when the aforesaid certain circuits have been closed by the clock mechanism 29 as explained in the foregoing.

The mechanism 36 is supported on the studs 35 by means of a plurality of flexible spacer plates 38, which plates may be formed of any suitable material such, for example, as wood, the plates being supported on the studs and shaped to conform to the end portions of the mechanism. The free end portions of the studs 35 extend through and are supported by a plate 39, which plate is shaped to conform slideably with the inner surface of the casing 11. The projecting portions of the studs are threaded to receive a plurality of nuts 41 whereby the mechanism 36 may be clamped between the plates 38 when the nuts are drawn up tight against the slideable plate 39, substantially as shown.

The reduced end portion of the mine casing, at the open end thereof, carries a ring member 42 which is secured to the casing as by welding or otherwise suitably secured thereto. A dish-shaped cover 43 is secured to the member 52 in watertight relation therewith as by a plurality of screws 44 carried by the flange portion 45 of the cover 43. The cover is provided with a central opening 46 for receiving a sound responsive device 47. The device 47 is provided with a flange portion 48 by means of which the device is secured, as by a plurality of screws 49, to the cover, a suitable gasket 51 being inserted between the cover and flange to insure a watertight connection therebetween.

The sound responsive device 47 is of a type adapted to generate electrical signals in accordance with sound pressure waves received thereby through the water in which the mine 10 is placed, the device preferably being adapted to give a substantially flat response over a range of frequencies such, for example, as five to fifty cycles per second. For this purpose, the device 47 may be a hydrophone of any well known type suitable for the purpose, but preferably is of a type comprising crystal microphones for the reasons that such a hydrophone is mechanically strong and is relatively smaller in size than other hydrophones capable of equivalent performance.

The electrical signals generated by the hydrophone 47 are applied to the firing control mechanism 36 by way of a cable 52. The free end of each of the cables 28, 31, 37 and 52 carries a plug or jack adapted interfittingly to engage a counterpart therefor carried by the firing control mechanism 36, thereby to provide an arrangement whereby the electrical connections of the system are facilitated when the mine is assembled. It will be understood, of course, that all necessary openings in the spacer plates 38 and the supporting plate 39 are provided to accommodate the extension of the cables therethrough.

The operation of the firing control system of the mine 10 and the arrangement of the several electrical components thereof will be best understood by reference to FIG. 2 of the drawings wherein the electrical system of the mine is shown diagrammatically.

The firing control mechanism comprises a signal channel, a firing channel and a protective channel indicated generally by the numerals 53, 54 and 55, respectively. The signal channel 53 comprises, in turn, the hydrophone 47 which is connected to a sensitivity switch 56 adapted to vary the voltage input to the signal channel from the hydrophone 47 in accordance with the depth to which the mine 10 is submerged. The switch 56 may be of any suitable type but for the purpose herein takes the form of a hydrostatically controlled switch which operates to allow greater amounts of hydrophone output voltage to be fed into the signal channel as the mine descends through the water by shorting out portions of resistance normally connected across the input terminals of the signal channel, thereby to prevent a firing actuation of the system at shallow depths and to prevent sound signals emitted from large vessels from building up too rapidly at shallow depths.

The signal channel 53 further comprises a two stage, bandpass amplifier which selects and amplifies the desired signal. The first amplifier stage includes a vacuum tube 57 having a plate or anode 58, a suppressor grid 59, a screen grid 61, a control grid 62, a cathode-filament 63 and a diode-plate 64, and operates as a conventional pentode, resistance coupled, A.C. amplifier with a band-pass input filter. The input filter consists of two low-pass sections, resistor 65 and condenser 66 and resistor 67 and condenser 68, and the coupling elements condenser 69 and resistor 71 which by-pass to ground the higher frequency components. A negative bias is applied to the control grid 62 of the pentode 57 from the battery 72 through the resistors 71 and 67. It will be noted that the diode-plate 64 of tube 57 is not used and therefore is connected to the ground leg of the cathode-

filament 63 of the tube. Voltage is applied to the plate 58 of tube 57 through the plate load resistor 73 and to the screen grid 61 thereof through the resistor 74, the condenser 75 acting as a leveling condenser for providing a constant potential to the screen grid. The suppressor grid 59 is connected to the cathode-filament in the usual manner.

The grid bias and plate load resistance 73 of the pentode 57 are so related that in the static state, the plate voltage thereof lies approximately in the middle of the linear range of the tube's characteristic. Therefore, the tube operates as a class A voltage amplifier whereby signal distortion is held to a minimum and the output voltage wave form is substantially the same as that which is applied to the control grid.

The output voltage of the first amplifier stage is coupled through a coupling condenser 76 to the input circuit of a second amplifier stage which is also operated as a class A voltage amplifier and further selects and amplifies the desired low-frequency band. A five element vacuum tube 77 identical with that of the first stage is provided with potential being applied to the plate 58 thereof through a plate load resistor 78 and to the screen grid thereof through a resistor 79, a condenser 81 acts as a leveling condenser to provide a constant voltage on the screen grid. The diode-plate 64 of the tube 77 is not used and is connected to the grounded leg of the cathode-filament 63 as is the suppressor grid 59 thereof. The input filter network for the second amplifying stage is provided by the two low-pass sections, resistor 82 and condenser 83, and resistor 84 and condenser 85; and the coupling elements, condenser 86 and resistor 87, which by-pass to ground the undesirable high frequency components. A negative bias is applied to the control grid 62 of the pentode 77 through the resistors 87 and 84 from the grid-biasing battery 72. A resistor 88 provides the gain control of the system and by varying the value of resistor 88 any fraction of the signal output of the first amplifying stage may be applied to the control grid 62 of the tube 77, thereby controlling the overall gain of the two amplifying stages.

The output voltage of the second amplifying stage is fed through an input filter network to a rectifier, D.C. amplifier stage. A third diode-pentode 89 is employed in this stage to accomplish both the rectifying and amplifying actions. The input filter network to the tube 89 comprises two coupling elements, condenser 91 and resistor 92, and condenser 93 and resistor 94, which elements serve to eliminate background noise and D.C. Three low-pass filter sections; resistor 95 and condenser 96; resistor 97 and condenser 98, and resistor 99 and condenser 101, are employed to attenuate the high frequency components. The control grid 62 of tube 89 is grounded through the resistors 99, 97, 95 and 94, the screen grid 61 thereof receives its potential directly from a battery, and potential is applied to the plate 58 thereof through a plate load resistor 102. The suppressor grid 59 is tied to the grounded leg of the filament-cathode 63 in the usual manner.

The A.C. output of the second amplifier stage is coupled to the diode plate 64 of the tube 89 through condenser 91 and resistor 92 such that any A.C. voltage developed across resistor 92 is applied between the diode plate 64 and filament-cathode 63 of tube 89. The diode plate operates as a half-wave rectifier and conducts on the positive half cycles such that during the negative half cycles a current flows through resistor 92 in such a direction as to cause the potential at point 103 in the circuit to become negative with respect to ground potential. If the potential at point 103 becomes increasingly negative, current will be caused to flow through resistor 94, the point 104 being initially at ground potential. Because of the current flow through resistor 94, the potential at point 104 follows that of point 103, thereby reducing the potential at point 104 to a value below that of ground

potential. The time constant of condenser 93 and resistor 94 is large so that the potential at point 104 does not immediately fall to zero when the average voltage at point 103 becomes constant.

The voltage which is developed at point 104 is coupled to the control grid 62 of the tube 89 through the three low-pass RC filter sections heretofore described. As the negative grid voltage builds up across condenser 101, the plate current of tube 89 decreases, thereby decreasing the voltage drop across the plate load resistor 102 and causing the plate voltage to increase.

It should be pointed out here that such operation of the rectifier, D.C. amplifier stage adjusts the zero signal level of the system at background noise level rather than at zero signal pressure level since the potential at point 104 in the circuit tends to approach ground potential when the signal becomes constant of when the average voltage at point 103 becomes constant. Moreover, the negative potential built up across condenser 101 by background noise is of such a value that the plate potential of tube 89 is relatively small, thereby requiring a substantially greater increase in signal level to raise the plate voltage sufficiently to actuate the firing channel that would be required if the zero level of the system were adjusted to zero signal pressure.

The firing channel 54 is coupled by means of a condenser 105 to the plate 58 of tube 89 and comprises two cold cathode gas tubes 106 and 107, each of the gas tubes 106 and 107 having an anode or plate 108, a cathode 109 and a control grid 111. The grid 111 of tube 106 is positively biased through resistors 112, 113 and 114 and the plate 108 thereof receives its potential through resistor 115. The grid 111 of tube 107 is positively biased through resistor 116 and the plate 108 thereof and condenser 117 receive a potential through resistor 118.

The protective channel 55 is also coupled by way of a condenser 119 to the plate 58 of tube 89 and comprises two cold cathode, gas tubes 121 and 122 of the same type as tubes 106 and 107 arranged in the firing channel 54, each of the tubes 121 and 122 having a plate 108, a cathode 109 and a control grid 111. Potential is applied to the plate 108 of tube 121 through a resistor 123 and is maintained at a predetermined value by a condenser 124, while the control grid 111 thereof obtains a positive static bias through resistor 125. Under static conditions, potential is applied to the plate 108 of tube 122 through the resistor 115 and is maintained at a predetermined value by a condenser 126, while the control grid thereof obtains a positive static bias through a resistor 127.

The firing channel 54 is adapted to respond to signals applied to the input thereof which have predetermined amplitude gradients or which increase in amplitude at a slow rate while the protective channel 55 is adapted to respond to signals applied to the input thereof which have different predetermined amplitude gradients or which increase in amplitude at a relatively rapid rate. The selective operation of the firing and protective channels will appear in greater detail as the description proceeds.

Included in the firing channel are the electroresponsive detonator 26 and an electroresponsive shipcounting device indicated generally by the numeral 128. The shipcounter 128 preferably is of a type having a plurality of fusible elements adapted to be melted in succession in response to the passage of a plurality of vessels over the mine 10 and is adapted to be operated by condenser 117 when the condenser is caused to discharge.

With reference again being made to FIG. 2 of the drawings, a description of the operation of the electrical system shown therein in response to the passage of a vessel over the mine 10 will now be given. Let it be assumed, for the purpose of description that the mine 10 has been launched into a body of water and has come to rest on the bed thereof. Let it be assumed further that the extender mechanism 25 has operated and moved the

detonator 26 into operative relation with respect to the booster charge 24. Let it be assumed still further that before the launching of the mine, the shipcounter 128 has been adjusted to count the passage of nine vessels over the mine before the detonator 26 will be fired.

After an interval of time has elapsed during which a salt washer comprising an element of the clock mechanism 29 is dissolved, a diaphragm 129 comprising another element of the clock mechanism is permitted to move under pressure of the surrounding water and to initiate the operation of a spring wound motor, which motor drives a cam 131 of the clock mechanism in a well-known manner. The cam 131 is mounted for rotation on a pivot 132 and moves in the direction of the arrow 133 until the cam engages a stop pin 134 disposed within an arcuate slot 135 provided in the cam. During this movement of the cam 131 the aforesaid pairs of contacts of the clock mechanism 29 are adapted to be closed in sequence. Each of the several pairs of contacts comprises a follower 136 of any suitable insulating material, which follower is urged into engagement with a cylindrical cam surface 137 provided on the cam 131. The cam surface is provided with a plurality of peripheral indentations 138, 139 and 141 therein, which indentations are adapted to receive the followers 136 and are of varying lengths, thereby to cause the pairs of contacts to close in sequence.

According to the foregoing arrangement, contacts 142 and 143 of the clock mechanism 29 are the first to close. Closure of these contacts supplies the potential of the A-battery section 144 to the filaments F of the amplifier tubes 57, 77 and 89 from the high voltage side of the battery section 144, contacts 142 and 143 of the clock mechanism, filament-cathodes of the tubes 57, 77 and 89 and thence to ground potential at the low voltage side of battery 144.

After a predetermined interval, contacts 145 and 146 of the clock mechanism 29 are closed, thereby to apply the potential of the B-battery section 147 to the plates 58 of the amplifier tubes 57, 77 and 89 from the high voltage side of the battery section 147 by way of conductor 148, contacts 145 and 146 of the clock mechanism, conductor 149, through the plate load resistors 73, 78 and 102 of the amplifier tubes 57, 77 and 89 respectively.

After a further predetermined interval, contacts 151 and 152 of the clock mechanism 29 are closed to complete a circuit between the cathode 109 of the gas tube 107 and the shipcounter 128 and detonator 26.

It should be noted here that the B-battery section 147 is provided with a plurality of taps, G, S, P and C whereby a proper static potential is applied to the control grids 111 of tubes 106 and 121, to the screen grid 61 of amplifier tube 89, to the control grids 111 of tubes 107 and 122 and to the plates 108 of tubes 107 and 122, respectively. It should also be noted that as the mine 10 descends through the water, the sensitivity switch 56 is operated hydrostatically thereby to decrease gradually the amount of resistance shunted across the hydrophone 47, in a manner described in the foregoing.

If a vessel emitting sound in the low frequency range of five to fifty cycles per second moves within the aforesaid area of sensitivity of the mine 10, the sound pressure signal which is caused to impinge against the outer surface of the hydrophone 47 is transduced into an electrical signal, the envelope of the electrical signal corresponding to the envelope of the sound pressure signal. The electrical signal is then fed into the signal channel 53 wherein the signal is filtered and amplified by the first and second amplifier stages in a well known manner, thereby to deliver the desired low frequency signal to the rectifier, D.C. amplifier tube 89 at the proper level.

As the envelope of the electrical signal slowly increases, the voltage at point 103 in the circuit becomes increasingly negative. When this occurs, the voltage at

point 104 in the circuit becomes more negative, as heretofore described, the voltage thus developed at point 103 being coupled to the grid 62 of tube 89 through the three section, low pass filter, thereby increasing the plate voltage of tube 89. This increase in plate voltage is coupled to the firing channel 54 through condenser 105, resulting in a voltage rise at point 153 in the firing channel. The rate at which the voltage at point 153 increases is controlled by the rate of increase in plate voltage of tube 89 and by the time constant of condenser 105 and resistor 112 which time constant is large enough so that the voltage rise at point 153 closely follows the increase in plate voltage of tube 89.

As the voltage at point 153 in the firing channel 54 increases, condenser 154 is charged through resistor 113, thereby increasing gradually the net potential applied to the control grid 111 of the gas tube 106. When the grid 111 of tube 106 reaches its firing potential, the control gap thereof breaks down, the discharge transferring thereafter to the main gap in a well known manner. When this occurs, the normally charged condenser 126 is caused to discharge through tube 106 and a resistor 155 which is connected between the cathode 109 of the tube and ground and which is of a value sufficient to prevent the tube 106 from arcing. The current flow through resistor 155 raises the cathode potential of tube 106 above ground, such increase in potential being coupled to the grill 111 of the gas tube 107 through a condenser 156, a resistor 157 and resistor 116, thereby causing the potential on the grid of tube 107 to increase.

When the grid 111 of tube 107 reaches its firing potential, tube 107 is caused to arc in a well known manner whereby the normally charged condenser 117 discharges over the following path; high side of condenser 117, conductor 158, tube 107, conductor 159, contacts 151 and 152 of the clock mechanism 29, conductor 161, fusible element 162 of the shipcounter 128, conductor 163 from whence the circuit is completed to ground, thereby melting the element 162 of the shipcounter and causing the spring contact element 164 associated therewith to move into engagement with the plate contact 165 of the second fusible element 166. During the interval required by the spring contact element 164 to move into engagement with the plate contact 165, condenser 117 discharges through a resistor 167 to ground, thereby lowering the voltage across condenser 117 sufficiently to prevent the second fusible element from being melted when the element 164 moves into engagement with plate contact 165. Moreover, as condenser 117 discharges, the potential applied to the plate 108 of tube 107 falls below the main gap sustaining voltage thereof thereby extinguishing the tube.

After firing, the system is rendered ineffective for a predetermined period of time, which period of time corresponds to the time required to recharge the firing condenser 117 through the resistor 118, this period being followed by a period of reduced sensitivity while the various circuit parameters become readjusted to normal sensitivity. As was pointed out hereinabove, the protective channel 55 is not actuated when the plate voltage of tube 89 rises slowly for the reason that such rise in voltage appears across condenser 119, thereby preventing the grid 111 of tube 121 to be elevated to its firing potential. In the event a small leakage current flows through resistor 168, it will be insufficient to charge condenser 169, thereby further preventing an appreciable elevation in grid potential of tube 121.

In a similar manner, the remaining eight fusible elements of the shipcounter 128 are destroyed successively by the next eight vessels which move successively within the aforesaid area of sensitivity of the mine 10, the last fusible element being adapted, when destroyed, to connect the electroresponsive detonator 26 into the discharge circuit of condenser 117. As the tenth vessel moves within the area of sensitivity of the mine, the low frequency

sound signal generated thereby is fed into the signal channel, filtered, amplified, rectified and further amplified, the voltage on the plate 58 of tube 89 varying in accordance with the envelope of the sound signal. When the plate voltage increases to a predetermined value, the firing channel 54 is caused to operate in a manner heretofore described whereby condenser 117 is discharged.

When condenser 117 is caused to discharge by the passage of the tenth vessel over the mine, current flows from the high side of condenser 117 over conductor 158, through tube 107, conductor 159, contacts 151 and 152 of the clock mechanism 29, conductor 161, electroresponsive detonator 26 from whence the circuit is continued to ground, thereby exploding the mine beneath a vulnerable portion of the tenth vessel to move over the mine.

In the event that a countermining explosion occurs within the vicinity of the mine 10 and the sound pressure signal produced thereby and characterized by a relatively rapid increase in amplitude impinges against the outer surface of the hydrophone 47, the sound signal is transduced thereby into an electrical signal corresponding thereto, which electrical signal is filtered, amplified, rectified and further amplified by the signal channel 53 in the foregoing manner. The output voltage of tube 89 varies in accordance with the envelope of the electrical signal and is coupled to the protective channel 55 through condenser 119. Since the rate of increase in amplitude of a countermining signal is rapid, the rapid rise in plate voltage of tube 89 is applied directly to the grid 111 of tube 121 through condensers 119 and 169, thereby causing tube 121 to glow and condenser 124 to discharge.

Condenser 124 discharges through tube 121 and a resistor 171 connected between the cathode 109 thereof and ground. The potential drop caused by the flow of discharge current through resistor 171 is coupled to the grid 111 of tube 122 through a condenser 172, a resistor 173 and resistor 127, thereby causing tube 122 to arc and discharge condenser 126 rapidly. When condenser 126 discharges, current flows from the high side thereof through tube 122 and a resistor 174 to ground. It will be noted that the plates 108 of tubes 106 and 122 are connected together by conductor 175 such that the discharge of condenser 126 removes the plate voltage on tube 106 in the firing channel, thereby rendering this tube inoperative for a period of time corresponding to the time required to recharge condenser 126 and preventing the operation of the firing channel 54.

When the plate voltage on tube 89 increases rapidly, the firing channel is not actuated by reason of the time delay afforded by the combination of resistor 113 and condenser 154. Although such a rapid increase in plate voltage appears at point 153, the grid 111 of tube 106 will not be elevated in potential sufficiently to cause the tube to glow until condenser 154 is charged. However, the rapid rise in plate voltage appears immediately at grid of tube 121, thereby causing the protective channel to be operated before the firing channel.

It should be noted that in order to operate the firing channel, the sound signal must not only increase in amplitude at a predetermined rate, but must prevail for an interval sufficient to charge condenser 154.

From the foregoing, it should now be apparent that an acoustic mine firing control system has been provided which is well adapted to fulfill the aforesaid objects of the present invention. Moreover, it should further be obvious that the system, by reason of the static or non-moving character of the component parts thereof, is well suited for use with a mine adapted to be launched from an aircraft in flight.

While the invention has been disclosed in particularity with respect to an example thereof which gives satisfactory results, it readily will be apparent to those skilled in the art, after understanding the invention, that further embodiments and variations may be made without depart-

ing from the spirit and scope of the invention as defined by the claims appended hereto.

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

1. In an acoustic mine firing control system of the character disclosed, a firing channel responsive to electrical signals of predetermined character, a protective channel responsive to electrical signals of different character and adapted to render said firing channel ineffective for a predetermined interval, a sound responsive device adapted to transduce sound pressure signals into electrical signals corresponding thereto, and a signal channel connected to said sound responsive device and adapted to generate and deliver said electrical signal of predetermined and different character to said firing and protective channels respectively at a predetermined frequency and a predetermined level when sound signals corresponding thereto are received by said sound responsive device.

2. In an acoustic mine firing control system adapted to be operated by the low frequency components of a ship's acoustic field, a firing channel responsive to electrical signals of predetermined amplitude gradient, a protective channel responsive to electrical signals of different amplitude gradient and adapted to render said firing channel ineffective for a predetermined interval, a sound responsive device for transducing low frequency sound signals into electrical signals corresponding thereto, a signal channel operatively connected to said sound responsive device and comprising at least one stage of low frequency band-pass amplifying means and a rectifier amplifier stage connected thereto and having an output voltage whose amplitude varies in accordance with the envelope of sound signals received by said sound responsive device, and circuit means for applying said output voltage to said firing and protective channels simultaneously.

3. In a firing system for a marine mine, means responsive to sound signals and adapted to generate electrical signals corresponding thereto, a signal channel controlled by said sound responsive means and comprising at least one stage of band-pass amplifying means and a rectifier amplifier stage connected thereto and having an output voltage which varies in accordance with the envelope of sound signals received by said sound responsive means, hydrostatically controlled means for adjusting the sensitivity of said signal channel in accordance with the depth of submergence of the mine, a firing channel including time delay means controlled by said signal channel for operating the firing channel when said output voltage increases at a predetermined rate and reaches a predetermined value, and a protective channel adapted to render said firing channel inoperative for a predetermined interval, said protective channel including a filter network controlled by said signal channel for operating the protective channel when said output voltage increases at a different rate and reaches said predetermined value.

4. In a firing system for a marine mine adapted to be operated by sound signals which prevail for a predetermined interval, means responsive to sound signals and adapted to generate electrical signals corresponding thereto, a signal channel connected to said sound responsive means and comprising a rectifier amplifier stage having an output voltage which varies in accordance with the envelope of sound signals received by the sound responsive means, hydrostatically controlled means for varying the sensitivity of said signal channel in accordance with the depth of submergence of said mine, a firing channel including time measuring means controlled by said signal channel and adapted to initiate the operation of said firing channel when said output voltage increases at a predetermined rate for at least said predetermined interval and reaches a predetermined value.

5. In an acoustic mine firing control system of the character disclosed, the combination of a firing channel responsive to electrical signals which increase at a predetermined rate, a protective channel responsive to elec-

trical signals which increase at a different rate and adapted to prevent the operation of said firing channel, a sound responsive device adapted to generate electrical signals corresponding to the sound signals received thereby, and a signal channel controlled by said sound responsive device for producing said electrical signals individual to said firing and protective channels and adapted to initiate the operation of the firing and protective channels selectively in accordance with the rate of increase of sound signals received by the sound responsive device.

6. In a marine mine adapted to be fired in response to sound signals transmitted through the surrounding water by a vessel moving within the zone of destructivity of the mine, a firing channel, a sound responsive device, a signal channel connected to said sound responsive device and adapted to initiate the operation of said firing channel when sound signals of predetermined amplitude are received by said sound responsive device, and means included in said signal channel for preventing the operation of said firing channel in response to the acoustic energy resulting from background noise present in the surrounding water and received by said sound responsive device.

7. In an acoustic mine firing control system of the character disclosed, the combination of a firing channel responsive to electrical signals of predetermined character, a protective channel responsive to electrical signals of different character, a sound responsive device adapted to generate electrical signals corresponding to the sound signals received thereby, a signal channel controlled by said sound responsive device for producing said electrical signals individual to said firing and protective channels and adapted to initiate the operation of the firing and protective channels selectively in accordance with the character of sound signals received by the sound responsive device, and circuit means included in said signal channel and adapted to adjust the signal level of the signal channel at substantially zero value in response to background noise.

8. In an acoustic mine firing control system of the character disclosed, the combination of a firing channel adapted to be operated in response to electrical signals having a predetermined amplitude time function, a protective channel adapted to be operated in response to electrical signals of different amplitude time function, means adapted to receive sound signals and generate electrical signals in accordance therewith, a signal channel controlled by said sound receiving means for delivering said electrical signals of predetermined and different amplitude time functions to said firing and protective channels respectively at a predetermined frequency and level when sound signals corresponding thereto are received by the sound receiving means, and circuit means included in said signal channel for adjusting the signal level of the signal channel at substantially zero value in response to background noise.

9. In a mine firing system of the character disclosed, means responsive to sound signals and adapted to generate electrical signals corresponding thereto, a signal channel connected to said sound responsive means and comprising a rectifier amplifier stage having an output voltage which varies in accordance with the envelope of sound signals received by said sound responsive means, circuit means for adjusting the signal level of the signal channel at substantially zero value in response to background noise, a firing channel responsive to electrical signals of predetermined amplitude gradient, time delay means included in said firing channel for coupling said signal and firing channels and for controlling the operation of the firing channel, a protective channel responsive to electrical signals of different amplitude gradient and adapted to render said firing channel inoperative for a predetermined interval, and a filter network included in said protective channel for coupling said signal and protective channels and for controlling the operation of the protective channel.

10. In an acoustic mine firing control system adapted to be operated by the low frequency components of a ship's

acoustic field and having firing and protective channels, the combination of, a sound responsive device for transducing low frequency sound signals into electrical signals corresponding thereto, a signal channel operatively connected to said sound responsive device and comprising a rectifier amplifier stage having an output voltage which varies in accordance with the envelope of sound signals received by the sound responsive device and is adapted to control the operation of said firing and protective channels, and circuit means for preventing the operation of said firing channel in response to background noise.

11. In an acoustic mine firing control system, the combination of a mine firing circuit, a sound responsive device, amplifying means controlled by said sound responsive device and adapted to produce an A.C. signal which corresponds to sound signals received by the sound responsive device, a rectifier D.C. amplifier device controlled by said A.C. signal and adapted to produce a D.C. signal which varies in accordance with the envelope of said A.C. signal, means controlled by said D.C. signal and adapted to operate said mine firing circuit when the D.C. signal increases at a predetermined rate, and circuit means controlled by said A.C. signal for decreasing said D.C. signal to a predetermined value and preventing a further increase thereof when the A.C. signal is constant.

12. In an acoustic mine firing control system, the combination of a mine firing circuit including a trigger device, a sound responsive device, amplifying means controlled by said sound responsive device and adapted to produce an A.C. signal which corresponds to sound signals received by the sound responsive device, a rectifier D.C. amplifier device controlled by said A.C. signal and adapted to produce a D.C. signal which varies in accordance with the envelope of said A.C. signal, a time delay circuit controlled by said D.C. signal and adapted to fire said trigger device when the D.C. signal increases at a predetermined rate and reaches a predetermined value, and circuit means controlled by said A.C. signal for decreasing said D.C. signal to a predetermined value and preventing a further increase thereof when the A.C. signal becomes constant.

13. In an acoustic mine firing control system, the combination of a mine firing circuit, a sound responsive device, amplifying means controlled by said sound responsive device and adapted to produce an A.C. signal which corresponds to sound signals received by the sound responsive device, a rectifier D.C. amplifier device controlled by said A.C. signal and adapted to produce a D.C. signal which varies in accordance with the envelope of the A.C. signal, means controlled by said D.C. signal and adapted to operate said mine firing circuit when the D.C. signal increases at a predetermined rate, circuit means controlled by said A.C. signal for decreasing said D.C. signal and preventing a further increase thereof when the A.C. signal becomes constant, and means controlled by said D.C. signal for preventing the operation of said mine firing circuit when the D.C. signal increases at a different rate.

14. In an acoustic mine firing control system, the combination of a mine firing circuit including a trigger device, a sound responsive device, amplifying means controlled by said sound responsive device and adapted to produce an A.C. signal which corresponds to sound signals received by the sound responsive device, a rectifier D.C. amplifier device controlled by said A.C. signal and adapted to produce a D.C. signal which varies in accordance with the envelope of said A.C. signal, a time delay circuit controlled by said D.C. signal and adapted to fire said trigger device when the D.C. signal increases at a predetermined rate and reaches a predetermined value, circuit means controlled by said A.C. signal for decreasing said D.C. signal and preventing a further increase thereof when the A.C. signal becomes constant, a protective circuit including another trigger device adapted to render said firing circuit inoperative for a predetermined interval, and a discriminatory network included in said protective circuit and

controlled by said D.C. signal for firing said other trigger device when the D.C. signal increases at a different rate and reaches said predetermined value.

15. In an acoustic mine firing control system of the character disclosed, a sound responsive device for converting sound signals to electrical signals, an electron discharge device having a plurality of elements including a plate and a control grid, a source of electrical energy for applying static operating potentials to said elements, coupling means including first timing means between said sound responsive device and the control grid of said electron discharge device for causing the plate potential of the electron discharge device to increase in accordance with the envelope of acoustic energy received by the sound responsive device, and a second timing means included in said coupling means for decreasing said plate potential to a predetermined value and preventing a further increase thereof when the acoustic energy received by said sound responsive device is constant.

16. In an acoustic mine firing system of the character disclosed, a sound responsive device for converting sound signals to electrical signals, a rectifier amplifier device having a plurality of elements including a plate and a control grid, a source of electrical energy for applying static operating potentials to said elements, coupling means including first timing means between said sound responsive device and the control grid of said rectifier amplifier device for causing the plate potential of the rectifier amplifier device to increase in accordance with the envelope of sound energy reaching the sound responsive device, a second timing means included in said coupling means for decreasing said plate potential to a predetermined value and preventing a further increase thereof when the acoustic energy received by said sound responsive device is constant, a firing channel including at least one trigger device having a plate and a control grid and adapted to be operated by the trigger device, said source of electrical energy also being adapted to apply a static operating potential to the plate and control grid of said trigger device, and a second coupling circuit included in said firing channel for applying the plate potential of said rectifier amplifier device to the control grid of said trigger device when the plate potential of the rectifier amplifier device increases at a predetermined rate and reaches a predetermined value, thereby firing said trigger device and operating said firing channel.

17. In an acoustic mine firing system of the character disclosed, a sound responsive device for converting sound signals to electrical signals, a rectifier amplifier device having a plurality of elements including a plate and a control grid, a source of electrical energy for applying static operating potentials to said elements, coupling means including first timing means between said sound responsive device and the control grid of said rectifier amplifier device for causing the plate potential of the rectifier amplifier device to increase in accordance with the envelope of sound energy reaching the sound responsive device, a second timing means included in said coupling means for decreasing said plate potential to a predetermined value and preventing a further increase thereof when the acoustic energy received by said sound responsive device is constant, a firing channel including at least one trigger device having a plate and a control grid and adapted to be operated by the trigger device, said source of electrical energy also being adapted to apply a static operating potential to the plate and control grid of said trigger device, a second coupling circuit included in said firing channel for applying the plate potential of said rectifier amplifier device to the control grid of said trigger device when the plate potential of the rectifier amplifier device increases at a predetermined rate and reaches a predetermined value, thereby firing said trigger device and operating said firing channel, a protective channel including a second trigger device having a plate and a control grid statically biased by said source of

electrical energy and adapted to render said firing channel inoperative for a predetermined interval when the second trigger device is fired, and a filter network included in said protective channel for applying the plate potential of said rectifier amplifier device to the control grid of said second trigger device when the plate potential of the rectifier amplifier device increases at a different rate and reaches said predetermined value, thereby firing said second trigger device.

18. In an acoustic firing control system for a marine mine, the combination of sound responsive means for transducing sound signals into electrical signals corresponding thereto, means including a pressure responsive device for adjusting the sensitivity of said sound responsive means in accordance with the depth of submergence of the mine, means for adjusting the level of said electrical signals to substantially zero value in response to background noise received by the sound responsive means, means responsive to said electrical signals for firing the mine when the electrical signals have predetermined amplitude gradient, and means responsive to the electrical signals for rendering said firing means ineffective for a predetermined interval when the electrical signals have a different amplitude gradient.

19. In an acoustic firing control system for a marine mine, the combination of means responsive to sound signals received through the surrounding water for generating electrical signals corresponding thereto, means including a pressure responsive device for adjusting the sensitivity of said sound responsive means in accordance with the depth of submergence of the mine, means including a rectifier amplifier for converting said electrical signals to a D.C. signal whose amplitude varies in accordance with the envelope of sound signals received by the sound responsive means, means for adjusting said D.C. signal to substantially zero value in response to background noise received by the sound responsive means, means responsive to said D.C. signal for firing the mine when the D.C. signal has a predetermined amplitude gradient, and means responsive to the D.C. signal for rendering said firing means ineffective when the D.C. signal has a different amplitude gradient.

20. In an acoustic firing control system for a marine mine, the combination of an electro-acoustic transducer, means including a pressure responsive device for adjusting the sensitivity of the transducer in accordance with the depth of submergence of the mine, means for converting the electrical output of the transducer to a D.C. signal whose amplitude varies in accordance with the envelope of sound signals received by the transducer, means for adjusting said D.C. signal to substantially zero value in response to background noise received by the transducer, and means responsive to the D.C. signal for firing the mine when the D.C. signal has a predetermined amplitude gradient.

21. In an acoustic firing control system for a marine mine, the combination of an electro-acoustic transducer, means for converting the electrical output of the transducer to a D.C. signal whose amplitude varies in accordance with the amplitude of the envelope of sound signals received by the transducer, means for adjusting said D.C. signal to substantially zero value in response to background noise received by the transducer, and means responsive to the D.C. signal for firing the mine when the D.C. signal has a predetermined amplitude gradient.

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