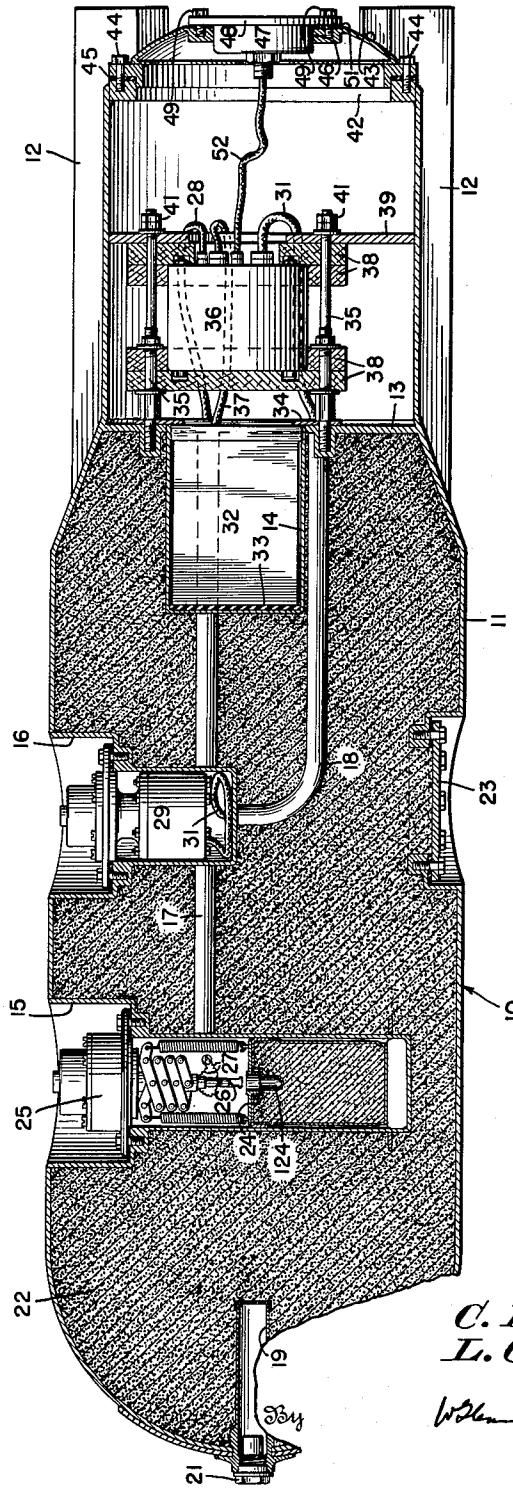
Dec. 12, 1961 C. B. BROWN ET AL 3,012,503

FREQUENCY SELECTIVE ACOUSTIC MINE FIRING CONTROL SYSTEM

Filed May 25, 1944 2 Sheets-Sheet 1

FIG. 1.



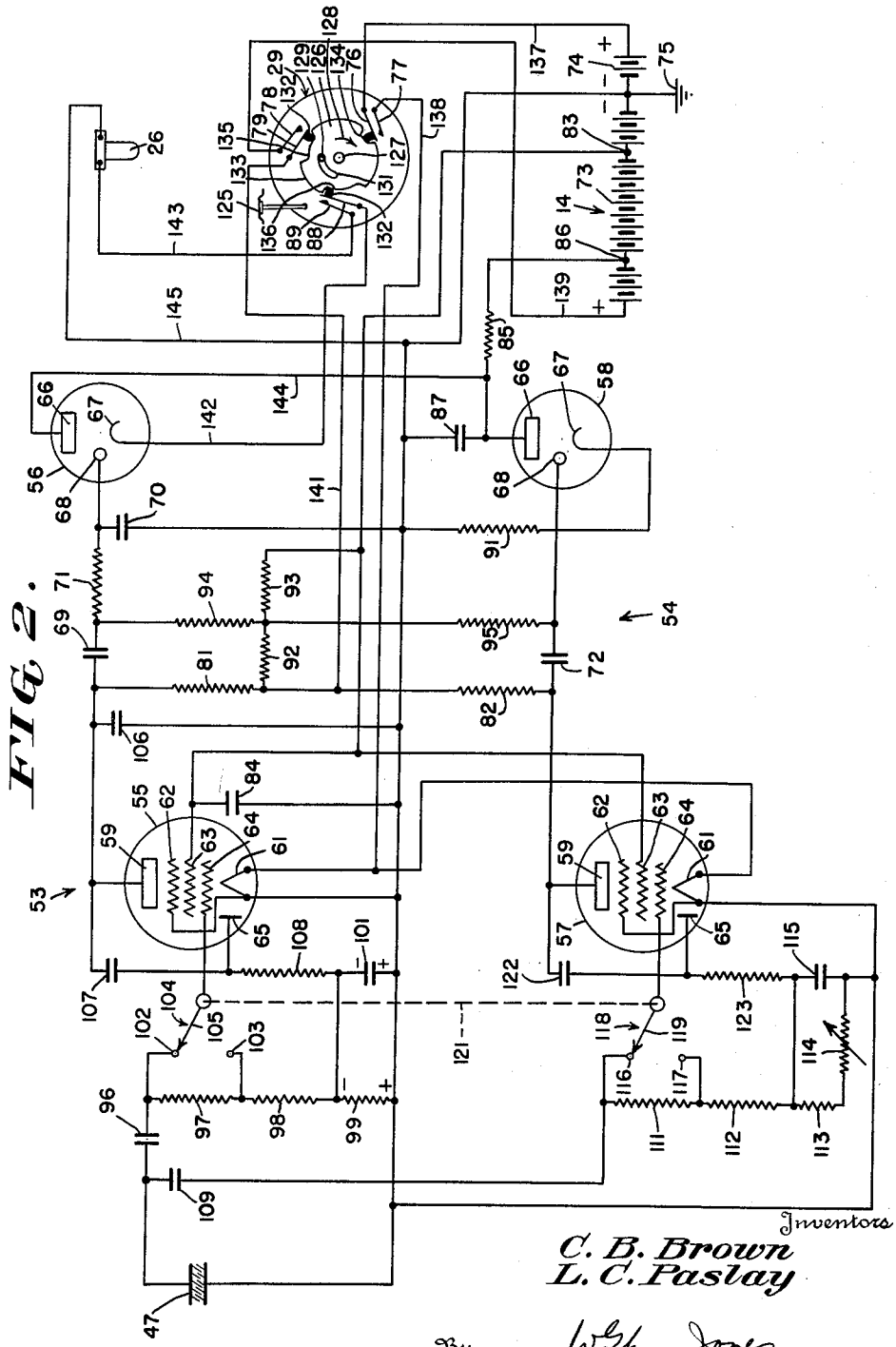
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FREQUENCY SELECTIVE ACOUSTIC MINE FIRING CONTROL SYSTEM

Filed May 25, 1944 2 Sheets-Sheet 2

FIG. 2.



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3,012,503

FREQUENCY SELECTIVE ACOUSTIC MINE FIRING CONTROL SYSTEM

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

This invention relates to mine firing control systems and more particularly to an acoustic mine firing control system for underwater mines wherein the system operates to detonate and explode the mine associated therewith when signals of predetermined character are received through the water from sound emitting bodies such as surface vessels, submarines, or the like, and the system operates to prevent a firing of the mine when signals of different character are received as when heavy explosive charges are exploded adjacent to the mine or when mine sweeping apparatus is operated within the vicinity thereof.

In acoustic mine firing control systems for underwater mines, it generally has been the practice to employ sound responsive devices adapted to be actuated by sound waves or vibrations transmitted through the water in which the mines are placed, the sound responsive devices being adapted, when actuated, to initiate the operation of apparatus adapted either to fire the mines, to respond insufficiently to fire the mines, or to prevent the firing thereof, as the case may be, depending upon the character of the signals received. In any case, when signals of predetermined character are received by such a mine from a sound emitting body adapted to be destroyed by the mine, the operation of the system is timed in such a manner as to fire the mine when the body has approached within the zone of greatest effectiveness of the mine.

In certain of the prior art systems, electric contact actuating apparatus comprising a plurality of contacts is employed wherein a first pair of the contacts is adapted to be actuated by sound waves or pulses of predetermined character such, for example, as those produced by a vessel, thereby to control the operation of a mine firing circuit, and a second pair of the contacts is adapted to be actuated by sound waves or pulses of different character such, for example, as explosion waves, thereby to prevent the first pair of contacts from controlling the firing circuit when such different sound waves or signals are received. Thus, by this arrangement, a certain measure of protection or discrimination against signals not adapted to produce a firing actuation of the system is provided. In accordance with such arrangement, a time delay device is usually employed to continue the control provided by the second pair of contacts for a predetermined interval of time, thereby to render the firing circuit inoperative until the aforesaid different signals have died out in the acoustic field or zone or receptivity of the mine.

In certain other of the prior art systems, micro-telephonic devices are employed to initiate the operation of intermediate devices adapted gradually to close a mine firing circuit in response to signals received from a vessel adapted to be destroyed by the mine employing the system. By reason of the gradual action in closing the mine firing circuit, the system is caused to begin its operation while the vessel is at a relatively great distance

from the mine, thereby to fire the mine only after a period of time sufficient to bring the vessel close enough to the mine to destroy or effectively damage the vessel. Such an arrangement affords a further advantage in that it precludes a firing of the mine by the explosion of shells or bombs in its vicinity, sound waves or pulses caused by such explosion being momentary only and entirely too brief to effect a firing actuation of the system.

In the arrangement of the present invention, an acoustic mine firing control system is provided which possesses all of the advantages of the prior art systems and employs additional devices and circuit arrangements whereby the system is rendered more critically responsive to signals of predetermined character adapted to produce a firing actuation of the system, and the system provides a higher degree of anti-countermine and anti-sweep protection than that afforded by the prior art systems.

In accordance with the present arrangement, a sound responsive device is employed, which device is adapted to convert underwater vibration in the range from fifty cycles per second to several thousand cycles per second, for example, to electrical signals corresponding therewith. The electrical signals generated are applied to a firing control channel and a protective or discriminating channel adapted to pass respectively, signals within the entire range of signal frequencies and those signals resident in the range above a predetermined frequency therein. Each of the channels comprises a vacuum tube amplifier and electrical filters associated therewith whereby the firing channel is set for maximum sensitivity over a range of signal frequencies from fifty to one hundred and fifty cycles per second, for example, and the protective channel is set for maximum sensitivity in the range above one thousand cycles per second, for example.

The arrangement of each of the amplifier tubes is such that the D.C. voltage on the plate thereof is adapted to vary in accordance with the sound envelope of the acoustic energy reaching the sound responsive device. In the case of each of the amplifier tubes, the D.C. voltage thereon is adapted to control the firing of a trigger tube of the cold cathode gas type. The trigger tube in the firing channel, when fired, is arranged to discharge a condenser through the detonator of the system, thereby to cause a firing operation of the system. The trigger tube of the protective channel, however, when fired, is arranged to discharge the condenser, thereby to prevent a firing actuation of the system, the charging time of the condenser being arranged to provide a suitable interval of time during which the firing channel is ineffective to cause a firing of the detonator.

Means comprising time delay circuits are provided in the respective channels whereby predetermined intervals of time are caused to elapse before plate voltages of sufficient value to operate the respective trigger tubes are developed by the amplifier tubes corresponding thereto. The relation of the time delays in the respective channels is set so that received signals having a frequency content and amplitude sufficient to actuate both channels are caused to actuate the protective channel first, thereby to prevent a firing actuation of the system and thus protect the mine against accidental or premature firing when subjected to signals originating from any source not adapted to cause an explosion of the mine.

A coupling circuit is provided between the amplifier and trigger tubes of the firing channel, which coupling

rcuit comprises a condenser and a discharge path there-
r adapted to prevent the application of a firing voltage
the trigger tube when the rate of increase of signals
ceived by the sound responsive device is below a pre-
termined value. The coupling circuit also provides
ı arrangement whereby a static bias voltage is applied
the trigger tube. Thus, by reason of the coupling
rangement, loud vessels approaching the mine at a
stance therefrom merely cause an increase in the D.C.
ate voltage on the amplifier tube without increasing
e voltage above the static voltage on the trigger tube
ıtil the vessels move within the zone of destructivity
: the mine whereupon the rate of increase of signals
ceived from the vessels increases to such an extent that
ı operating bias is applied to the trigger tube. More-
ver, it readily will be understood that, for the same rea-
ın, sweep apparatus operating at a safe distance from
ıe mine will be unable to cause a firing actuation thereof.

Anti-sweeping protection also is obtained to some
ctent by the aforesaid selection of signal frequencies
dapted to actuate the firing channel for the reason that
veep apparatus heretofore deemed suitable for sweeping
ıines of the type considered herein is not adapted to pro-
uce signal frequencies within the selected range at a
ıtisfactory level for safe sweeping. Moreover, addi-
onal protection is afforded by the protection channel
hich operates to prevent a firing actuation of the sys-
:m when the sweep apparatus produces a high propor-
on of high frequency signals.

An arrangement is provided whereby the sensitivity of
ıe firing control channel may be adjusted at will to
ny one of a plurality of signals levels. In addition, the
haracter of the amplifier tubes employed is such as to
ause variations in the sensitivities of different mines
mploying the firing control system of the present inven-
on. Accordingly, in practice, such mines may be set
/ith a wide variety of sensitivities thereby to provide a
ıeasure of discrimination against ships which produce
ifferent noise levels and to render the sweeping of such
ıines more difficult.

According to the mine firing control system of the
resent invention, the elements or component parts there-
f comprise static elements such, for example, as crystal
ıicrophones, electronic tubes, and condensers and re-
istors, which elements are not critically susceptible to
lamage caused by shocks associated with the launching
f a mine. Accordingly, the system of the present in-
'ention is well adapted for use with mines adapted to
ıe launched from an aircraft in flight.

An object of the present invention is to provide an
ıcoustic mine firing control system for underwater mines,
vhich system is rendered more critically responsive to
ignals of predetermined character than like systems
ıeretofore proposed for the purpose.

Another object in an acoustic mine firing control sys-
em is the provision of new and improved anti-counter-
nine and anti-sweep protection for underwater mines
:mploying the system.

Another object is the provision of a new and improved
ıcoustic mine firing control system in which the system
ɔperates in response to signals of predetermined char-
ıcter to actuate a mine firing control circuit and operates
n response to signals of different character to prevent
he operation of such circuit.

Another object is the provision of a new and im-
ɔroved acoustic mine firing control system in which the
ystem operates to produce a firing actuation thereof only
n response to signals which increase at a predetermined
:ate and reach a predetermined degree of strength.

Another object in an acoustic mine firing control sys-
:em is the provision of a firing control channel and a
ɔrotective channel for preventing a firing actuation of
he system in which the protective channel is caused to
ɔperate first when signals adapted to actuate both of the
channels are received by the system.

Another object of the invention is the provision of a frequency responsive mine firing control system in which a single sound responsive device is employed to initiate a firing actuation of the system when signals of predetermined frequency are received thereby and to cause the system to operate in such a manner as to prevent a firing actuation thereof when signals of different frequency are received thereby.

A further object is the provision of an acoustic mine firing control system for underwater mines in which the system operates to fire the mines in accordance with the character of the sound envelope of the acoustic energy reaching the mines from a sound emitting body moving within the vicinity of the mines.

A still further object in a frequency responsive mine firing control system is the provision of a firing channel and a protective channel in which the maximum sensitivity of the firing channel is set within a predetermined range of frequencies and the maximum sensitivity of the protective channel is set within a range of frequencies outside said predetermined range.

Still another object in an acoustic mine firing control system is the provision of new and improved means for varying the sensitivity of the system.

A still further object in an acoustic mine firing control system for underwater mines resides in the provision of new and improved means for causing the D.C. plate voltage on an amplifier tube to vary in accordance with the sound envelope of the acoustic energy received by the system through the water and to fire a trigger tube in accordance with such voltage variation.

An additional object in an acoustic mine firing control system in which a trigger tube is fired in accordance with signals of predetermined character received by the system is the provision of new and improved means for maintaining a static bias on the trigger tube.

Still other objects of the invention, not specifically set forth hereinabove, are those inherent in or implied from the novel combination and arrangement of parts as will become more clearly apparent as the description proceeds, reference being had to the accompanying drawings wherein:

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 circuit 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 planted. 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, 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 a 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 water tight 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 electro-responsive detonator 26 for igniting the booster charge 24 and is adapted to move the detonator into operative engagement with the booster charge when the mine reaches a predetermined depth of submergence in the water, as is well known in the art to which this 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 multiconductor 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 42 in watertight relation therewith as by a plurality of screws 44 carried by the flange portion 45 of the cover. The cover is provided with a central opening 46 for receiving a sound responsive device 47. The device 47 is provided with a flange 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 the 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 waves or vibrations 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 wide range of signal frequencies such, for example, as fifty to two thousand 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, has a substantially constant sensitivity notwithstanding the depth of submergence of the hydrophone within the water, and is relatively smaller in size than other hydrophones capable of equivalent performance.

Crystal hydrophones of the type employed herein are well known in the art. Accordingly, a brief description of a device suitable for the purpose herein will suffice. The hydrophone 47 preferably comprises a plurality of crystals such, for example, as Rochelle salt crystals, which crystals are cemented between a cast iron housing and a steel diaphragm. Pressure from the surrounding water is transmitted to the diaphragm through an outer rubber housing secured to the cast iron housing and thence through a suitable type of oil such as castor oil disposed between the diaphragm and the rubber housing. A small hole is provided in the diaphragm by means of which hole hydrostatic equilibrium is established between the rubber and cast iron housings.

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 firing control mechanism 36 comprises a firing channel adapted to fire the detonator 26 when operation of the mechanism is initiated by the sound responsive device 47 in response to signals of predetermined frequency received thereby. The control mechanism 36 also comprises a protective channel adapted to prevent firing of the detonator when operation of the mechanism is initiated by the sound responsive device 47 in response to signals of different frequency received thereby. Each of the firing and protective channels comprises, among other elements, an amplifier detector tube of the electron discharge type and a cold cathode type trigger tube controlled thereby, as will appear in greater detail as the description proceeds.

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

The firing mechanism 36 comprises a firing control channel and a protective or countermine channel designated generally by the numerals 53 and 54 respectively. The firing control channel comprises an amplifier-detector tube 55 of the electron discharge type and a cold cathode gas type trigger tube 56 controlled thereby. The protective channel similarly comprises an amplifier-detector tube 57, which may be identical to tube 55 of the firing channel, and a trigger tube 58 controlled thereby, tube 58, if desired, being identical to trigger tube 56 of the firing channel.

The amplifier-detector tubes 55, 57 each comprises a plate or anode 59, a combined cathode-filament 61, a suppressor grid 62 connected to the cathode in the usual manner, screen grid 63, and control grid 64, which elements comprise the amplifier circuit of the tubes. Each of tubes 55, 57 also comprises a detector circuit which includes the plate 65 and cathode 61. The function of the detector circuit, as will appear in greater detail hereinafter, is to apply an increasing negative bias to the control grid 64 in response to A.C. signals of predetermined character applied thereto, thereby to increase the potential on the plate 59 in proportion to said applied A.C. signals.

Each of the trigger tubes 56, 58 comprises a plate or anode 66, a cathode 67, and a control grid 68. With a potential of 150 volts, for example, between the plate 66 and cathode 67 of each of the trigger tubes 56, 58, each tube is fired or triggered when a potential such, for example, as 70 volts is applied to the control grid thereof. Each of the control grids 68, however, normally is maintained at a static or non-firing bias such as 55 volts,

or example, in a manner to appear in detail hereinafter. The rise in potential above the static bias on each of the trigger tubes **56**, **58** is controlled by the rise in potential on the plates **59** of the amplifier tubes **55**, **57** respectively associated therewith. For this purpose, the plate **59** of tube **55** is coupled by way of a condenser **9** and a resistor **71** to the control grid **68** of trigger tube **56**. In like manner, the plate **59** of amplifier **57** is coupled by way of a condenser **72** to the control grid **8** of trigger tube **58**.

The operating voltages for the amplifier and trigger tubes are provided by the battery **14** which comprises a B-battery section **73** and an A-battery section **74**, the low voltage sides of which sections are grounded at **75**. The A-battery section **74** supplies the filaments **61** of amplifier tubes **55**, **57**, the filaments being grounded on one of the sides thereof and connected on the other sides thereof to the high voltage side of A-battery section **74** by way of contacts **76**, **77** of the clock mechanism **29**. The high voltage side of B-battery section **73** is applied to the plates **59** of the amplifier tubes **55**, **57** by way of contacts **78**, **79** of clock mechanism **29** and plate load resistors **81**, **82** of control channels **53**, **54** respectively. The screen grids **63** of amplifier tubes **55**, **57** are maintained at the potential provided by a low voltage tap **83** of the B-battery section **73**, and the screen grid **63** of tube **55** is stabilized at this potential by means of a condenser **84** connected between the screen grid and ground in a well known manner.

The plates **66** of trigger tubes **56**, **58** are connected by way of a resistor **85** to a high voltage tap **86** provided on the B-battery section **73**, the voltage thereat being maintained on a condenser **87** connected between the plates **66** and ground, which condenser obtains the charge thereon by way of resistor **85**. The cathode **67** of trigger tube **56** is connected through contacts **88**, **89** of clock mechanism **29** and detonator **26** to ground potential **75**. Cathode **67** of trigger tube **58** is connected by way of a protective resistor **91** to ground potential at **75**.

The aforesaid static biases applied to the control grids **68** of trigger tubes **56**, **58** are provided by means of a voltage divider network comprising resistors **92**, **93** connected in series across the portion of the B-battery section **73** between the high voltage side thereof and low voltage tap **83** thereon. The voltage at the junction of resistors **92**, **93** is applied through resistors **94** and **71** to the control grid **68** of trigger tube **56** in the firing channel. In like manner, the voltage at the junction of resistors **92**, **93** is applied by way of a resistor **95** to the control grid **68** of trigger tube **58** in the protective channel.

The A.C. signals generated by the hydrophone **47** are applied through a condenser **96** to an attenuator network comprising resistors **97**, **98**, **99**, and a condenser **101** shunted across the resistor **99**. These resistors and condensers comprise the input to the firing control channel **53**. Condenser **96** is selected to pass without attenuation electrical signals over the aforesaid frequency range of 50 to 2000 cycles per second. Resistor **97** is also connected to the fixed contacts **102**, **103** of a manually adjustable sensitivity switch **104** the wiper or switch arm **105** of which is electrically connected to the control grid **64** of amplifier-detector tube **55**.

By reason of the provision of sensitivity switch **104** the maximum A.C. input appearing across the attenuator network may be applied to the control grid **64** when the wiper arm **105** is moved into engagement with the contact **102** of switch **104**. Or, when desired, the firing channel **53** may be rendered less sensitive by moving the wiper **105** into engagement with the contact **103**, in which case, a relatively larger input signal voltage is required across the attenuator network to fire the trigger tube **56**.

In any case, the A.C. voltages applied to the control grid **64** of amplifier tube **55** are amplified in the amplifier plate circuit thereof. The high frequency content of the amplified signals appearing at plate **59** of amplifier tube **55** are by-passed to ground through a condenser or filter **106** such that the firing control channel **53** is caused to give a maximum sensitivity within the frequency range from 50 to 150 cycles per second, for example. The amplified signals in this frequency range pass through a condenser **107** and the detector circuit comprising plate **65** and cathode **61** of amplifier-detector tube **55**, thereby to rectify such signals. The rectified current flows through the resistor condenser combination **99**, **101** and a resistor **108**, thereby charging condenser **101** negatively with respect to ground. The negative potential developed on condenser **101** is applied as negative bias on the control grid **64** of tube **55** by way of resistors **98**, **97** or resistor **98**, as the case may be, depending upon the instant position of wiper **105** of sensitivity switch **104**.

The condenser resistor combination **101**, **108** is selected to provide a time constant or delay such that the bias developed on the control grid **64** of tube **55** causes a rise in the D.C. potential on plate **59** thereof, which rise in potential is proportional to the sound envelope of the acoustic energy received by the hydrophone **47** from a vessel of a type adapted to be destroyed by the mine **10**.

The condenser resistor combination **69**, **94** comprising the coupling between the tubes **55**, **56** provides an arrangement whereby the signal envelope of the sound reaching the hydrophone **47** is required to increase at a rate which exceeds the rate of discharge of the condenser **69** through the resistor **94**. Thus, the trigger tube **56** is fired only when signals within the aforesaid frequency range of 50 to 150 cycles per second are received by the hydrophone **47** and only when such signals reach a predetermined degree of strength and increase at a rate which exceeds the discharge rate constant of condenser resistor combination **69**, **94**.

The A.C. signals generated by the hydrophone **47** also are applied through a condenser **109** to an attenuator network comprising resistors **111**, **112**, **113**, an adjustable resistor **114**, and a condenser **115** shunted across resistors **113** and **114**, these resistors and condensers comprising the input to the protective channel **54**. Resistor **111** is also connected to fixed contacts **116**, **117** of a sensitivity switch **118**, the wiper **119** of which is electrically connected to the control grid **64** of amplifier tube **57** and is mechanically coupled to the wiper **105** of switch **104** as indicated by the dash line **121** therebetween. Accordingly, it will be understood, wiper **119** of switch **118** is caused to engage contact **116** thereof when the wiper **105** of switch **104** engages the contact **102** thereof. Also, when the wiper **104** of switch **105** is caused to engage contact **103** thereof, the wiper **119** of switch **118** is caused to engage contact **117** thereof.

The condenser **109** is selected to give the protective channel a maximum sensitivity above the range of 1000 cycles per second, for example, and the sensitivities of the channels with respect to the signal levels at the attenuator networks individual thereto are rendered adjustable with respect to each other by means of the adjustable resistor **114**. In practice, for example, the ratio of the signal input at 100 cycles per second required to cause firing of the trigger tube **56** of the firing control channel to the signal input at 2000 cycles per second required to cause firing of the trigger tube **58** of the protective channel is preferably such that the protective channel affords a slightly greater sensitivity. Thus, when sound signals are received by the hydrophone **47**, which signals have a frequency content and signal level critical to the actuation of both channels, the operation of the protective channel is insured, thereby to prevent a firing actuation of the firing control system. It will be understood, of course, that the adjustable resistor **114** may comprise an element of the attenuator network of the firing control channel rather than that of the protective

channel or each of the networks may comprise an adjustable resistor, if desired.

As in the case of amplifier tube 55 of the firing control channel, A.C. signals appearing on the control grid 64 of the amplifier tube 57 are amplified in the plate circuit thereof and appear at the plate 59 of the tube. The amplified A.C. signals pass through a condenser 122 and the detector circuit comprising plate 65 and anode 61 of tube 57, such signals being rectified by reason of the detector circuit. The rectified current flows through the condenser resistor combination 115, 114, 113 and a resistor 123 and develops a charge on condenser 115, which charge is negative with respect to ground potential. The voltage on condenser 115 is applied as negative bias on the control grid 64 of tube 57 by way of resistors 112, 111 or resistor 112 as the case may be, depending on the position of wiper 119 of switch 118. The time constant of condenser resistor combination 115, 123 is such that the negative bias developed on control grid 64 is caused to produce a rise in the D.C. potential on plate 59 of tube 57, which rise in D.C. potential is proportional to the sound envelop of the high frequency content of signals received by the hydrophone 47.

Thus, by reason of the foregoing arrangement, high frequency signals such, for example, as explosion waves caused by counter-mining produce an actuation of the protective channel. The relation or ratio of the time delays provided by condenser 101, resistor 108, and condenser 115, resistor 123 of the firing control and protective channels respectively, is arranged to be in the ratio of fifty to one, for example, such that the protective channel is caused to operate first in the event that signals having a frequency content critical to the operation of both channels are concurrently received by the hydrophone 47.

As in the case of the firing control channel, the condenser resistor combination 72, 95 of the protective channel provides an arrangement whereby a gradual rise of the D.C. potential on plate 59 of tube 57 does not produce a rise in potential above the static bias applied to the control grid 68 of trigger tube 58, when the rate of such potential rise does not exceed the time of discharge of condenser 72 through resistor 95. Such an arrangement is desirable in that it prevents a firing of either of the trigger tubes 56, 58 in the event that the D.C. potential at plate 59 of either of the amplifier tubes 55, 57 rises by reason of the aging of the tubes or by reason of a decrease in the battery potential at the filaments 61 thereof.

Moreover, by making the product of the condenser resistor combination 69, 94 large with respect to the product of the condenser resistor combination 72, 95, countermine protection operation is prevented when the amplitude of the incoming signal is rising slowly even though the signal is composed of high and low frequencies.

When trigger tube 56 is fired, a circuit is completed for discharging condenser 87 through the detonator 26, thus producing a firing actuation of the firing control system. However, when the trigger tube 58 is fired, a circuit is completed for discharging condenser 87 through tube 58 and resistor 91, thus preventing the energization of detonator 26 notwithstanding the subsequent appearance of a firing potential at control grid 68 of trigger tube 56. The time constant of condenser resistor combination 87, 85 is such that sufficient time is provided to allow for the cessation in the acoustic field of mine 10 of signals which initiate operation of the protective channel.

Having described the several electrical components of the control system and the arrangement thereof, the operation of the system will now be described. Let it be assumed 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 engagement with the booster charge 24 by placing the detonator within a cavity 124 formed within the booster charge. Let it further be assumed that before the launching of the mine, the sensitivity switches 104, 118 have been moved into their full line positions to provide a maximum sensitivity of the mine firing system whereby the mine 10 is adapted to respond to and destroy surface vessels, or other sound emitting bodies, which transmit through the water sound signals at a relatively low sound level and of a character adapted to produce a firing actuation of the mine.

After an interval of time has elapsed during which a salt washer comprising an element of the clock mechanism 29 is dissolved, a diaphragm 125 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 126 of the clock mechanism in a well-known manner. The cam 126 is mounted for rotation on a pivot 127 and moves in the direction of arrow 128 until the cam engages a stop pin 129 disposed within an arcuate slot 131 provided in the cam. During this movement of the cam 126 the aforedescribed 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 132 of any suitable insulation material, which follower is urged into engagement with a cylindrical cam surface 133 provided on cam 126. The cam surface is provided with a plurality of peripheral indentations 134, 135, 136 therein, which indentations are adapted to receive the followers 132 and are of varying lengths, thereby to cause the pairs of contacts to close in sequence.

According to the foregoing arrangement, contacts 76, 77 of clock mechanism 29 are the first to close. Closure of these contacts supplies the potential of the A-battery section 74 to the filaments 61 of the amplifier tubes 55, 57 by way of a circuit which may be traced as follows: from the high voltage side of A-battery section 74 through a conductor 137, contacts 76, 77 of clock mechanism 29, a conductor 138, and thence through filaments 61 of tubes 55, 57 to ground potential at the low voltage side of A-battery section 74.

After a predetermined interval of time, contacts 78, 79 of the clock mechanism 29 are closed, thereby to apply the potential of B-battery section 73 to the plates 59 of amplifier tubes 55, 57 by way of a circuit which may be traced as follows: from the high voltage side of B-battery section 73 through a conductor 139, contacts 78, 79 of clock mechanism 29, a conductor 141, and thence through the plate load resistors 81, 82 to the plates 59 of amplifier tubes 55, 57 respectively.

After a further predetermined interval of time, contacts 88, 89 of clock mechanism 29 are closed to complete a circuit between the cathode 67 of trigger tube 56 and the detonator 26. This circuit includes cathode 67 of trigger tube 56, conductor 142, contacts 88, 89 of clock mechanism 29, and a conductor 143 connected between the contacts and the detonator 26.

When the potential at the several points in the electrical system reaches a stable or steady state condition, a potential of approximately 30 volts appears at each of the plates 59 of the amplifier tubes 55, 57, a potential of approximately 55 volts appears at each of the control grids 68 of the trigger tubes 56, 58, and a potential of approximately 150 volts appears at each of the plates 66 of the trigger tubes.

In the event that a vessel which emits underwater sound within the frequency range of 50 to 150 cycles per second and at a higher level than sounds of other frequencies emitted by the vessel approaches the mine 10 at a distance therefrom, such sounds are received by the hydrophone 47 and produce a rise in the D.C. potential at plate 59 of amplifier tube 55, which rise in potential is proportional to the sound signal envelope resident in the aforesaid frequency range and received by the hydrophone 47 as

he vessel approaches progressively nearer to the mine **10**. n the event that the sound envelope increases at a rate which corresponds substantially to the charging rate of condenser **101**, a D.C. voltage of approximately 45 volts appears at the plate **59** of amplifier tube **55** at a time when he vessel moves into the zone of destructivity of the mine 10. The increase in the potential to 45 volts on one side of condenser **69** produces a corresponding increase in the potential to 70 volts on the other side of the condenser, thus applying the aforesaid firing potential of 70 volts on he control grid **68** of trigger tube **56**. When this occurs, he trigger tube is fired and the condenser **87** discharges herethrough, thereby to energize the detonator **26** by way of a circuit which may be traced as follows: from one side of condenser **87** through a conductor **144**, plate 56 and cathode **67** of trigger tube **56**, conductor **142**, contacts **88**, **89** of clock mechanism **29**, conductor **143**, detonator **26**, and thence through a conductor **145** to ground potential at the other side of condenser **87**.

In the event that the approaching vessel is relatively noisy and produces underwater sound at a high level such that a rise in potential occurs at the plate **59** of tube **55** while the vessel is still at a relatively great distance from the mine **10**, the potential increases too slowly to produce an increase in potential at the trigger tube side of condenser **69**, the charge on condenser **69** being dissipated through the resistor **94** as the voltage on the opposite side of the condenser increases toward the static voltage on the trigger tube side thereof. Accordingly, an increased voltage on condenser **69** sufficient to fire the trigger tube **56** is not developed on the condenser until the vessel approaches sufficiently near to the mine to cause a rise in potential at the plate **59** of tube **55** at a rate which exceeds the discharge rate of condenser **69** through resistor **94**. Thus, by reason of the arrangement provided by the resistor condenser combination **94**, **69**, the zone within which firing of the mine will occur in response to the presence of a vessel therein is substantially narrowed. Moreover, in like manner, sweep apparatus which produces at a high level sound signals critical to a firing actuation of the firing control channel and which apparatus is operated outside the zone of destructivity of the mine **10** merely raises the potential level at the plate **59** of tube **55** without producing an increase in the potential on the trigger tube side of condenser **69** sufficient to cause a firing of trigger tube **56**.

When it is desired to limit the response of the mine to relatively loud vessels, the sensitivity switch **104** may be adjusted such that the wiper **105** thereof engages the fixed contact **103** in which position of the switch a substantially greater A.C. input is required across the attenuator network comprising the input of the firing control channel to cause a firing actuation of the channel, the operation of the channel otherwise being the same. It will be appreciated, of course, that several mines adjusted for different sensitivities may be planted in a given area and thereby provide response as a group to vessels producing different sound levels. The character of the amplifier tubes also is such as to cause a variation in the sensitivities of different mines, thereby to provide a wide variety of sensitivity settings therefor.

The condenser **106**, as described in the foregoing, is selected to by-pass all signals in the firing control channel **53** not adapted to produce a firing actuation thereof. However, in the event that a burst of energy produces a sudden rise in potential at the control grid **68** of trigger tube **56**, the filter comprising the resistor condenser combination of resistor **71** and a condenser **70** is provided to by-pass such transient signals to ground potential, thereby to prevent a spurious and accidental firing of the trigger tube **56**.

In the event that an approaching vessel which produces underwater sound having a frequency content adapted to produce a firing actuation of the firing control channel **53** also produces underwater sound having a frequency content above a frequency of 1000 cycles per second and which sound is produced at substantially the same level as the sound resident in the first named frequency content, or in the event that sweep apparatus having the same sound producing capacity is operated within the vicinity of the mine **10**, or in the event that heavy explosive charges or a like mine is exploded within the vicinity of the mine **10**, the high frequency waves or vibrations, however caused, are transmitted through the water to the hydrophone **47**. The electrical signals generated by the hydrophone, which signals correspond to the high frequency waves received thereby, produce a rise in the D.C. potential at plate **59** of amplifier tube **57** sufficient to apply a firing potential on the control grid **68** of trigger tube **58**, the potential rise on plate **59** of tube **57** appearing well in advance of a rise in potential on plate **59** of tube **55** by reason of the relation of the time delays provided in the channels, as described in the foregoing.

Firing of trigger tube **58** provides a discharge path for condenser **87** therethrough by way of the protective resistor **91**, thus rendering the firing control channel ineffective to energize the detonator **26** notwithstanding the subsequent appearance of a firing potential at the control grid **68** of trigger tube **56**. In case the firing of trigger tube **58** has been caused by an explosion wave reaching the hydrophone **47**, the charging time of condenser **87** is such that sufficient time is provided to permit the explosion levels to die out before a steady state or stable condition of the firing channel is established.

The character of the amplifier tubes **55**, **57** is such that the amplification provided thereby is non-linear. Thus, when the D.C. potential at the plate **59** of tube **55** is raised to a predetermined value, the D.C. potential thereon does not substantially increase notwithstanding a continuous increase in the A.C. input applied to the control grid **64** of the tube. Accordingly, sweep apparatus which produces underwater sound at an unusually high level is unable to produce a firing actuation of the firing control channel notwithstanding that the increase in such sound be at a rate otherwise adapted to produce such firing actuation.

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 invention. Moreover, it further should 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 described 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 of the invention may be made without departing from the spirit and scope of the invention as defined by the appended claims.

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

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

1. An acoustic mine firing control system of the character disclosed comprising, in combination, a mine firing circuit, means for controlling the operation of said circuit, a sound responsive device, means controlled by said sound responsive device for operating said circuit controlling means when signals of predetermined character are received by said device, and means controlled by said sound responsive device for preventing the operation of said firing circuit when signals of different character are received by the device.

2. In an acoustic mine firing control system of the character disclosed, the combination of a mine firing circuit, a sound responsive device, and a plurality of frequency selective circuits controlled by said device and

effective in response to a predetermined rate of increase of sound signals in the selective frequency thereof reaching said device for selectively controlling the operation or hold-off of operation of said firing circuit when signals having said predetermined rate are received by the device.

3. In an acoustic mine firing control system of the character disclosed, the combination of a mine firing circuit, a sound responsive device, impedance networks selectively responsive to signals of differing frequency bands received by said device, which signals increase at a predetermined rate and reach a predetermined value, for selectively controlling the operation or hold-off of operation of said firing circuit when said signals are received by the device.

4. In a frequency responsive underwater mine of the character disclosed, the combination of a mine firing circuit, means responsive to sound signals received through the surrounding water and having a predetermined frequency content for controlling the operation of said firing circuit, means responsive to sound signals received through the water and having a frequency content different from said predetermined frequency content for preventing the operation of said circuit, and means for causing said preventing means to operate before said circuit controlling means operates when signals respectively adapted to operate said controlling and preventing means are received concurrently through the surrounding water.

5. In an acoustic underwater mine of the character disclosed, the combination of a mine firing and protective circuit, means responsive to sound signals received through the water from a sound emitting body moving within the vicinity of the mine, a plurality of frequency selective channels including amplifying means controlled by said sound responsive means for producing an electrical signal which increases in value in proportion to the sound envelope of acoustic energy reaching the sound responsive means from the sound emitting body, and trigger means controlled by said electrical signal in each of said channels for causing a firing actuation of said firing circuit or a protection of said firing circuit against actuation, correlative with the frequency content of said sound signals with respect to the predetermined selected frequency of said channels when the electrical signal increases at a predetermined rate and reaches a predetermined value.

6. In an acoustic mine firing control system, the combination of a mine firing circuit, means responsive to sound signals within a predetermined frequency range for causing a firing actuation of said circuit when said sound signals are received by the sound responsive means, means responsive to sound signals of different frequency for preventing a firing actuation of said circuit when said signals of different frequency are received by said last named sound responsive means, and means for substantially equalizing the sensitivities of said actuating and preventing means with respect to said signals individual thereto.

7. In an acoustic mine firing control system, the combination of a mine firing circuit, means adapted to receive sound signals and generate electrical signals in accordance therewith, means controlled by said electrical signals and adapted to cause a firing actuation of said circuit when said electrical signals comprise signals within a predetermined range of frequencies, means controlled by said electrical signals and adapted to prevent a firing actuation of said firing circuit when said electrical signals comprise signals within a different range of frequencies, means for substantially equalizing the sensitivities of said circuit actuating and preventing means with respect to signals individual to the operation thereof, and means for causing said preventing means to operate first when signals adapted to initiate the operation of both said circuit actuating and preventing means concurrently are generated by said sound receiving means.

8. In an acoustic underwater mine of the character disclosed, the combination of a mine firing and protective circuit, means responsive to sound signals received from a sound emitting body approaching the mine at a distance therefrom, a plurality of frequency selective channels including amplifying means controlled by said sound responsive means for producing an electrical signal which varies in value in proportion to the sound envelope of acoustic energy received from said sound emitting body when the body approaches the mine at a predetermined speed, a plurality of trigger means controlled by said electrical signal in each of said channels for causing a firing actuation of said firing circuit or a protection of said firing circuit against actuation, correlative with the frequency content of said sound signals with respect to the predetermined selective frequency of said channels when said electrical signal reaches a predetermined value, and means settable at will to different settings for varying the sensitivity of said electrical signal producing means thereby to produce a firing actuation of said firing circuit when said electrical signal reaches a different predetermined magnitude and rate of increase.

9. In an acoustic mine firing control system, the combination of a mine firing circuit, a sound responsive device, means controlled by said sound responsive device and effective to cause a firing actuation of the firing circuit a predetermined period of time after signals of predetermined character are received by said device, and means controlled by said sound responsive device and effective to prevent a firing actuation of said circuit a predetermined interval of time after signals of character different from said first named signals are received by the sound responsive device.

10. In an acoustic mine firing control system, the combination of a mine firing circuit, means responsive to sound signals received thereby within a predetermined range of frequencies, means controlled by said sound responsive means for controlling the operation of said firing circuit, means controlled by said sound responsive means for preventing the operation of said firing circuit, means for providing said circuit controlling means with a maximum sensitivity with respect to signals resident in a portion of said frequency range, and means for providing said preventing means with a maximum sensitivity with respect to signals resident in another portion of said frequency range.

11. In an underwater mine, an acoustic mine firing control system therefor, comprising, in combination, a sound responsive device adapted to receive sound signals transmitted through the water, means controlled by said device for firing the mine a predetermined interval of time after sound signals are received by the device from a sound emitting body adapted to be destroyed by the mine, means effective when operated to prevent the operation of said mine firing means during a predetermined interval of time, and means controlled by the sound responsive device for initiating the operation of said preventing means a predetermined interval of time after signals are received by the sound responsive device from a sound emitting body not adapted to be destroyed by the mine.

12. In an acoustic mine firing control system, the combination of a mine firing control circuit including a trigger device, a sound responsive device, an amplifier device controlled by said sound responsive device and adapted to produce an electrical signal which varies in value in proportion to the sound envelope of the acoustic energy reaching said sound responsive device, and a coupling circuit between said trigger device and said amplifier device adapted to apply a static bias to said trigger device and to apply a firing potential thereto when said electrical signal increases at a predetermined rate and reaches a predetermined value.

13. In an acoustic mine firing and protective control system, the combination of a mine firing circuit, a plurality of frequency selective networks, a sound responsive device, a plurality of amplifier-detector devices connected

o said frequency selective networks and controlled by aid sound responsive device and adapted to produce elec- rical signals which increase in value in accordance with ound signals of predetermined character received by he sound responsive device, and a plurality of trigger neans controlled by said electrical signals and for selec- ively rendering said circuit inoperative for protection hereof or to operate said firing circuit correlative to the requency content of said sound signals with respect to he selective frequency passed by respective ones of said requency selective networks when said electrical signals ncrease at a predetermined rate.

14. In an acoustic mine firing control system, the com- ination of a mine firing circuit, a sound responsive de- vice, a firing control channel controlled by said sound esponsive device and adapted to operate said circuit when signals of predetermined character are received by the sound responsive device, and a protective channel con- trolled by said sound responsive device and adapted to prevent the operation of said firing circuit when signals of different character are received by said sound responsive device, each of said channels comprising an amplifier-de- tector tube and a trigger tube controlled thereby.

15. In an acoustic mine firing control system, the com- bination of a sound responsive device, a mine firing control channel controlled by said device, a protective channel controlled by said device, and means individual to each of the channels for respectively providing the channels with maximum sensitivities which correspond respectively to sound signals critical to the operation of the channels.

16. In an acoustic mine firing control system, a sound responsive device, a mine firing control channel, a pro- tective channel, adjustable means for varying at will the sensitivities of said channels with respect to the sound level of acoustic energy received by said sound responsive device, and means adjustable at will for substantially equalizing the sensitivities of the channels.

17. In an acoustic mine firing control system, the com- bination of a mine firing control channel, a protective channel, a sound responsive device for generating signals adapted to initiate the operation of said channels, time delay means individual to each of said channels for pre- venting the operation thereof until a predetermined in- terval of time has elapsed after sound signals critical to the operation of said channels respectively have been re- ceived by said sound responsive device, said time delay means being arranged in such a manner as to cause the protective channel to operate first when sound signals critical to the operation of both channels concurrently are received by said sound responsive device.

18. In an acoustic mine firing control system, the com- bination of a sound responsive device, a detonating de- vice, a mine firing control channel responsive to signals of predetermined character received by sound responsive device for operating said detonating device a predeter- mined interval of time after said signals are received, a protective channel responsive to signals of different char- acter received by said sound responsive device and adapt- ed to be operated a predetermined interval of time after such different signals are received, and means controlled by said protective channel for preventing the operation of said detonating device by said firing channel during a pre- determined interval of time following an operation of the protective channel.

19. In an acoustic mine firing control system, the com- bination of a mine firing control circuit including a plu- rality of trigger tubes each comprising a plurality of elements including a control grid, amplifier-detector tubes each comprising a plurality of elements including a plate, a source of electrical energy for supplying operating elec- trical potentials for the elements of said tubes, means including said energy source and voltage divider networks for applying a static bias to said control grids, means for applying D.C. potentials to said plates from said energy source, an energy storing device connected be- tween each of said plates and said control grids, a sound responsive device adapted to generate electrical signals in accordance with sound signals received thereby, a plurality of frequency selective electrical circuit means including said amplifier-detector tubes for selectively ap- plying said electrical signals to said amplifier-detector tubes in such a manner as to cause a rise in the D.C. potentials on said plates when sound signals of prede- termined character are received by said sound responsive device, and electrical connecting means between said en- ergy storing device and said voltage divider networks for causing said rise in D.C. potentials on said plates to de- velop firing potentials on each of said trigger tube control grids only when the D.C. potentials on said plates each increase at a selectively predetermined rate.

20. In an underwater acoustic mine adapted to be launched from an aircraft in flight, the combination of a sound responsive device including at least one static ele- ment adapted to generate electrical signals in accordance with sound signals received through the surrounding water, a firing control channel controlled by said elec- trical signals and comprising a plurality of static ele- ments adapted to operate in a predetermined manner to fire the mine when sound signals of predetermined char- acter are received by said sound responsive device, and a protective channel controlled by said electrical signals and comprising a plurality of static elements adapted to operate in a predetermined manner to prevent a firing of the mine when sound signals of different character are received by said sound responsive device.

21. An acoustic mine firing control system of the char- acter disclosed comprising, in combination, a sound re- sponsive device adapted to generate A.C. signals in ac- cordance with sound signals received thereby, a plurality of frequency selective channels actuated by said sound responsive device, one of said channels including a first RC circuit, a second RC circuit, means including said first RC circuit and controlled by said A.C. signals for producing a D.C. signal which reaches a predetermined value when sound signals of predetermined character are received by the sound responsive device for an interval of time exceeding the time constant of the first RC circuit, a mine firing circuit, and means including said second RC circuit and controlled by said D.C. signal for oper- ating said firing circuit when the D.C. signal reaches said predetermined value and has increased at a faster rate than the discharge rate of the second RC circuit.

22. An acoustic mine firing control system of the character disclosed comprising, in combination, a sound responsive device adapted to generate A.C. signals in accordance with sound signals received thereby, a first RC circuit, a second RC circuit having a shorter time constant than said first RC circuit, a third RC circuit, a fourth RC circuit having a shorter time constant than said third RC circuit, a first electronic circuit means including said first RC circuit and controlled by said A.C. signals for producing a first D.C. signal which reaches a predetermined value when sound signals within a first predetermined frequency range are received by said sound responsive device and reach a predetermined strength after an interval of time controlled by the first RC circuit, a second electronic circuit means including said second RC circuit and controlled by said A.C. signals for producing a second D.C. voltage which reaches a predetermined value when sound signals within a second predetermined frequency range are received by the sound responsive device and reach a predetermined strength after an interval of time controlled by the second RC circuit, a mine firing circuit, a third electronic circuit means including said third RC circuit and controlled by said first D.C. signal for operating said mine firing cir- cuit when the first D.C. signal reaches said predetermined value thereof and has increased at a faster rate than the discharge rate of the third RC circuit, a fifth RC circuit,

a fourth electronic circuit means including said fifth RC circuit and effective when operated to prevent operation of the mine firing circuit for an interval of time controlled by the fifth RC circuit, and a fifth electronic circuit means including said fourth RC circuit and controlled by said second D.C. signal for operating said fourth electronic circuit means when the second D.C. signal reaches said predetermined value thereof and has increased at a faster rate than the discharge rate of the fourth RC circuit.

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