March 23, 1954 W. P. CONNER 2,672,813

METHOD OF FIRING ELECTRIC DETONATORS AND CIRCUIT THEREFOR

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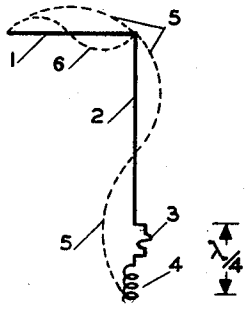


FIG. 1

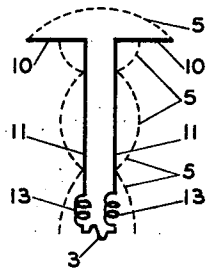


FIG. 2

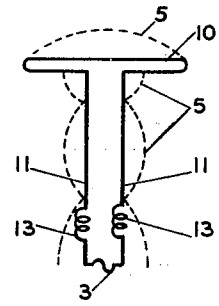


FIG. 3

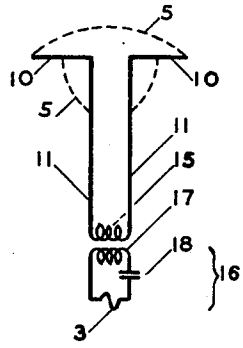


FIG. 4

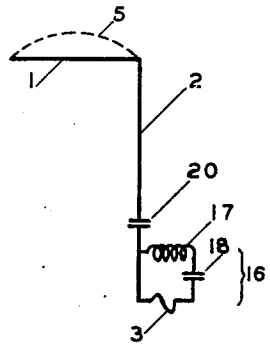


FIG. 5

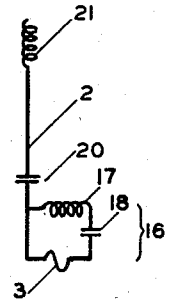


FIG. 6

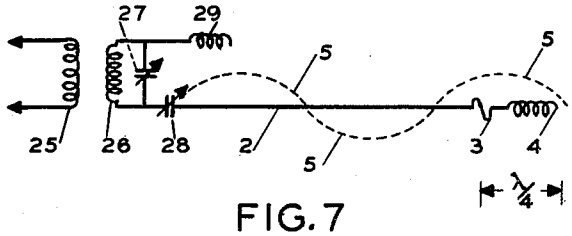


FIG. 7

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METHOD OF FIRING ELECTRIC DETONATORS AND CIRCUIT THEREFOR

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4 Claims. (Cl. 102—27)

1

This invention relates to a method for firing electric detonators and to an electric circuit therefor. More particularly, it relates to the method of firing electric detonators from energy derived from high frequency electric currents and to an electric circuit therefor.

In an electric blasting cap unit comprising the detonator and a pair of electricity-conducting leg wires, the cost of the leg wires is an appreciable part of the entire cost of the unit, especially when wire lengths greater than about 20 feet are concerned.

It has been proposed to reduce the cost of leg wires by using a single leg wire terminating in a priming composition within and insulated from a conductive shell and passing a current of such high frequency through the wire so that a spark is produced between the end of the wire terminating in the priming composition and the conductor shell, thereby detonating the priming composition. This method of priming detonators requires that the conductive shell container of the detonator have a large electrical capacity to ground. Sufficient capacity is provided by mines and bombs having large metallic shells, but sufficient capacity is not provided by the small blasting caps of commerce or by nonmetallic blasting caps.

It is an object of this invention to reduce the length of wire required to supply current for firing electric detonators and thereby to reduce the cost of the detonator unit.

It is a further object to provide a method for firing electric detonators free of the hazards of accidental firing due to stray electric currents.

Another object is to provide a method of firing both metallic and nonmetallic detonators with a single wire transmission line.

It is a still further object to provide an electric circuit by which this method may be carried out.

Generally described, the method of firing electric detonators in accordance with this invention comprises inducing a high frequency current in a resonant circuit which includes the bridge wire of the electric detonator of the frequency of said circuit. The current flow created in the resonant circuit heats the bridge wire and fires the detonator. The high frequency current is preferably induced in the resonant circuit by subjecting the circuit to electromagnetic waves.

The invention, as generally described, is illustrated further by the accompanying drawings and the description of the method of operation in connection therewith, wherein Fig. 1 is a simple

2

resonant circuit including a simple antenna and a bridge wire of an electric detonator, Fig. 2 is a resonant circuit including the bridge wire of an electric detonator and a dipole antenna, Fig. 3 is a resonant circuit including a folded dipole antenna and the bridge wire of an electric detonator in the circuit, Fig. 4 is a resonant circuit including the bridge wire of an electric detonator and an inductively coupled dipole antenna, Fig. 5 is a resonant circuit including the bridge wire of an electric detonator and a simple capacitively coupled antenna, Fig. 6 is a resonant circuit including the bridge wire of an electric detonator and circularly polarized capacitively coupled antenna, and Fig. 7 is a resonant circuit inductively coupled to a source of electromagnetic radiation.

Referring now particularly to Fig. 1, 1 is an antenna, 2 is a feed wire or transmission line, 3 is a bridge wire, and 4 is a terminating coil. The dotted lines show the distribution of current in the circuit when subjected to electromagnetic waves of the frequency of the circuit. Dotted lines 5 indicate the distribution of current at the fundamental frequency and, 6, the distribution at the second harmonic. When the circuit of Fig. 1 is subjected to electromagnetic waves created by a radio frequency oscillator and radiated by a suitable transmitting antenna (not shown), the waves are picked up by the antenna 1. When the circuit is tuned to the frequency of the electromagnetic waves picked up by the antenna 1, current flows through the circuit and is reflected at the ends of the circuit in such a manner that a standing wave is set up. The current flow is at a minimum at the ends of the circuit, as indicated by the dotted lines 5. When the antenna length is one-half the wavelength of the electromagnetic waves (i. e. $\frac{1}{2}\lambda$), the current is at a minimum at the two ends of the antenna. There is a gradual increase in current flow in the feed wire 2 to a maximum and then a decrease again to a minimum. The over-all length of the circuit is such that current flow is at a minimum at the terminus. The terminating coil 4 has the function of tuning the circuit by adjustment of the inductance of terminating coil 4 so that the current flow is at a minimum at the terminus. When the bridge wire of an electric detonator is placed at such a position to feed wire circuit 2 as to be at a position of maximum current flow, the bridge wire is heated and the detonator is fired.

In practice, for example, in blasting with dyna-

mite, the inductance 4 may be a coil of wire around the stick of dynamite, the bridge wire of the detonator is connected to the coil through one leg wire and to the antenna through the other leg wire of the detonator. The detonator is inserted in the stick of dynamite. The stick of dynamite with the detonator and inductance are inserted in the bore hole and the antenna is placed outside the bore hole. The blasting cap is then fired by directing electromagnetic waves at the antenna from a transmitting antenna activated by a high frequency oscillator placed at a safe distance from the bore hole.

The lengths of antenna, feed wire, and inductance are those calculated for producing a resonant circuit of the frequency of the electromagnetic waves to be used as the source of energy. In the simplest case an antenna of one-half wavelength may be used. The feed wire is any integral multiple of the antenna length, and the bridge wire is in the calculated position for maximum current flow. The terminating coil is wound in such a manner as to shorten the effective length from the bridge wire to the terminus and to tune the circuit to the desired frequency. It is understood with regard to lengths that the electrical length is meant unless otherwise specified. The electrical length may or may not be the same as the physical length and it will depend upon the particular system involved but may be readily determined by those skilled in the art. Tuning may be accomplished by adjusting the length of any of the components of the circuit as desired.

Fig. 2 is a variation of Fig. 1, wherein a dipole 10 is connected to two transmission lines 11 which are, in turn, connected to form a series circuit including inductances 13 and the bridge wire 3. As above, the dotted lines 5 indicate standing waves of the fundamental frequency. The bridge wire 3 is in the position of maximum current flow for the desired frequency to which the system is tuned. The inductances 13 are varied to adjust the effective length so that the bridge wire is at a position of maximum current flow. In place of two inductances 13, one inductance 13 may be used if desired.

Fig. 3 is a further modification of Fig. 2, wherein the antenna 10 is a folded dipole. Otherwise, the transmission lines 11, tuning inductances 13, and bridge wire 3 are positioned as described above.

In Figs. 1, 2, and 3, the method of operation depends upon the setting up of standing waves in the circuit. In order to accomplish this, the antenna and feed lines are both critically tuned. The antenna is tuned by adjusting, for example, its length, and the feed line is tuned by varying the inductance of coil 4 of Fig. 1 or coils 13 of Figs. 2 and 3.

Fig. 4 represents a circuit which requires less critical tuning of the transmission line. The dipole antenna 10 is in resonance with a transmitter of electromagnetic radiation and has a current flow therethrough, usually as a result of a standing wave. The transmission line 11 leads to an inductance 15 through which current drawn from the antenna flows. Inductively coupled with inductance 15 is a resonant circuit 16 which includes an inductance 17, a condenser 18, and a bridge wire 3 of a detonator in series with each other. Coupling is accomplished through inductances 15 and 17. In this circuit, inductance 15 need not be at a position of maximum current flow and a standing wave need not be set up on the transmission line 11. However, the resonant circuit 16 is preferably carefully tuned to the same frequency as the antenna in order to derive a maximum of current flow through the resonant circuit 16 and through the bridge wire 3.

Fig. 5 represents a circuit similar to that of Fig. 4, using a single transmission line 2. Electromagnetic waves are applied to antenna 1, current flows through transmission line 2. A standing wave may or may not be set up on transmission line 2. This line 2 is coupled by capacitance 20 to the resonant circuit 16 which includes the inductance 17, condenser 18, and bridge wire 3 as above. Current flows through circuit 16 and heats bridge wire 3 sufficiently to fire the detonator of which it is a part. Circuit 16 is preferably carefully tuned to the same frequency as the antenna, but transmission line 2 does not need to be as carefully tuned.

Fig. 6 represents a circuit similar in all respects to that of Fig. 5 except that the antenna 21 is a helix for reception of circularly polarized electromagnetic waves. A helical antenna 21 with a circumference of one wavelength may serve as a receiving antenna for circularly polarized waves transmitted by a similar helical antenna fed by an oscillator. The circularly polarized waves are highly directive from such an antenna and have the advantage that very little energy is lost due to extraneous radiation. The transmission line 2, coupling condenser 20, and circuit 16 are otherwise similar to similar elements described above with respect to Fig. 5.

Fig. 7 is a further modification of Fig. 1, wherein the transmission line 2 is fed by inductive coupling to an oscillator. Inductance 25 is connected to a source of high frequency oscillations. Inductance 26 is inductively coupled with inductance 25. Variable condenser 27 provides a means of tuning the coupling circuit. Variable condenser 28 provides means for tuning the transmission line circuit including the transmission line 2, the bridge wire 3, and the terminating coil 4. The terminating coil 29 aids in tuning the overall circuit so as to create a standing wave on the transmission line 2 and on that part of the circuit including the bridge wire 3. The bridge wire 3 is disposed in a position of maximum current flow which is a distance of $\lambda/4$ from the terminus of the circuit. In a circuit such as that of Fig. 7 the transmission line 2 may be used to transfer energy from the high frequency source to the site of the detonator over very long distances without excessive loss of power and with only a single transmission line thereby greatly reducing the cost of wire required.

The source of electromagnetic waves may be any radio frequency power generator such as a radio transmitter. The power may be transmitted by inductive feeding to the resonant circuit which includes the bridge wire of the detonator as in Fig. 7 or it may be radiated by any suitably designed antenna to a receiving antenna. The waves may be polarized in any plane such as vertically or horizontally or they may be circularly polarized. For maximum efficiency they are preferably directed by radiation from a suitable directive antenna. The frequency of the electromagnetic waves may be of any frequency above about one megacycle, and preferably within the range of about 10 and about 3000 megacycles. Very high frequency waves are preferred because of their readily directive character and because small antennas, inductors, and capacitors may be used. This is especially important where a

number of charges with individual circuits are placed close to one another.

The electromagnetic waves may be transmitted at a fixed frequency or at a variable frequency. It is advantageous to use a variable frequency, for example, a frequency varied rapidly over a range, which may be a relatively narrow range, to detonate effectively a blasting cap in a circuit tuned to an unknown frequency or in a circuit inaccurately tuned.

The electromagnetic waves may be transmitted continuously or in pulses. It is advantageous to transmit in pulses because less expensive and more readily portable equipment may be used for the transmitter, and large amounts of energy can be transmitted in a short pulse with equipment not capable of transmitting large amounts of power continuously.

While the bridge wire may be at any position of high current flow in the circuit, it is preferred, in order to get maximum efficiency and to assure proper firing of the detonators with a minimum of power that the bridge wire be at or approximately at the position of maximum current flow in the circuit. While the bridge wire of the detonator is preferably placed at a position of maximum current flow as in the examples, the bridge wire need be placed in a position of only sufficiently high current to fire the detonator to be operable. By using a variable frequency generator as a source of power a high current flow may be effected by tuning the generator to the proper frequency of the circuit including the blasting cap to cause it to fire. Broadly, therefore, resonant circuits including the bridge wire of an electric detonator in a position of high current flow in the circuit is contemplated and the term "high current flow" is understood to mean sufficient current flow to fire the detonator when the circuit is properly energized.

By means of the method of firing detonators of this invention, shots may be fired progressively by beaming the waves progressively from one antenna of a resonant circuit of this invention to another. Likewise, shots may be fired progressively by arranging a series of charged bore holes with resonant circuits tuned to different frequencies and subjecting all of these circuits to electromagnetic waves whose frequency is progressively varied over the range of frequencies to which the various resonant circuits are tuned. Such progressive firing is of particular interest in quarry shots where it is desirable to reduce ground vibrations by firing 10 or 20 shots at intervals of 5 to 50 milliseconds.

It is obvious from examination of the various resonant circuits of this invention that they are circuits through which direct current or alternating current of low frequency will not flow and that they are therefore free from stray currents of a type which might cause accidental detonation in the field. Each of the circuits requires less wire than is required in commercial blasting. In the case where a single line is used to carry the high frequency current to the site of the detonator only about one-half as much wire is required as in the usual circuits. In the case where electromagnetic radiation is used for transmitting the power from the transmitter antenna to the receiving antenna much less wire is required. In the mining of coal where bore holes in the face of the mine are not deep, the transmission line from antenna to the blasting cap is relatively short and a great saving in wire may be effected in such a case.

What I claim and desire to protect by Letters Patent is:

1. The method of firing an electric initiator having a bridge wire which comprises formation of a resonant electrical circuit consisting of an inductance, a capacitance and the bridge wire of the electric initiator, positioning the bridge wire in the circuit at a point of high current flow for the resonance frequency, coupling the resonant circuit to a second circuit comprising an antenna for the resonant frequency, subjecting the antenna circuit to electromagnetic radiation of the resonance frequency to induce a current in the resonant circuit, heat the bridge wire and fire the initiator, said bridge wire receiving its critical firing current from the increased current flow caused by the resonance of the circuit.

2. A resonant circuit which consists of an inductance, a capacitance and the bridge of an electric detonator, said bridge wire being positioned at a point of high current flow of the resonance frequency in said circuit; said resonant circuit being coupled to an antenna circuit.

3. A resonant circuit which consists of an inductance, a capacitance and the bridge of an electric detonator, said bridge wire being positioned at a point of high current flow of the resonance frequency in said circuit; said resonant circuit being capacitively coupled to an antenna circuit.

4. A resonant circuit which consists of an inductance, a capacitance and the bridge of an electric detonator, said bridge wire being positioned at a point of high current flow of the resonance frequency in said circuit; said resonant circuit being inductively coupled to an antenna circuit.

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