

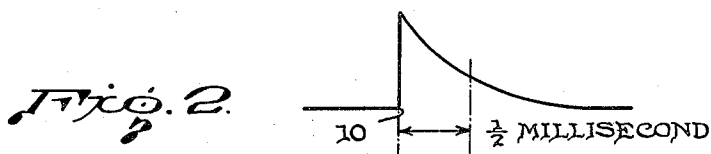
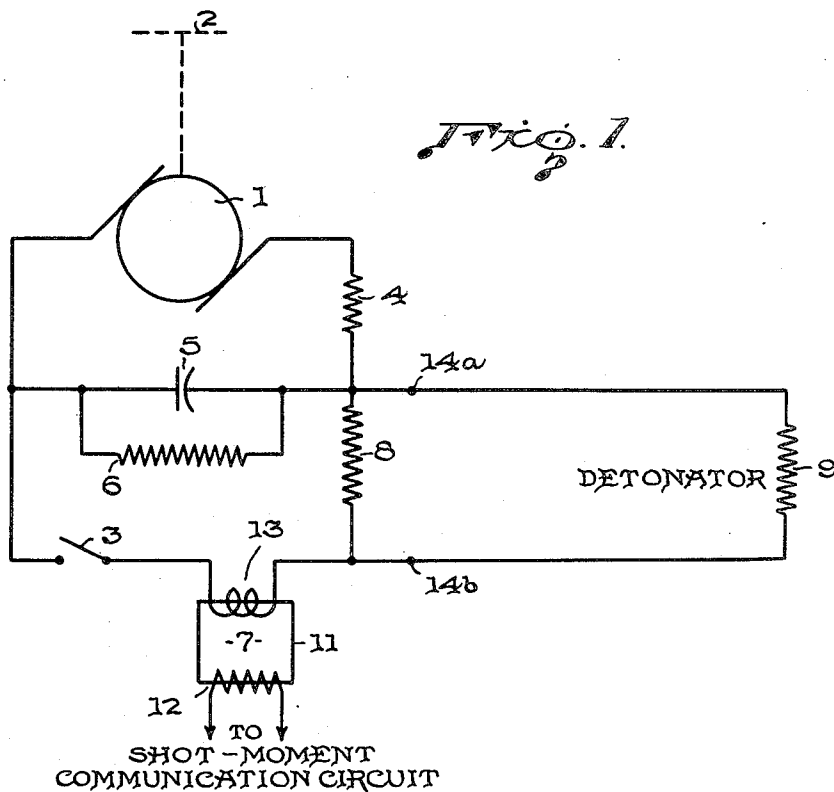
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ELECTRIC PULSE-FORMING SHOT-FIRING DEVICE

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ELECTRIC PULSE-FORMING SHOT-FIRING
DEVICE

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This invention concerns an apparatus for firing electric detonators and is particularly useful in seismograph-prospecting operations in that the apparatus facilitates the accurate, unambiguous and definite recording of the instant at which the explosive detonates.

In seismograph geophysical-prospecting operations it is customary to fire one or more explosive charges usually but not necessarily buried in the earth, and to record distant earth tremors resulting from the explosion. A study is made of the travel times of the tremors and from an analysis of such travel times geophysicists may in known manner deduce the structure of the underlying rock formations. In order to measure the travel time of the various tremors or seismic disturbances produced by the dynamite explosion, it is necessary to record along with the seismograph tremors the instant at which the shock or tremor is initiated, namely, the instant at which the tremor-producing explosion occurred. The instant is ordinarily termed the "shot moment."

One way in which the shot moment has heretofore been obtained is to draw a so-called shot-moment wire around the dynamite so that upon explosion of the dynamite the shot-moment circuit is ruptured producing a deflection (called the shot-moment kick) on one of the galvanometers which record on the same recording medium as the galvanometers which record the tremors received by the seismographs. There are numerous difficulties associated with this manner of obtaining the shot moment. It requires the use of additional wires running down the shot hole, two wires being required for the electric detonator and two separate wires for the shot-moment circuit. Furthermore, the shot-moment wires may be violently blown out of the shot hole immediately after the explosion, with the result that the insulation is at least partially destroyed from the shot-moment wires whereupon the wires may ground or short-circuit, thus producing spurious kicks on the shot-moment record, which signals are often mistaken for the true shot-moment particularly if the latter is weak or interfered with as by static or other disturbances. In addition, there is always some danger that current from the shot-moment circuit may leak into the detonator circuit and prematurely fire the shot.

In view of the above-mentioned difficulties an attempt has been made to obtain the shot moment from the detonator circuit itself. At first this led to some inaccuracies in the shot moment, because the older types of electric detonators had

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varying amounts of time delay between the fusing of the detonator bridge wire and the actual detonation of the explosive. These delays often amounted to several milli-seconds and constituted a source of error in the subsequent interpretation of the seismogram. However, the manufacturers of electric detonators soon developed an improved type of detonator for use in seismograph operations. The new detonators have little or no thermal delay less than one milli-second) and this type of no-delay detonator is now customarily employed in all seismograph-prospecting operations.

However, in spite of the use of detonators having substantially no delay, many of the difficulties inherent in obtaining the shot moment from the detonator circuit still remain due to the fact that the detonator wires can and often do short-circuit after the explosion resulting in confused and erratic shot-moment kicks on the record. In fact, the explosion gases themselves may contain sufficient ionized material to carry the detonator current for an appreciable interval after the detonator bridge wire has severed. Furthermore, the association of signalling devices with the detonator circuit introduces a hazard. By the use of my invention an unmistakable, unambiguous shot moment may be obtained from the detonator circuit. Furthermore, the shot moment obtained by the use of my invention is of controlled and uniform character so that the interpreter of the seismogram may easily recognize the shot-moment kick and accurately ascertain the true shot moment. At the same time the hazard incident to the association of signalling circuits is minimized.

It is accordingly an object of my invention to provide a detonator-firing apparatus which produces an easily recognizable shot-moment pulse.

It is another object of my invention to provide a detonator-firing apparatus having a high degree of safety against the danger of electrical energy being transferred from the signalling or recording circuit to the detonator circuit.

Another object of my invention is to provide a detonator-firing apparatus which eliminates time delay between actual explosion and the recorded shot-moment kick.

Another object of my invention is to provide a detonator-firing apparatus which eliminates false shot-moment indications due to noisy circuits or poor connections or short-circuits in the detonator circuit.

Another object of my invention is to provide a detonator-firing apparatus which is capable

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of firing several electric detonators substantially simultaneously.

Another object of my invention is to provide a safe electric-detonator-firing apparatus which may be used either for tripping radio-signalling circuits or for direct connection in oscillograph or telephone circuits.

It is a further object of my invention to provide a detonator-firing apparatus which produces accurate shot-moment indications having a sharp, uniform and unambiguous character.

It is another object of this invention to provide a detonator-firing apparatus characterized by simplicity and a high degree of reliability and safety.

These and other objects of my invention are accomplished by the apparatus described in this specification of which the drawing forms a part, and in which

Figure 1 is a schematic wiring diagram of the apparatus of my invention;

Figure 2 shows an oscillogram of the current applied by my apparatus to an electric detonator; and

Figure 3 shows an oscillogram of a typical shot-moment impulse obtained by the use of the apparatus of my invention.

The apparatus of my invention comprises a hand-driven source of electrical energy which charges a condenser and thereafter closes a switch between the condenser and the detonator circuit when the generator has attained operating speed and the condenser is charged. The condenser-detonator circuit is provided with a series-parallel network of resistors arranged so that the charge can under no circumstances remain on the condenser more than a few milli-seconds, and so that the shot-moment pulse which is transmitted to the shot-moment-recording circuit is of a definite, predetermined, uniform character which is substantially independent of the characteristics either purposely or accidentally imparted to the detonator circuit. Thus the detonator, which is of the low-thermal-delay type now customarily used in seismograph shooting, will either fire during the milli-second in which current is applied to it or, under exceptional circumstances, will not fire at all and may be detonated subsequently when such exceptional circumstances have been corrected. Furthermore, the shape of the shot-moment kick is predetermined and is therefore easily recognizable by the interpreter of the seismogram.

Referring to Figure 1, numeral 1 indicates a direct-current electric generator such as is customarily used in manually-operated blasting machines and which is operated by energetically pushing handle 2 or some similar manually-operated means for driving the generator 1. The driving means 2 is arranged so that substantially at the end of the stroke it mechanically closes a switch 3 whose function in the circuit will become evident later. The switch 3 is arranged so that it is normally open, but closure thereof takes place after the generator has reached operating speed, that is, the generator is delivering electrical energy at the time switch 3 is closed.

Connected in series with the generator 1 is a resistor 4 and a condenser 5. The resistor 4 has a resistance sufficiently high so that should an electric detonator be connected to the detonator terminals without the condenser, firing of the detonator would in no event take place. The resistor 4 is therefore in the nature of insurance against delayed firing that might otherwise occur

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in case the condenser should fail. The resistor 4 however is sufficiently low in resistance so that the generator 1 may charge condenser 5 to a high voltage in a relatively short time, that is, in the time normally taken to manually actuate the driving means 2. Thus, the generator 1 transfers its electrical energy to the condenser 5 during the operating stroke of the driving means 2. It has been found that with the customary push-down type of blasting generator, the resistor 4 may be of the order of 600 ohms. In order to prevent a sustained charge from remaining on the condenser 5, the latter is shunted by a resistor 6 which may be of the order of 50,000 ohms. This value of resistor 6 is sufficiently high to present substantially no load on the generator 1 and yet be capable of discharging the condenser 5 in a few seconds if normal firing does not otherwise do so. Condenser 5 is of a sufficiently large capacity to store substantially more energy at the voltage generated by generator 1 than is required to fire the type of electric-detonator employed in seismograph operations. It has been found that a capacity of 20 to 100 mfd. is satisfactory. The condenser 5 may be of the electrolytic type and may of course be in one or more sections as is customary in high-capacity condensers.

Connected to the terminals of condenser 5 is a series circuit comprising the switch 3 mentioned above, the primary winding 13 of a transformer 7 (which is to be described in more detail later) and a resistor 8. The detonator itself is indicated in Figure 1 by the resistance 9 and is connected across the terminals 14a and 14b of resistor 8 so that the detonator 9 is in parallel with resistor 8. The purpose of resistor 8 is to assure that the energy in the condenser 5 will be practically all dissipated within one milli-second even though the detonator circuit should accidentally be of too high a resistance to discharge the condenser rapidly, due to a poor connection or the like. Without the resistor 8, a poor detonator circuit might cause firing several milli-seconds after the shot-moment kick, but by employing the resistor 8 the detonator will either fire before the condenser is substantially discharged or not fire at all. Thus resistor 8 is a desirable element to assure that delayed firing will never occur. It has been found that a resistance of 20 ohms is a satisfactory value to use for resistor 8 if used with a condenser 5 at about 50 mfd. The function of transformer 7, which will be described in more detail later, is to transfer the pulse to a radio, telephone or other communication circuit which reaches to the recording station so that the shot-moment pulse may be recorded on the seismogram with the records of the seismographs customarily employed.

The operation of the apparatus is therefore as follows: Mechanical energy imparted through the handle 2 to the generator 1 is converted into electrical energy by the generator and transferred to condenser 5. At the end of the stroke of handle 2, switch 3 is closed, whereupon the energy stored in the condenser discharges through the transformer winding 13 and resistor 8 building up across this resistor sufficient voltage to fire the detonator connected thereto.

Figure 2 shows a typical oscillogram of the type of voltage or current pulse which is delivered by the apparatus of Figure 1 to the resistor 8 with a detonator connected as shown. Up to the instant 10 no current flows in the detonator. At the instant 10 switch 3 closes and a current starts

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to flow through resistor 8 delivering across its terminals a potential which has been observed to be of the order of 75 volts. Thereafter, the potential decays exponentially in the well-known manner characteristic of a condenser discharging through a resistance. Its duration will depend on the resistance of the detonator circuit in parallel combination with resistor 8 and should fall between about .001 sec. for a high resistance circuit and about .00005 sec. for a low resistance circuit. The transformer 7 is of a type which introduces substantially no inductance into the circuit.

Transformer 7 which transfers the pulse of Figure 2 to the communication circuit is of a saturable-core type. Satisfactory results have been obtained when the primary winding 13 of transformer 7 consisted of 23 turns of ordinary copper magnet wire. The transformer 7 may have a partly laminated core 11 having a relatively small cross-section so that a pulse of only a moderate amplitude may be transmitted. A core which has been found to be satisfactory has solid legs of $\frac{3}{8}$ -inch diameter S. A. E. 1020 steel inserted in each coil, and a connecting leg of about $\frac{1}{8}$ " by $\frac{1}{4}$ " minimum cross-section made up of laminations of a high-permeability alloy, as for example "mu-metal." The solid legs tend to suppress high frequencies which might accidentally get into the timing circuit and keep them from passing through the transformer to the detonator circuit. The mu-metal laminations provide easy saturation to control the pulse amplitude, and also limit the transfer of stray energy.

Preferably the secondary should be wound with resistance wire and wound with substantially more turns than the primary 13. It has been found that a resistance-wire secondary winding of approximately 2400 ohms and comprising 750 turns is satisfactory. The transformer 7 is of a closed-core type and has its primary and secondary windings on separate legs of the core. The transformer 8 will produce a large voltage pulse in an open circuit for tripping electron-tube trigger circuits in radio-relay apparatus if shot moment is to be conveyed by radio, and the transformer will produce a pulse of limited current into a low-resistance circuit such as an oscillograph or a telephone line leading directly to an oscillograph. The transformer 7 by virtue of its high secondary resistance, its easily saturable small-cross-section core, and the physical separation of the primary and secondary windings on separate legs of the core, also acts as a safety device which prevents any possibility of stray current from the shot-moment communication circuit from getting into the detonator circuit. The use of resistance in the secondary winding itself rather than incorporating it in a separate resistor is merely a safety measure to avoid the possibility that the resistor might be short-circuited and allow stray current in the timing circuit to go through the transformer to the detonator circuit.

Figure 3 shows a typical oscillogram of the type of voltage pulse which is delivered by the apparatus of Figure 1 to a shot-moment communication circuit connected to the terminals of the secondary winding 12. This pulse has a sharp kick 15 in one direction followed by a very flat deflection in the other direction. It has been found that the amplitude of the sharp peak 15 is of the order of 50 volts on open circuit. The flatness of the succeeding oppositely-directed deflection gives the pulse

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the appearance of a unidirectional kick whose total duration is of the order of one-tenth milli-second as indicated in Figure 3. Experiments with various commercial brands of low-thermal-delay electric detonators obtained from various manufacturers have shown that under normal conditions the detonators all fire within 1 milli-second of the time indicated by the peak 15 of the recorded pulse of Figure 3. This is well within the required time accuracy for seismograph-prospecting purposes. Experiments have further shown that even under marginal conditions, the maximum delay is 2 milli-seconds. Experiments have also shown that several detonators may be connected in series across the terminals 14a and 14b of Figure 1, and under normal conditions all will fire within 1 milli-second of each other and of the peak 15 of the recorded pulse of Figure 3. The pulse form shown in Figure 3 is that observed with a high-speed oscillograph, such as a cathode-ray tube. With such an instrument, the height and duration of the observed pulse will vary with the detonator-circuit resistance. However, this pulse is ordinarily recorded in seismograph field operations by means of a galvanometer element having a natural frequency of perhaps 150 or 200 cycles per second. The pulse of Figure 3 lasts for such a short time compared to the period of the usual galvanometer that it is in effect a ballistic kick which is proportional to the flux change occurring in the transformer as it is magnetized to saturation by the firing current.

Experiments indicate that the ballistic kick is nearly equivalent for any value of detonator-circuit resistance since the amplitude variations are offset by variations in duration of the pulse. The actual record made by the usual type of seismograph galvanometer is consequently not only uniform, but it is characteristic of the natural frequency and the damping constant of the galvanometer. As long as the same galvanometer is used, or one of the same characteristics, the shot-moment kicks will be very uniform. This characteristic of the shot-moment kick which is recorded by the use of my invention is of primary importance to the interpreter of the seismogram who must be able to identify accurately the shot-moment instant.

The transformer 7 introduces a safety measure into the apparatus in that it would require 3000 volts or more at 60 C. P. S. to be connected to the secondary in order to fire a detonator in the primary circuit. Such voltages are not likely to be used in communication circuits. At a higher optimum transformer frequency of several thousand cycles the transformer would require lower voltages (about 400 volts) to fire a detonator but the power input required would be at least 50 watts. Such power even at the optimum frequency is also not likely to be used in communication circuits. The apparatus therefor possesses a high degree of safety.

The apparatus of my invention provides an electric detonator-firing means having a combination of condenser and resistors which always assures a short pulse (less than 1 milli-second) regardless of the detonator-circuit resistance, thereby assuring firing of low-thermal-delay detonators within a known time interval which can easily be identified by a sharp recorded instant. Absence of energy except at the firing instant eliminates the recording of noises caused by electrical leaks, poor contacts, crossed wires after the explosion, and other effects.

What I claim as my invention is:

1. An electric detonator-firing apparatus comprising a source of direct-current energy, a first resistor and a condenser connected in series across the terminals of said source, a normally-open switch and a second resistor connected in series across the terminals of said condenser, means for connecting a detonator directly across the terminals of said second resistor, and means for closing said switch.
2. An electric detonator-firing apparatus comprising a direct-current electric generator, a condenser connected across the terminals of said generator, a first resistor connected across the terminals of said condenser, a normally-open switch and a second resistor connected in series across the terminals of said condenser, means for connecting a detonator directly across the terminals of said second resistor, and means for closing said switch.
3. An electric detonator-firing apparatus comprising a manually-driven direct-current electric generator, a first resistor and a condenser connected in series across the terminals of said generator, a normally-open switch and a second resistor connected in series across the terminals of said condenser, means for connecting a detonator directly across the terminals of second resistor, and means for closing said switch when said generator has attained operating speed.
4. An electric detonator-firing apparatus comprising a manually-driven direct-current electric generator, a first resistor and a condenser connected in series across the terminals of said generator, a second resistor connected across the terminals of said condenser, a normally-open switch and a third resistor connected in series across said condenser, means for connecting a detonator directly across the terminals of said third resistor, and means for closing said switch when said generator has attained operating speed.
5. An electric detonator-firing apparatus comprising a manually-driven direct-current electric generator, a first resistor and a condenser connected in series across the terminals of said generator, a second resistance of high value connected across said condenser, a normally-open switch and a third resistance of low value connected in series across the terminals of said condenser, means for connecting a detonator directly across said low resistance, and means for closing said switch when said generator has attained operating speed.
6. An electric detonator-firing apparatus comprising a manually-driven direct-current electric generator, a condenser connected across the terminals of said generator, a high resistance connected across the terminals of said condenser, a normally-open switch and the primary winding of a transformer and a third resistance of low value connected in series across the terminals of said condenser, a secondary winding of high resistance on said transformer, means for connecting said secondary winding to a utilization circuit, means for connecting a detonator across said low resistance, and means for closing said switch when said generator has attained operating speed.
7. An electric detonator-firing apparatus comprising a manually-driven direct-current generator, a first resistor and a condenser connected in series across the terminals of said generator, a second resistance of high value connected across said condenser, a normally-open

- switch and the primary winding of a transformer and a third resistance of low value connected in series across said condenser, a secondary winding of high resistance on said transformer, means for connecting said secondary winding to a utilization circuit, means for connecting a detonator across said low resistance, and means for closing said switch when said generator has attained operating speed.
8. An electric detonator-firing apparatus comprising a manually-driven direct-current generator, a first resistor and a condenser connected in series across the terminal of said generator, a transformer having a saturable core and a low-impedance primary winding and a high resistance secondary winding of substantially more turns than the primary winding, a normally-open switch and the primary winding of said transformer and a second resistor connected in series across said condenser, means for connecting said secondary winding to a utilization circuit, means for connecting a detonator across said second resistor, and means for closing said switch when said generator has attained operating speed.
9. An electric detonator-firing apparatus comprising a manually-driven direct-current generator, a first resistor and a condenser connected in series across the terminals of said generator, a high resistance connected across said condenser, a transformer having a saturable core and a low-impedance primary winding and a high resistance secondary winding of substantially more turns than the primary winding, a normally-open switch and the primary winding of said transformer and a low resistance connected in series across said condenser, means for connecting said secondary winding to a utilization circuit, means for connecting a detonator across said low resistance, and means for closing said switch when said generator has attained operating speed.
10. An electric detonator-firing apparatus for seismograph shot-moment timing comprising a condenser of high capacitance, a charging circuit for said condenser including a direct-current source and a series resistor having a resistance of the order of four ohms per volt of the source voltage to limit the source current to a value less than the current required to fire a detonator, and a series-connected discharge circuit for said condenser including a switch arranged to be closed when the charge on the condenser is substantially at its maximum value, the primary winding of a pulse transformer whose secondary winding may be connected to a time-recording circuit, and a pair of detonator terminals paralleled by a resistor of sufficiently low ohmic resistance to assure a maximum time-constant of discharge of said condenser of the order of one milli-second.
11. An electric detonator-firing apparatus for seismograph shot-moment timing comprising a condenser of high capacitance, a charging circuit for said condenser including a manually-controlled direct-current source and a series resistor having a resistance of the order of four ohms per volt of the source voltage to limit the source current to a value less than the current required to fire a detonator, and a series-connected discharge circuit for said condenser including a switch arranged to be closed after a substantially full charge is built up on said condenser, a low-impedance primary winding of a pulse transformer having a high-impedance secondary winding connectable to a time-recording

circuit and a core including a leg which is readily saturable by the discharge current, and a resistor in parallel with which a detonator may be connected, said last-named resistor being of sufficiently low ohmic resistance to constitute with said condenser and transformer primary a time-constant of discharge of the order of one milli-second.

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REFERENCES CITED

The following references are of record in the file of this patent:

10

Number
582,582

UNITED STATES PATENTS

Number	Name	Date
1,890,445	Asire -----	Dec. 13, 1932
2,313,101	Stuart -----	Mar. 9, 1943
2,370,909	Martin -----	Mar. 6, 1945
2,395,600	Weisglass -----	Feb. 26, 1946
2,465,696	Paslay -----	Mar. 29, 1949
2,490,461	McKinney -----	Dec. 6, 1949

FOREIGN PATENTS

Number	Country	Date
582,582	Germany -----	Aug. 3, 1933