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METHOD OF AND APPARATUS FOR FIRING EXPLOSIVES

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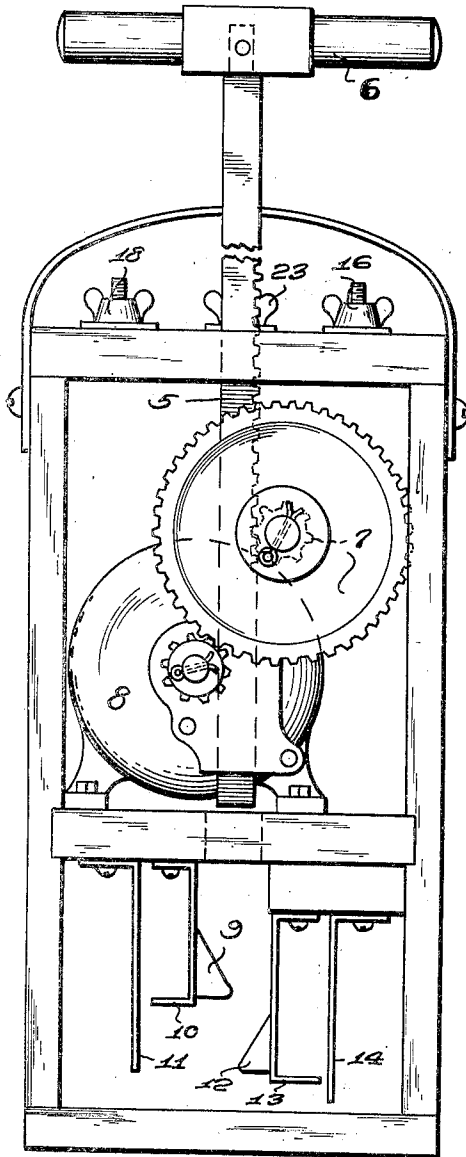


Fig. 1.

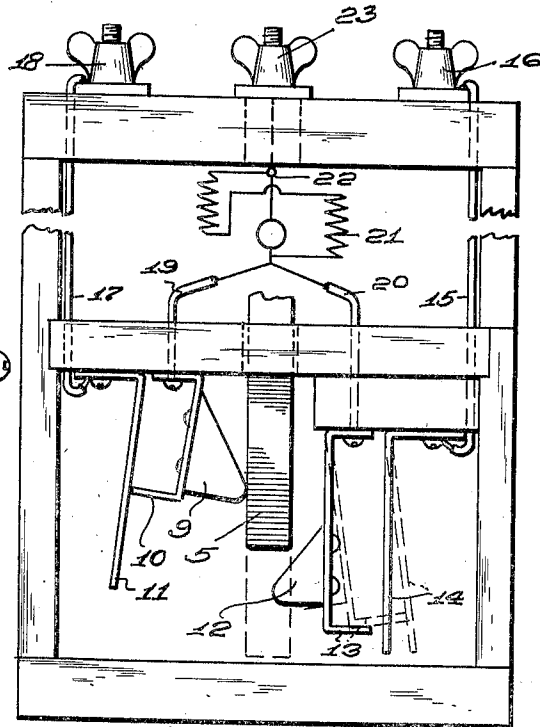


Fig. 2.

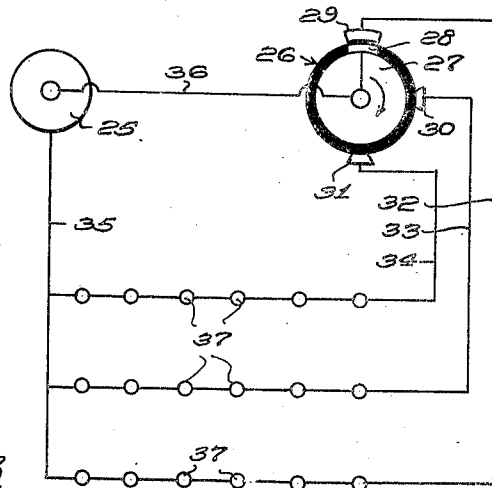


Fig. 3.

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UNITED STATES PATENT OFFICE

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METHOD OF AND APPARATUS FOR FIRING
EXPLOSIVESDavid M. McFarland, West Chester, Pa., assignor
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28 Claims. (Cl. 175—91)

This invention relates to new and useful improvements in a method of and means for firing a plurality of electric firing elements and particularly to the firing of a plurality of series of electric firing elements. While especially applicable to the firing of blasting charges of explosives and particularly in relatively large numbers, it is also applicable to many other fields, including, for example; artillery, tear-gas installations, propellant charges for prime-movers, etc.

The chief objects of the invention are: (1) to increase the number of electric firing elements that may be fired with a source of current, such as an electric generator, (2) to improve the reliability with which large numbers of electric firing elements may be fired with a given source of current, through the reduction of the number of misfires that may occur due to current leakage, and (3) to increase the flexibility and utility of electric firing element systems toward improved firing control and technique.

Broadly, my improved method of firing a plurality of electric firing elements comprises the imparting of electrical energy from a source of current to a plurality of circuits, each of which comprises one or more electric firing elements connected in series, through a time-switch mechanism adapted to actuate the several circuits at progressively different times.

Long experience and present practices show that certain formations may be blasted more satisfactorily by firing a number of separate charges of explosives than by firing one concentrated charge of explosive having a weight equivalent to the combined weight of the separate charges. If a suitable electric blasting cap is embedded in each of a plurality of separate charges and these electric blasting caps are connected into a single circuit so that each one will receive adequate and equal current when the firing current is applied to the circuit, the electric blasting caps will fire simultaneously and detonate at the same time the explosive charges in which they are embedded.

In certain blasting operations there has developed a demand for a method of initiating the detonation of a series of separate charges of explosives simultaneously and, a fraction of a second thereafter, initiating the detonation of a second series of separate charges of explosives simultaneously. The commercial types of delay electric firing elements; meaning any such type of firing element that may be actuated in the same series with instantaneous firing elements, afford time intervals ranging from .005 second

upward; the methods for obtaining the very short delay intervals being confined mostly to alterations and variations in the inflammable flash composition. The longer delay intervals, about 0.10 second and greater, are usually obtained by using time fuses between the igniting elements and explosive charges. Commercial types of delay electric firing elements are not nearly accurate enough in time of firing to provide the requisite delay action between series along with the desirable simultaneous action in the succeeding series. In general, it may be said that the time of firing of any series of delay type of firing elements is ragged as compared to the simultaneous action of a series of instantaneous electric blasting caps.

This progressive firing of a plurality of series of charges can not be accomplished by means of detonating fuse because it is well recognized that the velocity of detonation of the fuse plays an important part in its action. A number of explosive charges may be detonated progressively by means of detonating fuse. Theoretically, it would also be possible, under certain limiting conditions, to detonate a plurality of series of explosive charges by means of detonating fuse so that all charges in any particular series would explode simultaneously. However, such a method would be very impractical and beyond the skill and training of the average shot firer.

Within certain current limits the time of firing of any particular brand of correctly designed and carefully manufactured electric blasting caps varies inversely as the magnitude of the current applied. By means of an oscillograph it is possible to determine accurately the time that it takes to fire a particular electric blasting cap with a certain current value. If this process is repeated, using current values from what is known as the minimum firing current, which is about 0.4 ampere to 3.0 amperes, the time-current values may be plotted and joined with a line giving a parabola type of curve.

A study of such a graph reveals that if it were possible to apply at the same time a current of greater magnitude to one series of electric blasting caps than is applied to a second series of electric blasting caps, the first series would be expected to fire before the second.

This has been accomplished by connecting two series of unbalanced resistance in parallel, as disclosed in McBride's U. S. Patent No. 1,738,595. This method has a number of disadvantages such as the unnecessary addition of electrical resistance in some cases, which is not desirable, and

the inherent inflexibility of the method. For example, the number of holes to be fired might be of such magnitude that the addition of electrical resistance to unbalance one or more of the circuits would cause an overload on the source of current which in turn would be likely to cause misfires.

Under my invention, it is entirely practical to initiate the detonation of a series of separate charges of explosives simultaneously and a fraction of a second thereafter to initiate the detonation of the charges of a second series, simultaneously, without resorting to unsatisfactory delay types of electric firing elements, without resorting to the use of the unbalanced series in parallel method and without increasing the possibility of misfires due to having a large number of caps in series.

The same time intervals as are obtained by the unbalanced series in parallel method and greater time intervals may be developed according to my invention by using, for example, a standard, manually actuated, shunt or compound wound blasting machine equipped with two or more firing switches and three or more binding posts. These firing switches are adjusted so that when the machine is being operated the first firing switch will close and fire the series of electric blasting caps connected in No. 1 circuit a fraction of a second before the series of electric blasting caps connected in No. 2 circuit. The difference in time of firing of the two series may be regulated within certain limits by the difference in time of closing of the two switches. As a non-limiting example, it is possible to obtain time intervals of the magnitude of about .005 to about .035 second with a standard shunt wound blasting machine equipped with two switches.

The current wave of the shunt wound type of manually operated blasting machine has a duration of about one quarter of a second. The time required for a current of 1.5 amperes to fire a series of a well known type of electric blasting caps, is but 0.002 to 0.003 second. With the time switch arrangement, the full output of the blasting machine is available for No. 1 circuit which fires first and before the switch for No. 2 circuit closes. Since No. 1 circuit is broken before the switch for No. 2 circuit closes, the entire output of the machine is available for No. 2 circuit. In making the connections for such a blast, precautions must be taken to arrange the wires so that any debris thrown by a hole in No. 1 circuit will not break No. 2 circuit prematurely. Also, depending upon the proximity of adjacent series, the time intervals between such series must be small enough to insure that the explosion of the charges in one circuit will not disrupt the electrical circuit in the next succeeding series. In certain types of blasting in soil or mud, time intervals of .10 second or greater between the firing of charges of explosives may be desired. As previously indicated, the use of time fuses to obtain such delays frequently results in inaccurate and non-simultaneous firing. Consequently, although my invention pertains to a method and apparatus for initiating the detonation of separate charges of explosive successively within a fraction of a second, it is not to be limited to particular time intervals other than that such intervals be greater than the time required to fire the first series of firing elements and, depending upon the type of blasting, proximity of shots, etc., less than the

time required for an explosion resulting from the firing of one series of firing elements to disrupt the electrical connections of the succeeding series, as distinguished from shorter or longer time intervals which result neither in an increase in the firing capacity of a blasting machine nor in the control of debris.

In the accompanying drawing:—

Figure 1 is a diagrammatic view of a standard, manually operated blasting machine having an extra switch applied thereto.

Figure 2 is a diagrammatic view of the wiring employed in conjunction with the machine of Figure 1 and

Figure 3 is a diagrammatic view illustrating the utilization of three circuits instead of two.

Like numerals designate corresponding parts in all the figures of the drawing.

In the conventional type of blasting machine such as that illustrated in Figure 1, a rack bar 5, when thrust downwardly by means of a handle 6, imparts a quick spin through suitable gearing indicated at 7, to the armature of the generator 8. After the generator has picked up speed and built up electrical energy, the lower end of the rack bar acts upon a cam lug 9 to close the electric circuit by bringing the contact foot 10 into engagement with contact strip 11. Since the rack bar 6 is manually operated by a downward thrust, the velocity increases from zero at the beginning of the stroke to a maximum, at the end of the stroke and the armature has an accelerated movement throughout.

In carrying out the present invention, I provide a second cam lug 12 so that continued downward movement of the rack bar will act to thrust a contact foot 13 against a second contact strip 14 to thereby close a second circuit. The wiring is illustrated in Figure 2. Here the contact strip 14 is connected by a conductor 15 with a binding post 16. The contact strip 11 is connected by a conductor 17 with a binding post 18, and the elements by which the feet 10 and 13 are carried, are connected by conductors 19 and 20 to the generator windings, indicated at 21; these latter being likewise connected by a conductor 22 with binding post 23.

If two separate circuits are employed in each of which a plurality of charges are arranged in series; said circuits having the binding post 23 as one common terminal and having their other terminals represented by the binding posts 16 and 18, it follows that the series included in the No. 1 circuit, which has the binding post 18 as one of its terminals will be fired first, and that upon continued downward movement of the rack bar, the No. 2 circuit will be completed and the charges therein will be fired. The second cam lug 12 is operated toward the end of the downward movement of the rack bar when the velocity of the armature is approaching a maximum. This ensures a maximum potential across the terminals of the No. 2 circuit.

In Figure 3 I have illustrated means for firing, in succession, the charges in three separate circuits. Here 25 designates any convenient source of electric energy, such as a power line, generator, battery, or blasting machine, and which may yield either alternating or direct current, 26 indicates a suitable switch comprising a rotative member 27 of non-conductive material, and carrying a contact segment 28 which, during the rotation of member 27, makes contact successively with contact blocks 29, 30, and 31. These blocks are included in circuits 32, 33 and 34; said cir-

cuits all having a common return 35 leading to the source of electric energy 25. A conductor 36 connects the source 25 with the contact segment 28.

5 When the element 27 is rotated the circuits 32, 33 and 34 are successively energized, and as each circuit is energized, the electric firing elements 37 therein are fired simultaneously.

10 In order for this method to function satisfactorily it is necessary that the current be of sufficient strength to fire each series of electric blasting caps (about 1.5 amperes) and of sufficient duration, meaning the sum of the times required to fire each series plus the sum of the time inter-
15 vals provided for between each series. When using a blasting machine for this method of firing a plurality of series of electric blasting caps, I prefer to use the shunt or compound wound type because of the longer current duration.
20 Bureau of Mines Bulletin No. 240, page 81 states "The chief characteristic of this wave form, which distinguishes it from discharge waves of series machines, is a shorter length of pulsation of the wave and a greater number per second, making
25 a more sustained value of current."

Another important advantage which results from this method of firing a plurality of series of electric blasting caps through a time-switch mechanism is that the firing capacity of the blasting machine is increased. By actual tests on a
30 standard 50 shot shunt wound machine, it has been determined that by the addition of one extra closing switch and one extra binding post the firing capacity of the machine may be doubled.
35 Previous to this invention attempts have been made to increase the firing capacity of a particular type of machine by increasing the size of the various parts. The difficulty with this method has been that the size is limited by the allowable
40 weight of the machine and the man power of the average operator.

The chances of current leakage from a series circuit and the chances of some of the electric blasting caps misfiring, increase in some proportion to the number of electric blasting caps connected in the series. (See Bureau of Mines
45 Technical Paper No. 471). It is generally recognized that the chances of failure are much less if 100 electric blasting caps are connected in two series of 50 electric blasting caps each than in
50 one series of 100, when the same voltage is available for each of the 50 cap series as would be available for the 100 cap series. Thus by a more judicious application of the current from the
55 blasting machine, it is possible to utilize part of the output that would normally be dissipated to fire an additional number of electric blasting caps. This may be done with but a negligible increase in weight of the blasting machine.

60 From the description and specifications given above, it will be apparent that my invention offers three distinct advantages in the firing of explosive charges, namely; (1) it provides a definite time interval or a delay action between successive
65 series, (2) it offers a simple and very economical method for increasing the firing capacity of blasting machines, and (3) it discloses a means whereby in firing a large number of electric blasting caps, as one blast, the chances for misfires may be reduced.

70 It will be understood that I do not intend that my invention shall be limited to the firing of commercial explosives, nor to any particular source of electrical energy, nor to the use of
75 particular type of firing element, nor to the use

of any particular type of time-switch since it is adaptable to other uses, as for example, the firing of guns and may be used with any suitable source of electrical energy, any form of electrically operated firing element and any suitable type of 5 time-switch.

By the term "electric firing element", I mean any device that embodies either an electrically heated bridge-wire or spark gap associated with a flash composition which becomes ignited 10 thereby with the passage of sufficient current through the said bridge-wire or spark-gap. They may be in any convenient form and embodied in combination with any inflammable or explosive or detonating charge, the initiation of which is 15 desired, as for examples, electric detonators, electric squibs, electric propellant cartridges, electrically fired rockets, electrically fired tear gas cartridges, etc.

When a number of so-called instantaneous 20 electric blasting caps are connected in a single series and an electric current of adequate strength is applied to the circuit to cause all of the electric blasting caps to detonate, they are said to fire simultaneously. I recognize that 23 there may be very minute differences in time of detonation of the individual electric blasting caps in the series, which differences are measurable with sensitive electrical recording devices. I use the term "simultaneous firing" in the generally 30 accepted meaning of the term as applied to electric blasting, which means all firing within the variations in time that may be expected of any reliable brand of properly designed and carefully manufactured electric blasting caps. 35

By the term "shunt wound blasting machine" I mean an electric blasting machine having a shunt winding in the generator field. I wish it to be understood that the generator field may have a shunt winding only, or it may have a shunt 40 winding and an additional series winding; the latter type being commonly known as a compound wound generator.

Having described my invention, what I claim is:

1. The method of firing electrical firing elements which comprises generating current by a single manual operation of a shunt wound blasting machine, imparting current so generated to a plurality of circuits, each of which comprises at least one electrical firing element connected in series, through a time switch mechanism adapted to actuate each circuit at progressively different times; the time intervals between the actuation of consecutive series circuits being within the 55 range of .005 to .035 second.

2. The method of firing electrical firing elements which comprises generating current by a single manual operation of a shunt wound blasting machine, imparting current so generated to a 60 plurality of circuits, each of which comprises at least one electrical firing element connected in series, through a time switch mechanism adapted to actuate each circuit at progressively different times; the actuation of the first of said 65 circuits occurring near the end of said single operation and the time intervals between the actuation of consecutive series circuits being greater than the time required for the source of current to fire the preceding series. 70

3. The method of firing electrical firing elements which comprises generating current by a single manual operation of a shunt wound blasting machine, imparting current so generated to a plurality of circuits, each of which comprises 75

at least one electrical firing element connected in series, through a time-switch mechanism adapted to actuate each circuit at progressively different times; the time intervals between the actuation of consecutive series circuits being at least .002 second.

4. The method of electrically firing explosive charges which comprises generating current by a single manual operation of a shunt-wound blasting machine imparting current so generated to a plurality of series of explosive charge firing elements through a time-switch mechanism adapted to actuate each series circuit at progressively different times; the time intervals between the actuation of consecutive series circuits being at least .002 second.

5. The method of electrically firing explosive charges which comprises generating current by a single manual operation of a shunt-wound blasting machine imparting current so generated to a plurality of series of explosive charge firing elements through a time-switch mechanism adapted to actuate each series circuit at progressively different times; the actuation of the first of the series circuits occurring near the end of said single operation and the time interval between the actuation of consecutive series circuits being greater than the time required for the source of current to fire the preceding series.

6. In combination with a manually operated, single stroke shunt-wound blasting machine having a transient output capacity and comprising an actuating part, a plurality of circuits each containing at least one electrical firing element connected in series, and circuit closing means for said several circuits incorporated in said blasting machine and means for actuating said circuit closing means successively at intervals of at least .002 second under the movement of said actuating part.

7. In combination with a shunt-wound blasting machine comprising a single-stroke, longitudinally movable rack bar and a generator actuated by the movement of said bar, a plurality of independent electric circuit closing elements; each of said closing elements being connected by means of separate electrical conductors to a plurality of binding posts on the machine adapted for connection to a plurality of external circuits and each of said closing elements being disposed at points spaced from each other along the line of movement of the rack bar and adapted to be moved to closed position successively under the movement of the rack bar, whereby successive energization of the external circuits is effected under a single stroke of the rack bar.

8. A structure as recited in claim 7, wherein the spacing of said circuit closing elements along the path of movement of the rack bar is such that the time intervals between the actuation of consecutive series circuits are greater than the time required for the source of current to fire the preceding series.

9. In combination with a shunt-wound blasting machine comprising a single-stroke, longitudinally movable rack bar and a generator actuated by the movement of said bar, a plurality of independent electric circuit closing elements; each of said closing elements being connected by means of separate electrical conductors to a plurality of binding posts on the machine adapted for connection to a plurality of external circuits and each of said elements being disposed at points spaced from each other along the line of movement of the rack bar and each of said elements

comprising a laterally movable spring strip, said strips being provided with cam projections having beveled upper faces adapted to be contacted successively by the lower end of the rack bar to thereby successively energize the respective external circuits.

10. A structure as recited in claim 7, wherein the spacing of the circuit closing elements is such, with respect to the capacity of the blasting machine, that a plurality of electrical blasting caps connected to the first of said binding posts will be fired prior to the closing of the next succeeding circuit, while the firing of the caps in a succeeding circuit will follow the firing of the caps in a preceding circuit in such a limited time as to prevent the firing of the caps in the first circuit from disrupting or disarranging the wires and caps of the succeeding circuit.

11. The method of progressively firing a plurality of electric firing elements which comprises inducing current in a conductor by movement of the conductor through a field at least a part of which is built up by the induced current, passing current so induced through a first electric firing element to fire the same, continuing the movement of the conductor and the induction of current in the conductor after passing current through said first electric firing element, and passing current induced by the continued movement of the conductor through a second electric firing element to fire the same, the initial passage of current through said second electric firing element occurring within .005 to 0.35 second after the initial passage of current through said first electric firing element.

12. The method of progressively firing a plurality of electric firing elements which comprises inducing current in a conductor by movement of the conductor through a field at least a part of which is built up by the induced current, passing a portion of the current so induced through a first electric firing element to fire the same, continuing the movement of the conductor and the induction of current in the conductor after passing current through said first electric firing element, and passing current so induced through a second electric firing element to fire the same, the time interval between the initial passage of current through said first element and the initial passage of current through said second element being greater than the time required for the current to fire said first element and not great enough to permit the explosion initiated by the firing of said first element to disrupt the electrical connection of said second element.

13. The method of progressively firing a plurality of electric firing elements which comprises manually inducing current in a conductor by movement of the conductor through a field at least a part of which is built up by the induced current, passing current so induced through a first electric firing element to fire the same, continuing the movement of the conductor and the induction of current in the conductor after passing current through said first electric firing element while utilizing induced current to maintain the field, and passing current so induced through a second electric firing element to fire the same, the time interval between the initial passage of current through said first element and the initial passage of current through said second element being of the order of .002 to .10 second.

14. The method of progressively firing a plurality of electric firing elements which comprises

inducing current in a conductor by movement of the conductor through a field at least a portion of which is built up by the induced current, passing a portion of the current so induced through a first electric firing element to fire the same while utilizing substantially all of the remaining portion of the current to maintain the field, continuing the movement of the conductor and the induction of current in the conductor after passing current through said first electric firing element while utilizing induced current to maintain the field, and passing current induced by the continued movement of the conductor through a second electric firing element to fire the same, the initial passage of current through said second electric firing element occurring within .005 to .035 second after the initial passage of current through said first electric firing element.

15. The method of progressively firing a plurality of electric firing elements which comprises manually inducing current in a conductor by accelerated movement of the conductor through a field at least a part of which is built up by the induced current, passing current so induced through a first electric firing element to fire the same, continuing the accelerated movement of the conductor and the induction of current in the conductor after firing said first electric firing element, and passing current so induced through a second electric firing element to fire the same, the time interval between the initial passage of current through said first element and the initial passage of current through said second element being of the order of .002 to .10 second.

16. A blasting machine comprising a current generator, means for conducting generated current to a first exterior circuit including a first switch, means for conducting generated current to a second exterior circuit including a second switch, and means for closing the second switch within .005 to .035 second after the closure of the first switch.

17. A machine for progressively firing a plurality of electric firing elements comprising at least three terminals adapted for connection to two external firing circuits and a time switch mechanism constructed and arranged to distribute a supply of current to one of the external circuits after the distribution of current to the other external circuit, said time switch mechanism including a first switch, a second switch, and a member operative to close the second switch between .005 and .035 second after the closure of the first switch.

18. Apparatus for distributing a supply of current to progressively fire a plurality of electric firing elements comprising at least three terminals adapted for connection to a first external firing circuit and a second external firing circuit, a first switch, a connection from said switch to the supply of current, a connection from said switch to one of said terminals, a second switch, a connection from said second switch to the supply of current, a connection from said second switch to a second of said terminals, means for closing said first switch and for closing the second switch within .005 to .035 second after the closure of the first switch, said means retaining the first switch in closed position during the closure of the second switch.

19. The method of firing electrical firing elements which comprises the imparting of the transient electric current generated by a single stroke of a shunt wound blasting machine to a

plurality of circuits, each of which comprises a plurality of firing elements connected in series, through a time switch mechanism adapted to actuate each circuit at progressively different times; the time intervals between the actuation of consecutive series circuits being greater than the time required for the source of current to fire the preceding series.

20. A manually operated, single stroke, blasting machine having a limited capacity to fire on a single stroke electric firing elements connected in single series, and comprising a shunt wound electric generator, at least two firing switches operated in sequence, and at least three binding posts for connection to a plurality of external firing circuits, the time interval between the operation of any two of the said firing switches being at least .002 second.

21. A manually operable blasting machine comprising a shunt wound generator, means for rotating the armature of the generator, including a member movable along a limited, substantially longitudinal path, at least three binding posts for connection to a plurality of external firing circuits, and at least two firing switches located adjacent one end of said path and arranged to be operated in sequence by the member toward the end of its movement, the time interval between the operation of any two of the said switches being greater than the time required for the generated current to fire a group of electric firing elements connected in series in an external circuit.

22. A manually operable blasting machine comprising a shunt wound electric generator, at least two firing switches, means for operating the switches in sequence, and at least three binding posts for connection to a plurality of external firing circuits, the time interval between the operation of any two of the said firing switches being of the order of .002 to .10 second.

23. A manually operable blasting machine comprising a shunt wound electric generator, at least two firing switches, means for operating the switches in sequence, and at least three binding posts for connection to a plurality of external firing circuits, and wherein the time interval between the operation of any two of the said successively operated firing switches is at least as great as the time required for the generated current to fire a group of electric firing elements connected in series in an external circuit, but not as great as the time required for an explosion resulting from the firing of one outside circuit to disrupt the electrical connections of the next succeeding outside circuit.

24. A manually operable blasting machine comprising a shunt wound electric generator, at least two firing switches, means for operating the switches in sequence, and at least three binding posts for connection to a plurality of external firing circuits, and wherein the time interval between the operation of any two of the said firing switches, operated consecutively, is within the range of .005 and .035 second.

25. The method of electrically firing explosive charges which comprises the imparting of the electric current generated by a single operation of a shunt wound blasting machine to a plurality of series of explosive charge firing elements through a time switch mechanism adapted to actuate each series circuit at progressively different times: the time interval between the actuation of consecutive series circuits being greater than

the time required for the source of current to fire the preceding series, and wherein the time interval between the actuation of consecutive series circuits is not great enough to permit an explosion resulting from the firing of the explosive charge firing elements in one series to disrupt the electrical connection of the next succeeding series before the latter is fired.

26. The method of operating a single stroke manually operable, shunt wound blasting machine having a limited capacity to fire on a single stroke electric firing elements connected in single series, which comprises imparting substantially the maximum current output of the machine exclusively to a first series of electric firing elements toward the end of the stroke, firing said first series to thereby break the series circuit, and thereafter imparting substantially the maximum current output of the machine exclusively to a second series of electric firing elements before the completion of the stroke.

27. In a blasting machine, the combination of a shunt wound electric generator, means for actuating the said generator, a plurality of cir-

cuit closing switches so arranged as to conduct current from said generator to a plurality of outside circuits, and means for closing the said switches successively under the influence of the said generator actuating means; the spacing between the several switches and the speed of operation of the said switch closing means being so regulated as to provide a time interval of at least .002 second between the closing of any two switches.

28. In a blasting machine, the combination of a shunt wound electric generator, means for actuating the said generator, a plurality of circuit closing switches so arranged as to conduct current from said generator to a plurality of outside circuits, and means for closing the said switches successively under the influence of the said generator actuating means; the spacing between the several switches and the speed of operation of the said switch closing means being so regulated as to provide a time interval from .005 to .035 second between the closing of any two switches.

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CERTIFICATE OF CORRECTION.

Patent No. 2,081,633.

May 25, 1937.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, second column, line 33, claim 11, for "0.35" read .035; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of March, A. D. 1938.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.