United States Patent

[11] 3,537,399

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[54] **METHOD AND DEVICE FOR BLASTING**
14 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **102/70.2**
[51] **Int. Cl.** **F42b 3/12**
[50] **Field of Search** ..... 102/28, 28(EBW), 70.2, 22, 23; 317/80

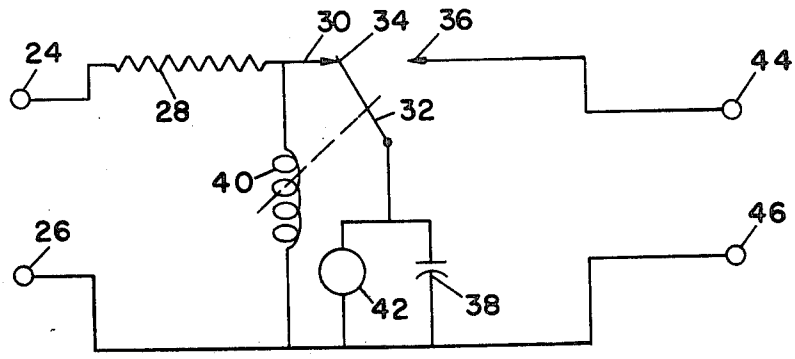
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ABSTRACT: A method and blasting device are disclosed for use in initiating up to about 150 blasting caps disposed in a parallel circuit. The blasting device includes a capacitor for delivering preferably an energy output of between about 210 to about 400 watt-seconds of energy over a relatively short period of time, and a voltage sensing switch for releasing energy from the capacitor when the required level of energy output is available. The output energy, although sufficient to initiate up to about 150 blasting caps disposed in a parallel circuit, is insufficient to cause malfunction by internal arcing of as few as one electric blasting cap disposed in the parallel circuit.



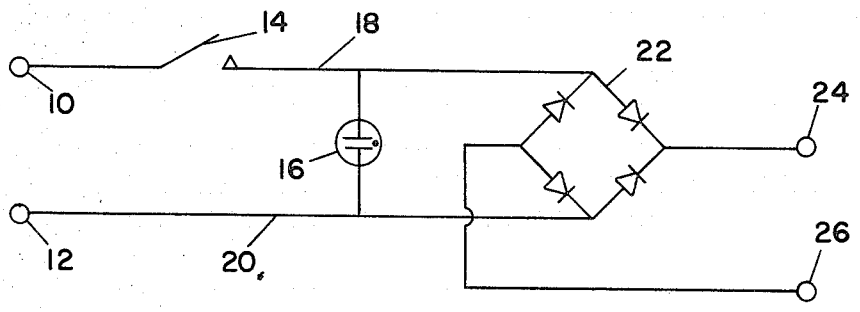


FIG. 1

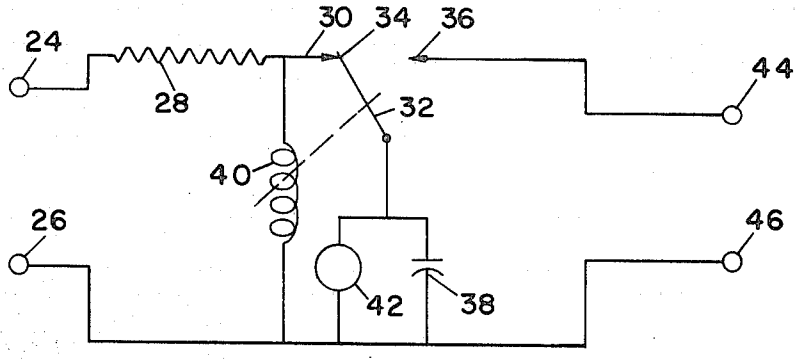


FIG. 2

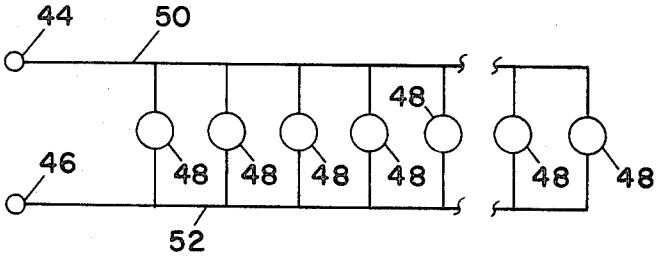


FIG. 3

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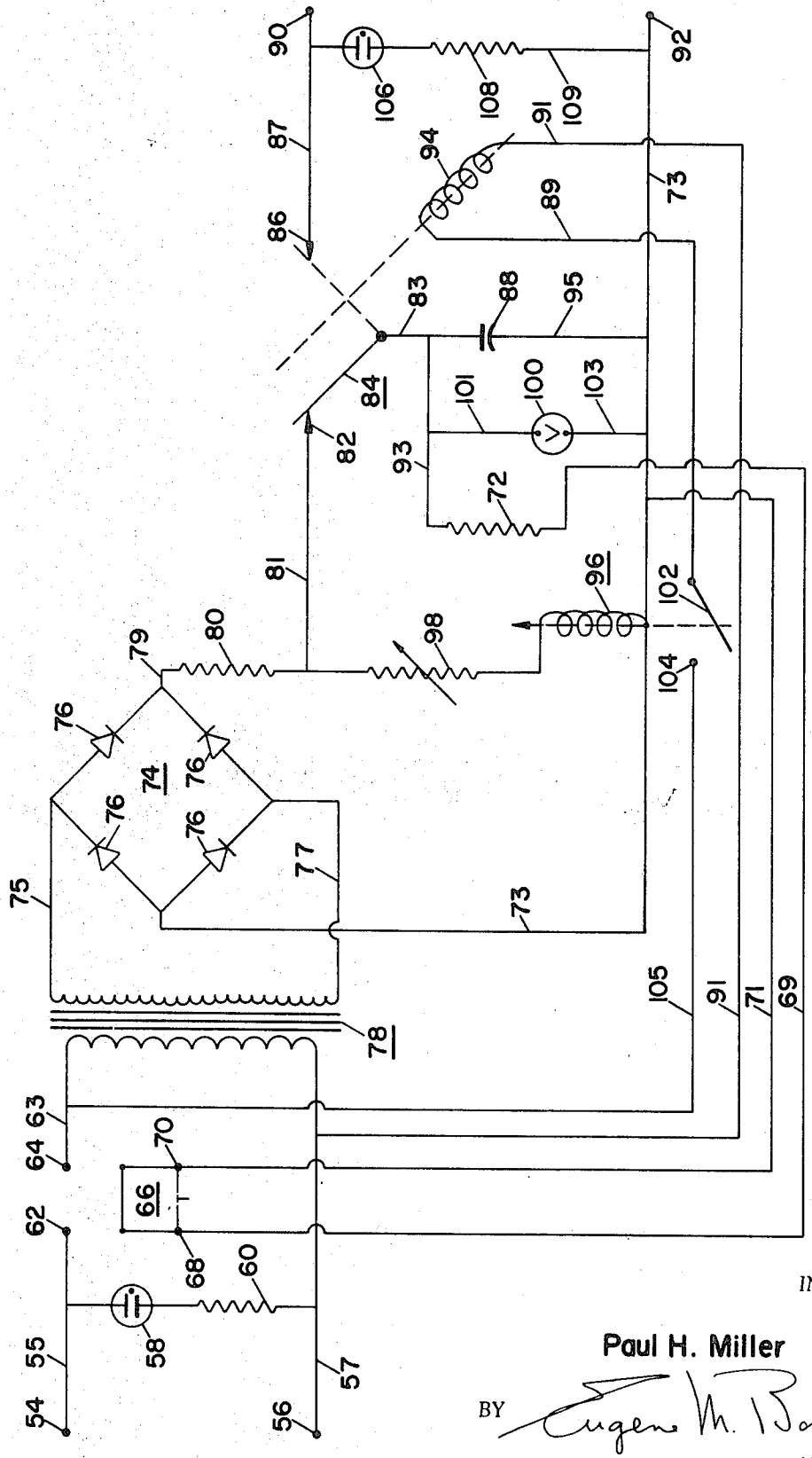


FIG. 4

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METHOD AND DEVICE FOR BLASTING

This invention relates to a condenser-discharge blasting device and, more particularly, to a method of initiating as many as about 150 electric blasting caps disposed in a parallel circuit arrangement without malfunction by internal arcing of as few as one electric blasting cap.

In certain blasting operations such as those performed in tunnels and shaft mining, it is generally desirable to connect electric blasting caps in a parallel circuit, principally because such a circuit permits rapid connection of the blasting caps with minimal possibility of error. Typically, the electric blasting caps are initiated with electric energy received from a readily available AC power line.

One cause of malfunctioning of electric blasting caps and in particular those of the delay type is the large amount of heat generated by an electrical arc which occurs within an electric blasting cap when an excessive electrical current is supplied. Although it is recognized that excess current may be usefully channeled in the parallel circuit by inclusion of additional blasting caps, both delay and inconvenience result unless a simple device is available which is operable for initiation of either as few as one or as many as about 150 blastcaps disposed in a parallel circuit.

Malfunctioning of electric blasting caps may occur when gases within the detonator are heated rapidly and a high internal pressure is soon built up. The heat and high pressure conditions within the blasting cap cause a speed up in the delay. timing. If the internal pressure builds up sufficiently, an outward rupture of the cap wall or a violent dislodging of the cap seal may result which rapidly releases the contained hot gases. The effect of this action on the blasting operation is unpredictable and varied. The sudden release of the gases may create conditions under which the burning of the delay element may be retarded, in which case the delay timing will be slow. Under some conditions, the burning delay element may be extinguished in which case the delay element will then fail to initiate the explosive charge of the detonator. Release of hot gases and flame from within a detonator can ignite the surrounding explosive which may burn at first but could eventually convert to detonation within the confines of a borehold. If the delay element is extinguished and the surrounding explosive charge is ignited, many minutes may elapse before heat from the burning explosive either causes detonation or initiates the explosive charge of the blasting cap which initiates the remainder of the burning explosive. Heat generated by the burning explosive may decompose the explosive charge of the blasting cap and, in such case, the surrounding explosive may, unpredictably, either burn completely or detonate at any point before it is completely consumed by burning. If the burning element is extinguished by the sudden release of the entrapped gases, and the explosive charge is not ignited by the hot gases, the shot may fail completely. Thus, the occurrence of a violent electrical arc within a delay electric blasting cap may result in various types of malfunctions such as, for example, erratic delay timing, misfire, or a delayed detonation commonly known as a "hangfire."

The various malfunctions caused by arcing occur more frequently when any of the various parallel circuit arrangements such as normal parallel, reverse parallel, and closed loop parallel are used with a continuous source of electrical energy of high potential such as a power line. When electric blasting caps are connected in parallel, the voltage across the bridgewire terminals frequently is high enough to sustain an electrical arc after the bridgewire melts and when a power line of high current capacity is used, the arc may generate enough heat within the blasting cap prior to detonation to cause malfunction. Parallel circuit arrangements of delay detonators are often used in the blasting art and the convenience and advantages of a power line as a source of electrical energy are well known. Thus, the majority of arcing difficulties encountered in blasting operations occur when a commonly used circuit arrangement is combined with a commonly used source of electrical energy.

One approach to solving difficulties encountered in initiating electric blasting caps disposed in a parallel circuit is disclosed by MacFarland in U.S. Pat. No. 3,056,349. MacFarland teaches a blasting circuit for initiating, in parallel arrangement, delay electric detonators by generally applying firing energy insufficient to cause malfunction of detonators by internal arcing. Firing current is received from a continuous source of electric energy, and a quick trip switch is employed to restrict the time interval over which the current is applied.

Various other approaches for limiting malfunctioning by arcing of electric blasting caps disposed in a parallel circuit such as limiting the magnitude of the firing current and reducing the resistance inside the electric blasting caps have realized limited success. These approaches have attempted to limit the energy available for initiating electric blasting caps disposed in a parallel circuit based on the fact that energy is a direct function of the square of the firing current, times the internal resistance of the cap, times the duration of time the current is applied.

There are several reasons why various prior art methods of initiating from one up to about 150 blasting caps disposed in a parallel circuit by a single device have not been completely successful in eliminating arcing malfunctions. One reason is that some of these methods attempt to control only one of the three contributing factors that determine the amount of heat generated inside the cap. If one, or both, of the other contributing factors become excessive, the limiting effect of the one being controlled may be overridden. Another reason is that other solutions depend on a human decision or action. Hence, human error easily negates their effectiveness.

An approach that has been tried in an attempt to eliminate the arcing problem when firing delay electric caps in parallel is to use a commercially available condenser-discharge blasting machine as the power source. Such blasting machines have been disclosed by Wolf in U.S. Pat. No. 2,892,128 and Bickel et al. in U.S. Pat. No. 2,908,847. This solution suffers from the disadvantage that these blasting machines can fire only a limited number of caps connected in parallel while avoiding malfunctioning when as few as only one blasting cap is initiated.

Heretofore, no commercially available blasting machine has been available which is rated to fire more than about 50 blasting caps connected in a parallel circuit. This situation is unsuitable because operators employing parallel circuits of blasting caps desire to employ more than 60 caps and many would desire to employ more than 100 caps in a single shot by a device which is also capable of initiating as few as one blasting cap without circuit modification and malfunctioning problems.

It has now been found that by the practice of the present invention, from one to about 150 electric blasting caps may be initiated in a parallel circuit arrangement without encountering arcing malfunctions. This may be accomplished without the necessity of a human decision or action; and, hence, misfires due to human error are eliminated. The present invention uses output energy as a function of the capacitance and voltage of a condenser-discharge blasting device.

Generally stated, the present invention provides a blasting device for initiating up to about 150 electric blasting caps disposed in a parallel relation by combining an energy output means capable of delivering between about 210 to about 400 watt-seconds of energy over a relatively short period of time from a capacitor having a preferred capacitance of about 2.8 $\times 10^{-3}$ farads to about 5.0×10^{-3} farads. A voltage sensing switch is also desirably included in the blasting device for sensing the voltage of the charge on the capacitor and, after the desired voltage level is reached, for discharging the capacitor and providing the discharged energy to initiate the electric blasting caps of the parallel circuit. Thus, by using a voltage sensing switch, the present blasting device may be operated without opportunity for human error. In an embodiment of the present invention, other voltage sensing means may be employed in the circuit although with less reliability due to opportunity for human error.

The invention will be further described in connection with the accompanying drawings which illustrate schematically a circuit which may be used in the practice of the present invention.

In the drawings:

FIG. 1 illustrates a circuit which may be employed for converting an alternating current to a direct current;

FIG. 2 illustrates a circuit of the present invention for obtaining a condenser discharge with controlled energy output;

FIG. 3 illustrates electric blasting caps which may number from one up to about 150 disposed in parallel relation; and

FIG. 4 illustrates in greater detail a preferred embodiment of the blasting device of the present invention.

In the drawing of FIGS. 1—3, terminals **10** and **12** are illustrated for receiving an alternating current from, for example, a power line, an alternating current generator or other source capable of supplying an AC voltage sufficient to charge the capacitor system described hereinafter. Switch **14** may be included in the circuit to control the flow of current into the system. Indicator light **16** may be also included for indicating the flow of electricity between lines **18** and **20**, which lines connect bridge rectifier **22** for conversion of the alternating current to a direct current passing to terminals **24** and **26**.

Resistor **28** may be included for limiting the flow of current in line **30** to switch **32** having charging position **34** and discharging position **36**. When switch **32** is in charging position **34**, direct current is received from terminals **24** and **26** for charging capacitor **38**. Capacitor **38** may appear as one or as a bank of capacitors as desired.

Desirably included in the circuit is electromagnetically operated unit **40** exemplified by either a relay coil or solenoid for use in conjunction with switch **32** to serve as a voltage sensing switch. The voltage sensing switch may also be any suitable electronic circuit capable of opening switch **32** when sensing a particular voltage applied to the energy storage capacitor. Optionally included in the circuit is voltage monitoring system **42** which may be either a voltmeter for visually reading the potential applied to capacitor **38** or a simple indicator lamp which may light when the required potential is applied to the capacitor.

In operation, when the required voltage is received from terminals **24** and **26** for charging capacitor **38**, electromagnetically operated unit **40** causes switch **32** to flip from charging position **34** to discharging position **36**. Energy is thus released within about 0.25 second from capacitor **38** to terminals **44** and **46** for initiating from one to about 150 electric blasting caps **48** disposed in parallel between bus wires **50** and **52** without malfunction of as few as one blasting cap because of arcing.

The voltage across terminals **24** and **26** for charging capacitor **38**, although illustrated in the drawing to be received from an AC source, may be received from a DC power line, battery, DC generator or the like provided that sufficient DC voltage of a magnitude of about 400 to about 500 volts and preferably about 450 volts is available for charging capacitor **38**. The charged capacitor upon discharging provides about 210 to about 400 watt-seconds of energy within about 0.25 second to initiate from one up to about 150 electric blasting caps disposed in a parallel circuit arrangement.

FIG. 4 illustrates, in greater detail, a preferred blasting device prepared by the practice of the present invention. Terminals **54** and **56** may receive an alternating current from, for example, a standard 115 volt AC outlet. Connected between lines **55** and **57** is a power-on indicator light **58**, exemplified by a NE-51H neon indicator lamp, in series with resistor **60**, exemplified by a 47,000 ohm, 0.5 watt, wire wound resistor. Line **55** joins one terminal post **62** of switch **66**, and line **63** joins a second terminal post **64** of switch **66**. Switch **66**, exemplified by a spring return, double-pole, double-throw toggle switch having a rating of 6 amperes and 125 volts, is illustrated in normal circuit position when connected to terminal posts **68** and **70**. Line **69** from terminal post **68** is electrically joined to resistor **72**, exemplified by a 500 ohm, 50 watt, wire wound resistor; and line **71** from terminal post **70** is electrically joined to bridge line **73**. Bridge line **73** connects into bridge rectifier **74** formed, for example, of four diodes **76**, exemplified by General Electric IN5062 silicon diodes. Adjacent diode connection lines **75** and **77**, to that of bridge line **73**, receive an electric current from the high potential side of a step-up transformer **78**, exemplified by a Thordarson-Meissner 24R100 transformer. Electric current to the low potential side of transformer **78** is received from lines **57** and **63** when switch **66** is in position providing a closed circuit across terminal posts **62** and **64**.

Corresponding to bridge line **73** for receiving rectified current from bridge rectifier **74** is bridge line **79** electrically joining resistor **80**, exemplified by a 1,000 ohm, 100 watt, wire wound resistor, which joins line **81** illustrated connected to charging position **82** of power relay switch **84**. Illustrated in phantom is switch **84** when connected to capacitor discharging position **86**. Line **87** receives current from capacitor discharging position **86** when discharging capacitor **88** for releasing energy to terminals **90** and **92** by lines **73** and **87**. The supplied energy to terminals **90** and **92** may be received by the circuit illustrated in FIG. 3 when initiating from one up to about 150 electric blasting caps disposed in parallel circuit arrangement.

Power relay **84** usefully includes switching coil **94** electrically positioned between lines **89** and **91**. An example of a usefully employed power relay is that commercially available from Rowan Controller Co. under the designation B-321-SP1 having a 110 volt AC coil.

Power relay **84** forms a capacitor discharging element of the voltage sensing switch generally illustrated as switch **32** in FIG. 2, and auxiliary relay **96** forms the voltage sensing element thereof. Auxiliary relay **96** is exemplified by that available from Potter and Brumfield, identified generally as a plate relay and illustrated in combination with variable resistor **98** to obtain a 450 volt pull-in capability when combined with power relay **84**.

Connected to power relay **84** is line **83** joining capacitor **88** and line **93** from resistor **72**. Capacitor **88** is further connected to line **73** by line **95** to complete a charging circuit connection. Capacitor **88**, disposed between lines **83** and **95**, may be formed of eight 400 microfarad, 500 working volt DC electrolytic capacitors connected in parallel; *i.e.*, a total capacitance of about 3.2×10^{-3} farad.

Usefully disposed in parallel to capacitor **88** is voltmeter **100** connected by line **101** to line **93** and by line **103** to line **73**. Voltmeter **100**, exemplified by a 0 —500 DC voltmeter, is usefully included for visually reading the potential applied to capacitor **88**.

In operation, the blasting device of FIG. 4 receives alternating current from a conventional outlet by terminals **54** and **56**. When switch **66** is in the illustrated normal position, a drain of any residual charge on capacitor **88** is effected through resistor **72** and connecting lines **69** and **71** which is a closed circuit with lines **73** and **95** on one side of capacitor **88** and lines **83** and **93** on the opposite side thereof. A safety feature thus results in the capacitor drain circuit in that capacitor **88** is maintained without charge during nonuse of the blasting device.

When switch **66** is advanced to terminals **62** and **64**, current is permitted to flow through lines **63** and **57** to the low potential side of transformer **78**. On the high potential side of transformer **78**, current is received through lines **75** and **77** by bridge rectifier **74** which converts alternating current to direct current for charging capacitor **88** by lines **73** and **81** when power relay **84** is in the capacitor charging position **82**. When the required charge is on capacitor **88**, auxiliary relay **96**, operated by a minimal amount of current, closes switch **102** with terminal **104** and makes available alternating current from line **105** and line **91** to coil **94** of power relay **84**. Power relay **84** is thus caused to rapidly switch to capacitor discharging position **86** to release energy from capacitor **88** through lines **87** and **73** and provide energy at terminals **90** and **92** for

initiating up to about 150 blasting caps 48 disposed in parallel circuit between lines 50 and 52 of FIG. 3.

Conveniently disposed between lines 87 and 73 is discharge indicator 106, exemplified by a NE51H neon lamp, in series with a resistor 108, exemplified by 140,000 ohm, 2 watt, wire wound resistor, positioned along line 109. Discharge indicator 106 usefully visually indicates when capacitor discharge is effected.

The invention is further illustrated by the following example:

EXAMPLE

Delay electric blasting caps in the number indicated in the following table were connected according to standard blasting procedures in a parallel circuit arrangement and initiated by a blasting device having an energy discharge of a magnitude in the amount indicated from a capacitor having a rating also indicated.

TABLE

Test No.	Capacitance (Farads)	Voltage (Volts)	Energy (Watt-seconds)	No. of Caps Connected in Parallel	Results
1	$2,840\times10^{-6}$	500	355	1	Cap fired normally.
2	$2,840\times10^{-6}$	500	355	20	All caps fired normally.
3	$3,880\times10^{-6}$	450	393	1	Cap fired normally.
4	$3,880\times10^{-6}$	450	393	20	All caps fired normally.
5	$4,970\times10^{-6}$	400	398	1	Cap fired normally.
6	$4,970\times10^{-6}$	400	398	20	All caps fired normally.
7	$3,000\times10^{-6}$	450	304	1	Cap fired normally.
8	$3,000\times10^{-6}$	450	304	20	All caps fired normally.
9	$3,000\times10^{-6}$	450	304	150	Do.

It is apparent from the foregoing example that the present blasting circuit releases energy from a capacitor sufficient to initiate up to about 150 electric blasting caps disposed in a parallel circuit arrangement while being an energy level insufficient to cause malfunction of any one electric blasting cap disposed in parallel circuit by internal arcing.

It is understood that the foregoing detailed description is given merely by way of illustration and that many variations may be made therein without departing from this invention.

I claim:

1. A blasting device for firing one to about 150 bridgewire-type electric blasting caps in parallel comprising:
   a. Capacitor means capable of discharging between about 210 and about 400 watt-seconds of energy; and
   b. Means for automatically discharging said capacitor means into the firing line of said electric blasting caps when said capacitor means has been charged sufficiently to discharge about 210 to about 400 watt-seconds of energy.

2. The blasting device of claim 1 wherein said means for automatically discharging said capacitor means is an electromagnetically operated unit.

3. The blasting device of claim 1 wherein said means for automatically discharging said capacitor means discharges said capacitor means within about 0.25 seconds.

4. A blasting device for firing one to about 150 bridgewire-type electric blasting caps in parallel comprising:
   a. Capacitor means having a capacitance of about 2.8×10^{-3} farads to about 5.0×10^{-3} farads;
   b. Voltage sensing means for sensing a voltage between about 400 and about 500 volts across said capacitor means; and
   c. Means for automatically discharging said capacitor means into the firing line of said electric blasting caps when said voltage sensing means senses a voltage of between about 400 and about 500 volts across said capacitor means and such that the energy discharged from said capacitor means is between about 210 and about 400 watt-seconds.

5. The blasting device of claim 4 wherein the capacitor means has a capacitance of about 3.2×10^{-3} farads.

6. The blasting device of claim 4 wherein the voltage sensing means is an electromagnetically operated unit.

7. The blasting device of claim 6 wherein the electromagnetically operated unit is a relay coil.

8. The blasting device of claim 6 wherein the electromagnetically operated unit is a solenoid.

9. The blasting device of claim 4 wherein about 450 volts is applied across said capacitor means.

10. A method of firing one to about 150 bridgewire-type electric blasting caps in parallel comprising charging a capacitor means, said capacitor means being capable of discharging between about 210 to about 400 watt-seconds of energy, and automatically discharging said capacitor means into the firing line of said electric blasting caps when said capacitor means has been charged sufficiently to discharge about 210 to about 400 watt-seconds of energy.

11. The method of claim 10 wherein an electromagnetically operated unit is used to automatically discharge said capacitor means when said capacitor has been charged to between about 210 to about 400 watt-seconds of energy.

12. The method of claim 10 wherein said energy is discharged within about 0.25 seconds.

13. A method of firing one to about 150 bridgewire-type electric blasting caps in parallel comprising charging a capacitor means having a capacitance of about 2.8×10^{-3} farads to about 5.0×10^{-3} farads, sensing the voltage across said capacitor as said capacitor is being charged, and automatically discharging said capacitor into the firing line of said electric blasting caps when the voltage across said capacitor has been sensed to be at a value between about 400 and about 500 volts such that the energy discharged from the capacitor means is between about 210 and 400 watt-seconds.

14. The method of claim 13 wherein the voltage across said capacitor is sensed by an electromagnetically operated unit.