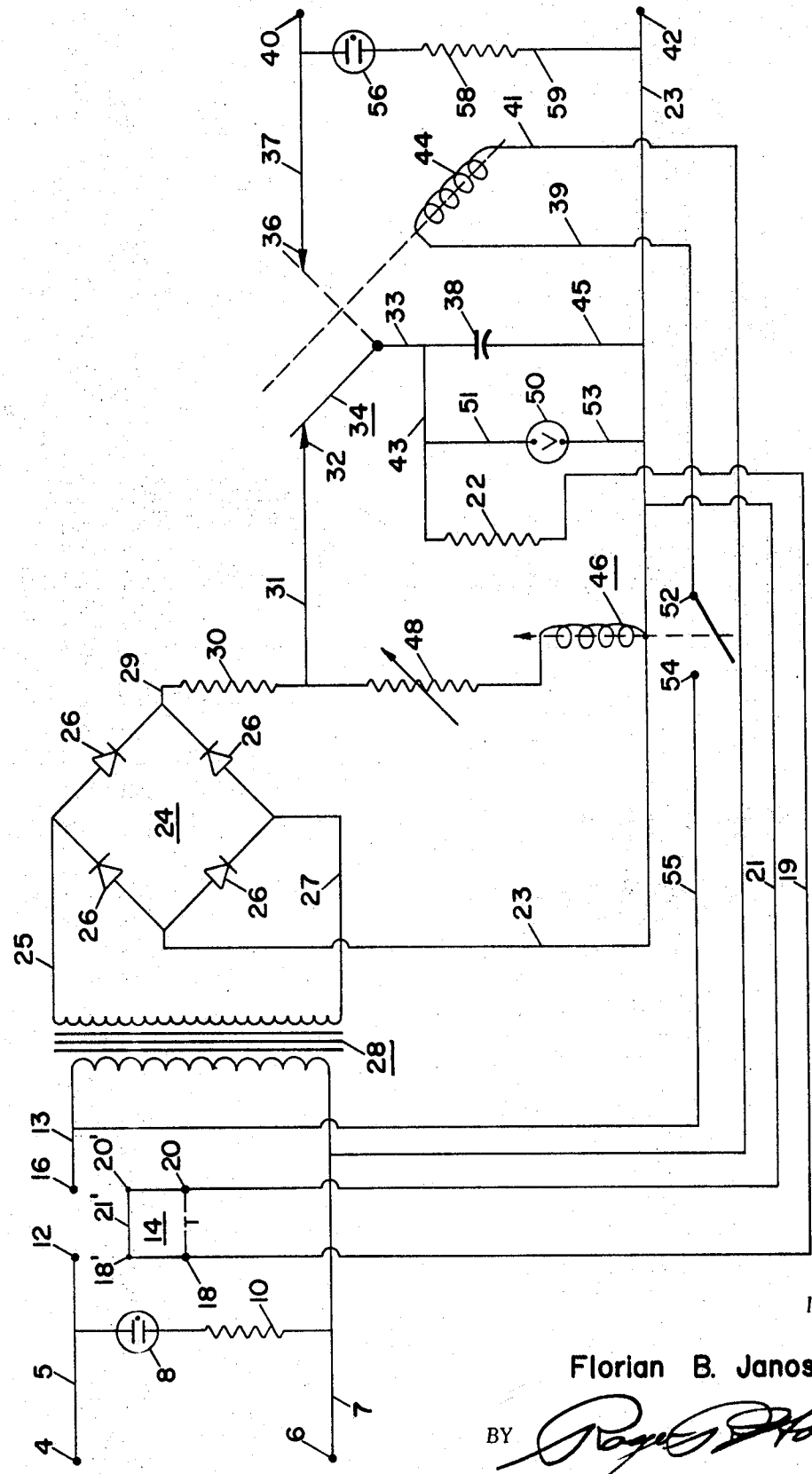
Nov. 3, 1970 F. B. JANOSKI 3,538,414

CAPACITOR-DISCHARGE DEVICE FOR BLASTING

Filed July 1. 1968



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United States Patent Office 3,538,414 Patented Nov. 3, 1970

3,538,414

CAPACITOR-DISCHARGE DEVICE FOR BLASTING

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Filed July 1, 1968, Ser. No. 741,402
Int. Cl. H02m 3/00
U.S. Cl. 320—1 11 Claims

ABSTRACT OF THE DISCLOSURE

A capacitor-discharge blasting device is disclosed having a capacitor drain means connected for limiting the voltage across the capacitance to a negligible level during periods of non-use. The present capacitor-discharge blasting device preferably includes the capacitor drain means in combination with a capacitor capable of delivering 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.

This invention relates to a capacitor-discharge blasting device having a capacitor drain means connected for limiting the voltage across the capacitance to a negligible level during periods of non-use, for safely and conveniently aborting a blast at any time prior to energizing of the external blasting circuit and, more particularly, to such a device for 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.

Malfunctioning of electric blasting caps and in particular those of the delay type may be attributed to 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, increased cost, 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 blasting caps disposed in a parallel circuit.

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 votage 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 initiation 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 McFarland in U.S. Pat. No. 3,056,349. McFarland 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 enegy, and a quick current-interrupting switch is employed to restrict the time interval over which the current is applied.

Another 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.

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.

One of the other disadvantages typically present in commercially available condenser-discharge blasting machines is that the condenser may retain an electric charge during periods of non-use. A dangerous situation is thus presented should electric blasting caps be connected such that the capacitor is prematurely discharged into the blasting circuit to accidentally fire the caps. One attempt to provide a capacitor drain in an effort to avoid premature discharge of a capacitor in a blasting device is disclosed by Bickel et al., in U.S. Pat. No. 2,908,847. Bickel et al., teach the inclusion of a resistor between the output wires for draining the circuit when the firing switch and ready switch are pressed and held in the fire and ready posi-

tions, respectively. Upon release of either of the switches, the resistor is disengaged from performing its task as a bleed-off path and a measurable voltage will remain on the capacitor for a considerable time. Another difficulty in such an approach is that, since the capacitor bleeding resistor remains permanently connected in the output circuit, it affords opportunity for draining energy from the circuit which would otherwise be effectively applied to initiating electric blasting caps.

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 and which has an efficient capacitor drain means connected for limiting the voltage across the capacitance to a negligible level during periods of non-use. This situation is unsuitable because operators employing parallel circuits of blasting caps desire to safely 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 when a firing switch is actuated, and the capacitor may be drained for limiting the voltage across the capacitance to a negligible level during periods of non-use. The device presented requires only the decision to fire the blast; and, upon activation, the necessity for further decision or action with regard to the device is eliminated. Misfires due to human error in premature functioning of the device 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 2.8×10^{-3} farad to about 5.0×10^{-3} farad. A voltage sensing switch is also desirably included in the blasting device for sensing the limit of the voltage required for charging the capacitor and, after the voltage level for charging the capacitor is obtained, for discharging the capacitor and providing the discharged energy to initiate the electric blasting caps of the parallel circuit. Also included in the combination of elements in the present device is a capacitor drain means connected for promptly limiting the charge on the capacitor to a negligible level during periods of non-use. Thus, by using a voltage sensing switch and incorporation of the prompt capacitor drain means, the present blasting device may be safely operated with a greatly reduced opportunity for human error. In an embodiment of the present invention, other voltage sensing means may be employed in the circuit to accomplish equivalent performance.

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

The figure illustrates a blasting device prepared by the practice of the present invention. Terminals **4** and **6** 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. A standard 115 volt AC outlet is generally sufficient. Connected between lines **5** and **7** is a power-on indicator light **8**, exemplified by a NE–51H neon indicator lamp, in series with resistor **10**, exemplified by a 47,000 ohm, 0.5 watt, wire wound resistor. Line **5** joins one terminal post **12** of switch **14**, and line **13** joins a second terminal post **16** of switch **14**. Switch **14**, 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 **18** and **20**. Line **21'** electrically joins terminal posts **18'** and **20'** of switch **14**. Line **19** from terminal post **18** is electrically joined to resistor **22**, exemplified by a 500 ohm, 50 watt, wire wound resistor; and line **21** from terminal post **20** is electrically joined to bridge line **23**. Bridge line **23** connects into bridge rectifier **24** formed, for example, of four diodes **26**, exemplified by General Electric IN5062 silicon diodes. Adjacent diode connection lines **25** and **27**, to that of bridge line **23**, receive an electric current from the high potential side of a step-up transformer **28**, exemplified by a Thordarson-Meissner 24R100 transformer. Electric current to the low potential side of transformer **28** is received from lines **7** and **13** when switch **14** is in position providing a closed circuit across terminal posts **12** and **16**.

Corresponding to bridge line **23** for receiving rectified current from bridge rectifier **24** is bridge line **29** electrically joining resistor **30**, exemplified by a 1,000 ohm, 100 watt, wire wound resistor, which joins line **31** illustrated connected to charging position **32** of power relay switch **34**. Charging of energy storage capacitor **38** can only take place when switch **14** is in position providing a closed circuit between terminal posts **12** and **16**. Illustrated in phantom is switch **34** when connected to capacitor discharging-to-output position **36**. Line **37** receives current from capacitor discharging position **36** when discharging capacitor **38** for releasing energy to terminals **40** and **42** by lines **23** and **37**. The supplied energy to terminals **40** and **42** may be received by a circuit having from one up to about 150 electric blasting caps disposed in parallel circuit arrangement.

Power relay **34** usefully includes a switching coil **44** electrically positioned between lines **39** and **41**. An example of a usefully employed power relay is that commercially available from Rowan Controller Co. under the designation B–321–S81 having a 110 volt AC coil.

Power relay **34** forms a capacitor discharging element of a voltage sensing circuit, and auxiliary relay switch **46** forms the voltage sensing element thereof. Auxiliary relay **46** is exemplified by that available from Potter and Brumfield, identified generally as a plate relay and illustrated in combination with variable resistor **48** to obtain a current sufficient to energize, and close contacts **52** and **54** of auxiliary relay **46** when the voltage across capacitor **38** is about 450 volts DC.

Connected to power relay **34** is line **33** joining capacitor **38** and line **43** from resistor **22**. Capacitor **38** is further connected to line **23** by line **45** to complete the circuit connection. Capacitor **38**, disposed between lines **33** and **45**, may be formed of eight 400 microfarads, 500 working volts DC electrolytic capacitors; i.e., a total capacitance of about 3.2×10^{-3} farad.

The voltage across terminals **4** and **6** 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**. In this case, the transformer and rectifier circuit would be eliminated and the DC voltage applied to terminals **4** and **6** would be presented from terminal **12** through switch **14** to line **29**, and from terminal **6** to line **23**. Coil **44** of power relay **34** would be specified for 80 volt DC operation with an appropriate series resistor, and resistor **10** would have an increased value. The charged capacitor upon discharging provides about 210 to about 400 watt-seconds of energy over a period of time within about 0.025 second to initiate from one up to about 150 electric blasting caps disposed in a parallel circuit arrangement.

Usefully disposed in parallel to capacitor **38** is voltmeter **50** connected by line **51** to line **43** and by line **53** to line **23**. Voltmeter **50**, exemplified by a 0 to 500 DC

voltmeter, is usefully included for visually reading the potential applied to capacitor **38**. A simple indicator lamp which may light when the required potential is applied to the capacitor may also be used if desired.

In operation, the blasting device receives current from a conventional outlet by terminals **4** and **6**. When switch **14** is in the illustrated normal position, the transformer-rectifier charging circuit is not energized and a drain of energy stored on capacitor **38**, and reduction of voltage to the zero level, is effected through resistor **22** and connecting lines **19** and **21** which is a closed circuit with lines **23** and **45** on one side of capacitor **38** and lines **33** and **43** on the opposite side thereof. A safety feature thus results in the capacitor drain circuit in that the normal position of the spring return toggle switch provides that resistor **22** is electrically across capacitor **38** and that the capacitor is not charged during non-use of the blasting device. The capacitor drain feature also provides a convenient means to safely abort initiation of blasting caps at any time during the period of capacitor charge build-up and prior to capacitor discharge to the output terminals. Switch **14** is simply released, and any stored charge is drained through resistor **22**.

When switch **14** is advanced to terminals **12** and **16**, current is permitted to flow through lines **13** and **7** to the low potential primary winding side of transformer **28**. On the high potential secondary winding side of transformer **28**, current is received through lines **25** and **27** by bridge rectifier **24** which converts alternating current to direct current for charging capacitor **38** by lines **23** and **31** when power relay **34** is in the capacitor charging position **32**. Resistor **30** limits the current surge and forms a voltage divider with resistor **48**. As the charge builds up on capacitor **38**, the trickle current through resistor **48** and the coil of auxiliary relay **46** increases. The current required to energize the coil of auxiliary relay **46** is set, by adjustment of variable resistor **48**, to coincide with the desired voltage level on capacitor **38**. When this current level is reached, terminal **52** is connected with terminal **54** and makes available alternating current to line **55** and line **41** for energizing coil **44** of power relay **34**. Power relay **34** is thus caused to rapidly switch to capacitor discharging position **36** for discharging the energy of capacitor **38** through lines **37** and **23** providing energy at terminals **40** and **42** for initiating up to about 150 blasting caps disposed in a conventional parallel circuit, not shown.

Conveniently disposed between lines **37** and **23** is discharge indicator **56**, exemplified by a NE51H neon lamp in series, with a resistor **58**, exemplified by a 47,000 ohm, 2 watt, wire wound resistor, positioned along line **59**. Discharge indicator **56** 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 a 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.

What is claimed is:

1. A blasting device for firing 1 to about 150 bridge-wire-type electric blasting caps in parallel comprising

(a) capacitor means capable of discharging between about 210 and about 400 watt-seconds of energy,

(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,

(c) capacitor drain means, and

(d) means for connecting said capacitor drain means to said capacitor means once said capacitor means has discharged and for disconnecting said capacitor drain means from said capacitor means when said capacitor means is being charged.

2. The blasting device of claim **1** wherein a single switch means is provided which connects said capacitor drain means to said capacitor means in its "off" position and disconnects said capacitor drain means from said capacitor means and charges said capacitor means in its "on" position.

3. The blasting device of claim **2** wherein said switch means is spring-biased to its "off" position.

4. The blasting device of claim **1** wherein said means of element (d) can additionally be made to connect said capacitor drain means to said capacitor means during the time that said capacitor means is partially charged.

5. The blsting device of claim **1** wherein said means for automatically discharging said capacitor means is an electro-magnetically operated unit.

6. A blasting device for firing 1 up to about 150 bridge-wire-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,

(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,

(d) capacitor drain means, and

(e) means for connecting said capacitor drain means to said capacitor means once said capacitor means has discharged and for disconnecting said capacitor

drain means from said capacitor means when said capacitor means is being charged.

7. The blasting device of claim **6** wherein a single switch means is provided which connects said capacitor drain means to said capacitor means in its "off" position and disconnects said capacitor drain means from said capacitor means and charges said capacitor means in its "on" position.

8. The blasting device of claim **7** wherein said switch means is spring-biased to its "off" position.

9. The blasting device of claim **6** wherein said means of element (d) can additionally be made to connect said capacitor drain means to said capacitor means during the time that said capacitor means is partially charged.

10. The blasting device of claim **6** wherein the capacitor means has a capacitance of about 3.0×10^{-3} farad.

11. The blasting device of claim **6** wherein about 450 volts DC is applied across said capacitor means.

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