United States Patent [19]

McKeown et al.

[11] **3,752,081**

[45] **Aug. 14, 1973**

[54] **BLASTING MACHINE**

[75] Inventors: **James E. McKeown; Earl M. Phinney**, both of Oneonta, N.Y.

[73] Assignee: **The Bendix Corporation**, Southfield, Mich.

[22] Filed: **Nov. 23, 1971**

[21] Appl. No.: **201,526**

[52] **U.S. Cl.** ..... **102/70.2 R**, 317/80, 320/1

[51] **Int. Cl.** **F42b 3/18**, F42b 3/12, F42b 3/10

[58] **Field of Search** 102/70.2; 320/1; 315/163; 250/214; 317/80; 321/2

[56] **References Cited**

UNITED STATES PATENTS

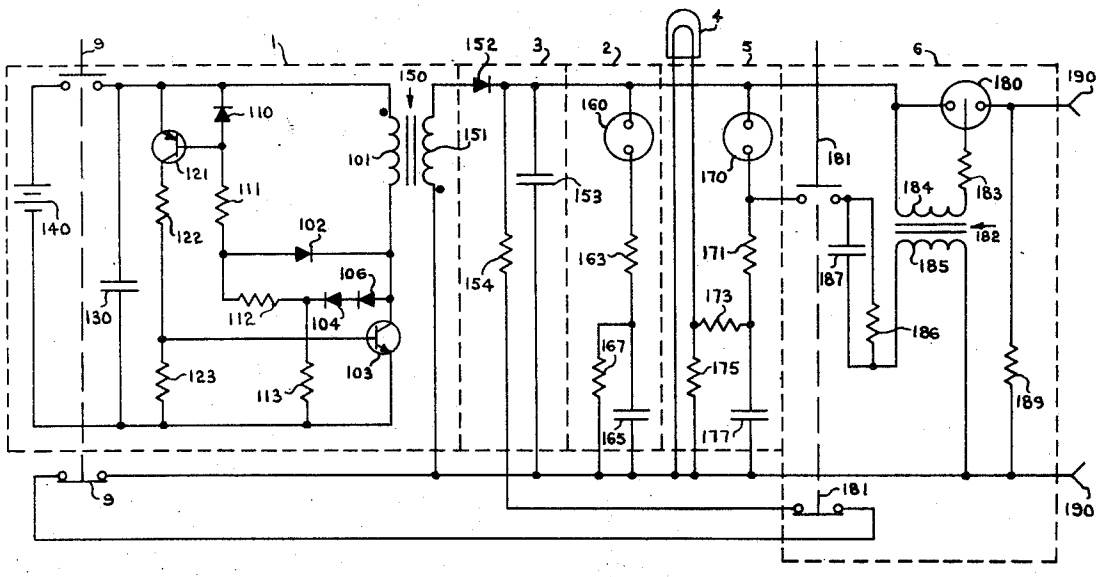
R26,999	12/1970	Elliot	250/214
3,213,344	10/1965	Jensen	320/1
3,316,445	4/1967	Ahrons	320/1
3,671,842	6/1972	McKeown	321/2

Primary Examiner—Benjamin A. Borchelt
Assistant Examiner—Thomas H. Webb
Attorney—Raymond J. Eifler et al.

[57] **ABSTRACT**

A blasting machine for firing an explosive bridge wire device or the like. The firing circuit of the apparatus includes a trigger pulse generating circuit that does not generate trigger pulses until the energy being stored in a capacitor to be discharged through explosive devices has reached a predetermined energy level, thereby preventing firing of the explosive devices before there is sufficient energy stored in the capacitor to assure that all the devices in circuit relationship with the capacitor are detonated. The charging circuit includes a battery powered blocking oscillator and a step up transformer for transforming the energy from a 12 volt battery to a 2,500 volt storage capacitor.

14 Claims, 2 Drawing Figures



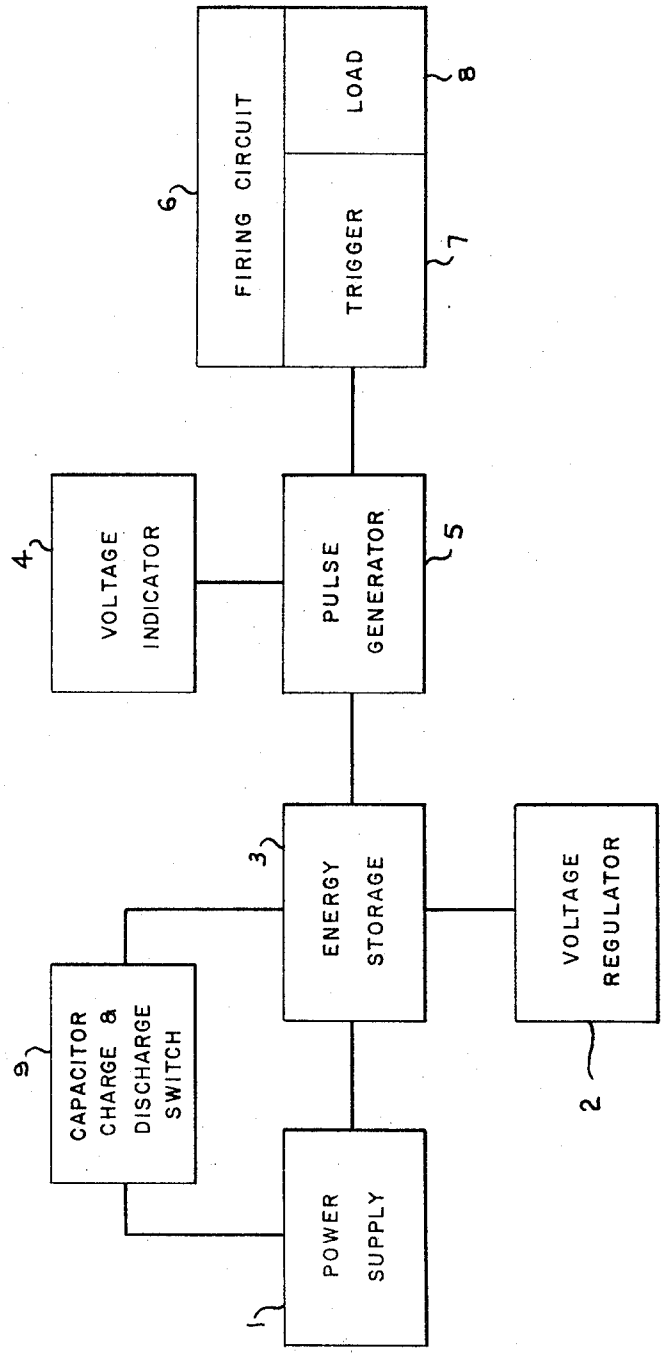

FIRING CIRCUIT
LOAD
TRIGGER
6
7
8
VOLTAGE INDICATOR
PULSE GENERATOR
4
5
ENERGY STORAGE
VOLTAGE REGULATOR
3
2
CAPACITOR CHARGE & DISCHARGE SWITCH
POWER SUPPLY
9
1

FIGURE 1

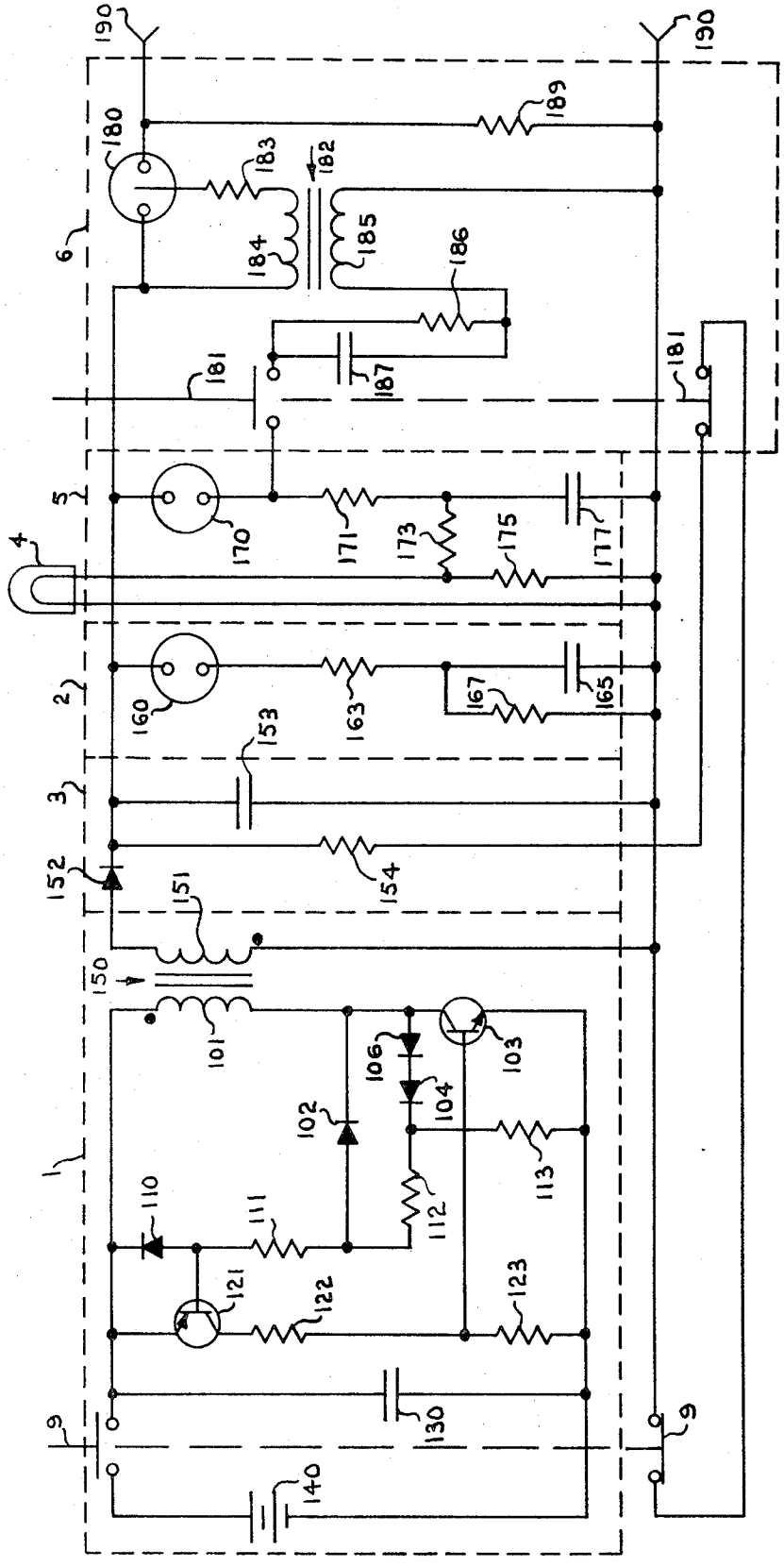

190
190
180
189
183
182
184
185
186
6
187
181
181
5
170
171
173
175
177
4
160
163
167
165
2
153
3
152
154
151
150
101
106
103
104
102
110
111
112
113
121
122
123
130
9
9
140

FIGURE 2

BLASTING MACHINE

BACKGROUND OF THE INVENTION

This invention relates to an improved blasting machine for detonating blasting caps or the like. The invention is more particularly related to a battery powered blasting machine of the capacitor discharge type.

Basically, electrical systems for firing explosive devices include a source or power such as a battery, an oscillator, a transformer responsive to the oscillator for stepping up the pulses therefrom, a storage capacitor which is charged by the pulses from the transformer, and a trigger circuit which allows the energy stored in the capacitor to discharge to fire an explosive device. The energy stored in the capacitor is discharged through the explosive device by means of a triggering circuit which may be operated automatically or manually. Examples of such blasting devices may be found in U. S. Pat. No. 3,417,306 entitled "Regulated Voltage Capacitor Discharge Circuit" to J. L. Knak, issued Dec. 17, 1968; and U.S. Pat. No. 3,275,884 entitled "Electrical Apparatus for Generating Current Pulses" to L. H. Segall et al., issued Sept. 27, 1966.

In certain blasting operations such as those performed in tunnels and shaft mining, it is generally desirable to connect as many as 150 blasting caps together in parallel circuit, principally because such a circuit permits rapid connection of the blasting caps with minimal possibility of error. To insure that all the blasting caps are fired, the blasting machine must always deliver a given minimum energy each time it is fired, otherwise, all of the blasting caps may not be fired.

Further, all too frequently, under heavy loading conditions, existing charging circuits utilizing transformers having a control winding (teritary), experience high frequency oscillations that affect the operation of the circuit and, therefore, the maximum power that can be transferred to the load. The high frequency oscillations occur because the amount of feedback to the control winding that turns "off" the switching transistor in series with the primary winding depends upon the voltage across the secondary winding in parallel with the load capacitor. At low magnitudes of charge on the load capacitor, the feedback to the control winding is frequently insufficient to overcome a positive bias on the switching transistor. Therefore, the switching transistor is "off" for very short intervals hence, high frequency oscillations.

SUMMARY OF THE INVENTION

This invention prevents the firing of a blasting machine until a predetermined minimum energy level is available within the blasting machine.

The invention also provides a battery powered oscillator circuit for charging a storage capacitor that is not subject to spurious high frequency oscillations that adversely affect operation of the blaster.

This invention further provides a battery powered blasting machine that prevents the application of insufficient voltages to blasting caps by incorporating into the discharge circuit of a storage capacitor a trigger circuit which only allows the capacitor to discharge when trigger pulses are being generated. The trigger circuit does not generate any pulses until the capacitor has reached a predetermined energy level.

The invention is a battery powered blasting machine characterized by a charging circuit that includes a battery powered blocking oscillator for charging a storage capacitor and a firing circuit that prevents the discharge of energy in the storage capacitor before it reaches a predetermined value by the inclusion of a circuit that generates trigger pulses, permitting the discharge of the capacitor, only when the capacitor has reached the predetermined energy level. The blasting machine may be designed to fire automatically upon the generation of trigger pulses or may be used in combination with a firing switch that is manually operated and an indicator that gives a visual or audible signal that trigger pulses have been generated.

In one embodiment of the invention, the blasting machine comprises: a capacitor; means for supplying electrical energy to the capacitor which includes: a battery; a transformer having a primary winding connected to the battery and a secondary winding; a diode and the capacitor connected together in series across the secondary winding to store energy generated by the current flowing through the primary winding; a solid state switch oscillator connected to the battery and the transformer to periodically interrupt current flow from the battery through said primary winding, the oscillator including: a first transistor having collector and emitter terminals in series with said primary winding, the first transistor having alternate conductive and nonconductive intervals to periodically interrupt the current flow from the primary winding; a first voltage divider network connected across the first transistor and the primary winding, the first voltage divider network including second diode means connected to the junction between the primary winding and the first transistor to direct current from the winding in a predetermined manner; and a second voltage divider network connected across the battery, the second voltage divider network including a second transistor having alternate conductive and nonconductive intervals to respectively control the conductive and nonconductive intervals of the first transistor whereby the flow of current from the battery to the primary winding is periodically interrupted causing current to flow in an oscillatory manner through the primary winding; means for producing a plurality of electrical pulses when the capacitor has reached a predetermined energy level; and switching means for receiving the pulses, the switching means operable to permit the discharge of the capacitor only during the presence of the pulses, whereby the capacitor cannot be discharged below the predetermined energy level.

Accordingly it is an object of this invention to combine a circuit in which a capacitor may be rapidly charged to a predetermined voltage level with a minimum of input power and a minimum average current flow in the supply circuit with a circuit which prevents the discharge of the capacitor below that predetermined voltage level.

It is also an object of this invention to prevent the application of the energy in a capacitor to blasting caps before a predetermined energy level is available in the capacitor and to charge that capacitor by a battery operated blocking oscillator circuit that is not subject to spurious oscillations.

Another object of the present invention is to provide novel means for maintaining the energy in a storage capacitor or the like with maximum efficiency.

It is another object of this invention to provide a novel method of triggering discharge of a storage capacitor in a blasting machine.

Still another object of this invention is to provide a safe and reliable blasting apparatus which does not discharge its energy until a capacitor therein has reached a predetermined energy level.

A still further object of this invention is to provide a novel electrical system for automatically firing electrically energized squibs and like firing units such as explosive bridge wire devices.

Another object of this invention is to provide a novel electrical system that prevents the manual firing of electrically energized squibs before sufficient energy is present in the blasting machine to detonate all the squibs attached to the blasting machine output.

A still further object is to provide a novel electrical system for firing an electrically energized squib and like firing units such as explosive bridge wire devices.

The above and other objects and features of this invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings and claims which form a part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a blasting machine that utilizes the principles of this invention.

FIG. 2 is a schematic diagram of a preferred embodiment of the circuitry for a blasting machine shown in FIG. 1.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, FIG. 1 illustrates a block diagram of a blasting machine which utilizes the principles of the invention. The basic portion of the system includes a power supply 1, an energy storage device 3, such as a capacitor for storing energy supplied by the power supply 1, a pulse generator 5 for generating pulses when the energy in the capacitor has reached a predetermined energy level, and a firing circuit 6 which permits the discharge of the energy in the energy storage device 3 through the load 8 which are the blasting caps or the like, when the trigger portion 7 of the firing circuit 6 receives pulses from the generator 5.

The power supply 1 may be either a.c. or d.c. and include the necessary electrical components for charging an energy storage device such as a capacitor.

The energy storage device 3 is preferably a capacitor. The voltage regulator 2 may be used in electrical circuit relationship with the energy storage device 3 to assure that the energy stored in the energy storage device 3 does not exceed a predetermined voltage level. The energy storage circuit may include a switch that, in the ON position permits the energy storage device 3 to store energy, and in the OFF position allows the energy storage device 3 to discharge so that no energy remains in the energy storage device 3 when the blasting machine is not in use. The charge and discharge switch 9 may be either a single switch or multiple switches and may also be part of the firing circuit 6.

A voltage indicator 4 may be used in combination with the pulse generator 5 to produce either visual or audible signals when the pulse generator 5 is generating pulses.

The firing circuit 6 includes a trigger 7 which allows the energy storage device 3 to discharge into the load 8. The trigger 7 may be a gaseous conductor of the three-electrode type wherein the trigger electrode upon receiving pulses from the pulse generator 5 allows the remaining two electrodes which are in series with the energy storage device 3 to conduct, thereby allowing the energy stored in the device 3 to discharge into the load 8. If it is desired that the blasting machine not be automatically triggered, a switch may be loacted in series with the pulse generator 5 so that when the voltage indicator 4 gives indication that pulses are present, manually operating the switch to close the contacts will cause the trigger to conduct and discharge the energy into the load.

FIG. 2 is a schematic diagram of a preferred embodiment of a blasting machine that utilizes a battery and an oscillator to charge the storage capacitor which will be discharged to fire a blasting cap or other explosive bridge wire device or the like. The dotted lines outlining portions of the circuitry indicate the power supply 1, the energy storage device 3, the voltage regulator circuit 2, the voltage indicator 4 associated with the pulse generator, the pulse generator circuit 5, and the firing circuit 6.

The power supply 1 in this embodiment includes a battery 140, a switch 9, a smoothing capacitor 130, and a transistorized oscillator circuit in combination with a step-up transformer 150, the output voltage of which is applied to the energy storage means 3. In operation, the power supply circuit 1 operates as follows:

A solid state switch oscillator is powered by a battery 140 or other direct current source. In one embodiment 12 1½volt batteries were used, which, because of the internal resistance thereof, provided a voltage between 10 to 12 volts. Connected across the battery 140 is a capacitor 130 which, when charged, provides additional current to the oscillator. A transformer 150 has its primary winding 101 connected into the oscillator circuit and its secondary winding 151 connected to a storage capacitor 153 through a diode 152 to store the energy generated by the oscillator. The windings 101 and 151 of transformer 150 are inductively coupled and wound and disposed in the manner indicated by the dots.

The solid state switch oscillator operates to intermittently interrupt current flow from the battery 140 through the primary winding 101 of the transformer 150 and includes a first switching transistor 103, a first voltage divider network (110, 111, 112, 113), a second voltage divider network (121, 122, 123), and first diode means (102, 104, 106) connected between the first voltage divider network and the primary winding 101 of the transformer 150 to direct the flow of current to and from the primary winding 101. The oscillator circuit shown is capable of producing oscillations in the range of 800 to 2,000 Hz.

The first voltage divider network includes a diode 110 and a plurality of resistors 111, 112 and 113 connected together in series across the primary winding 101 of the transformer and the first transistor 103.

The diode means that directs the current from the primary winding 101 includes a first diode 102 connected by its anode terminal to the junction between the primary winding 101 and the first transistor 103. To permit current to flow from the primary winding 101 when transistor 103 is "off", diodes 104 and 106 are connected in series with one anode terminal connected to the junction between the primary winding 101 and

the first transistor **103** and one cathode terminal connected to the junction between the second transistor **112** and the third transistor **113.**

The second voltage divider network includes a transistor **121,** a resistor **122,** and a resistor **123** connected togther in series across the battery **140.** The base of the first transistor **121** is connected, for biasing purposes, to the junction between the diode **110** and resistor **111** of the first voltage divider network. The base of the first transistor **103** is connected to the junction between resistors **122** and **123** to supply a current to the base of transistor **103** when the transistor **121** is in the conductive state.

The secondary winding **151** of the transformer **150** is connected to a diode **152** and a capacitor **153.** When the battery **140** is 10 to 12 volts, the maximum charge that can be obtained on capacitor **153** is about 7,000 to 8,000 volts. However, voltages of this magnitude are not generally required in battery powered explosive ignition systems, therefore, an additional circuit (not shown) may be added to limit the voltage across the capacitor **153.** The energy stored in the capacitor **153** is used for firing an explosive bridge wire device or the like.

In this embodiment, when a constant current source having an output voltage of about 10 volts is used in lieu of the battery **140** and the capacitor **153** is a 100 microfarad capacitor, the capacitor **153** can be charged to 200 joules within 10 seconds and to 400 joules within 20 seconds. Since batteries deteriorate with use, they are capable of achieving the initial charged energy previously stated, but tests reveal that when they are used to charge the capacitor **153** to 400 joules three times a day for 21 days, it would take a maximum of 71 seconds of charge time to obtain 400 joules of energy at the capacitor **153.** The minimum charge time at the end of this period to obtain 400 joules of energy at the capacitor **153** would be 49 seconds.

The energy storage means **3** includes a blocking diode **152** and a storage capacitor **153** in circuit relationship with the secondary winding **151** of the transformer **150.** The discharge resistor **154** allows the energy storage in capacitor **153** to be discharged when the switch **9** in the power supply **1** is in the OFF position.

The voltage regulator **2** which prevents the voltage on the capacitor **153** from exceeding a predetermined value includes a two-electrode spark gap **160,** a resistor **163,** a capacitor **165,** and a resistor **167.** The function of the regulator circuit is to drain excessive energy off the storage capacitor **153** to prevent the storage capacitor from exceeding a predetermined upper energy limit. The spark gap **160** is a normally nonconducting device that conducts when the voltage across the device has reached a predetermined voltage. In this instance, the breakdown voltage of the spark discharge device **160** is chosen to be the predetermined upper voltage limit desired across storage capacitor **153.** In operation, the voltage across the storage capacitor **153** appears across the spark gap **160.** As the storage capacitor **153** is charged, the voltage across the spark gap **160** increases until the breakdown voltage of the device is reached. The spark gap **160** then breaks down and conducts current to charge capacitor **165.** The current through the spark device **160** decreases as capacitor **165** becomes more fully charged. Eventually the current through the spark device **160** decreases to the point where it no longer will support an arc in the discharge device **160.** The arc extinguishes and spark gap **160** ceases conduction. The charge on the capacitor **165** is then discharged through resistor **167.** As capacitor **165** discharges, the voltage across the spark gap device **160** therefore increases, and if the voltage across the storage capacitor **153** is still greater than the breakdown voltage of the spark gap discharge device **160,** the discharge device **160** again conducts and the cycle is repeated again. If desired, a neon indicator light could be used in combination with this circuit to give an indication when the voltage regulator is operating. The suggested method with respect to a voltage indicating device would be to place a neon indicator light and resistor across capacitor **165** which is responsive to the charging and discharging of capacitor **165.**

The pulse generator circuit **5** includes a two-electrode spark discharge device **170,** resistor **171,** capacitor **177,** resistor **173,** and resistor **175.** The voltage indicator light **4,** such as a neon bulb, is in circuit relationship with resistor **173** and **175** and is responsive to the charging and discharging of capacitor **177.** In operation, the two-electrode spark discharge device **170** will remain in a nonconducting state as long as the voltage on the storage capacitor **153** is less than the breakdown voltage of the spark discharge device **170.** When the voltage on the storage capacitor **153** exceeds the breakdown voltage of the discharge device **170,** the device conducts allowing current to pass through resistor **171** to charge capacitor **177.** As the voltage on the capacitor **177** increases, the voltage across the spark device decreases until the spark device **170** returns to the original nonconducting state. At this time, capacitor **177** then discharges through resistors **173** and **175** which further applies a voltage to the neon light **4** which gives an indication that this circuit is in operation. When the voltage across the spark discharge device **170** again rises to the breakdown potential of this device, conduction begins again and the cycle repeats itself. Each time capacitor **177** is charged, voltage is applied to neon indicator light **4** through the resistor divider network **173, 175.** The neon indicator light **4** stays lit until the voltage across the light drops below the minimum sustaining voltage of the light **4.** By this means, each time capacitor **177** is charged, there is a visible light pulse to signal the operator that the minimum voltage has been reached and the blasting machine may be fired. With this circuit, when the minimum voltage across the capacitor **153** is reached and pulses are being generated by the pulse generator, pressing the firing switch **181** in the firing circuit **6** will cause the pulses to be transmitted to the firing circuit.

The firing circuit **6** includes a three-electrode spark gap discharge device, a step-up transformer for raising the voltage of the pulses received from the pulse generator **5** and applying them to the trigger electrode of the spark discharge device **180,** and a firing switch **181** which permits the trigger pulses from the pulse generator **5** to be transmitted to the primary winding **185** of the step-up transformer. For further details concerning the particular type of three-electrode spark gap discharge device required for this circuit see U.S. Pat. Nos. 3,187,215 entitled "Spark Gap Device" to I. E. Linkroum issued June 1, 1965, and 3,229,146 entitled "Spark Gap Device with a Control Electrode Intermediate the Main Electrodes" to I. E. Linkroum issued

Jan. 11, 1966. In operation, when the firing switch **181** is in the OFF position, no pulses are being supplied to the spark discharge gap **180** thereby preventing the firing of any blasting caps attached to the output terminals **190.** Further, the firing switch **181** in the OFF position is yet in combination with the power switch **9** in the OFF position to place the discharge resistor **154** across the storage capacitor **153** to drain any charge thereon. When the firing switch **181** is placed in the ON position, the storage capacitor **153** will discharge if trigger pulses are present. Therefore, to discharge the energy in capacitor **153** to blasting caps attached to the output terminals **190,** it is necessary that the pulse generator **5** is generating pulses and that the firing switch **181** is in the ON position. When these two conditions are met, the output pulses of the pulse generator **5** are transmitted to the primary winding **185** of the step-up transformer where the pulses are stepped up to a higher voltage and applied to the trigger electrode of the spark gap discharge device through resistor **183** thereby causing ionization within the spark gap discharge device and permitting current to flow through the two main electrodes which allows the energy storage capacitor **153** to discharge through the blasting caps connected to the output terminals **190.** If it is desired to eliminate manual firing of the blasting caps and to have the blasting machine discharge the energy in the capacitor **153** automatically when it has reached a predetermined energy level, the firing switch **181** may be eliminated completely. In this instance, as soon as voltage pulses are available from the pulse generator **5,** the three-electrode spark discharge device **180** would be triggered to discharge the energy in the capacitor **153** through the blasting caps (not shown) connected to the terminals **190.**

OPERATION

Referring now to FIG. **2,** the circuit operates as follows: When switch **9** is in the OFF position, resistor **154** removes the energy stored in capacitor **153.** When switch **9** is closed, resistor **154** is removed from the circuit and current flows from the battery **140** through capacitor **130** and through transistor **121,** resistor **122** and resistor **123.** Accordingly, a voltage is applied across the voltage divider network containing transistor **121** and the voltage dividing network containing diode **110.** Since there is a positive voltage applied across the emitter base circuit of the transistor **121,** the transistor **121** conducts permitting a current to flow through resistors **122** and **123** and through lead **124** to the base of transistor **103** which is in the nonconducting state. When the current to the base of transistor **103** is sufficient, transistor **103** conducts (ON). When the transistor **103** conducts, current flows through the transformer primary winding **101** and transistor **103.** With current flowing to ground through the primary winding **101,** transistor **121** begins to return to the nonconductive (OFF) state as the base to emitter current of that transistor begins to decrease. Eventually transistor **121** becomes nonconductive, removing the necessary base current to transistor **103** which also becomes nonconductive (OFF). Once the transistor **131** turns OFF, the electrical energy stored in the primary winding **101** during the ON or conduction period of transistor **131** is removed as current leaves the primary winding **131** and flows through diodes **104, 106, 110** and resistors **111** and **112.** This action also operates to back bias transistor **121** so that it remains in the nonconductive state. Further, since during this time the rate of change of current with respect to time (*di/dt*) becomes sharply negative the voltage induced across the secondary winding **151** for this period also reverses and the secondary winding **151** becomes a current source. Therefore, during the time *di/dt* is negative, most of the energy stored in the primary winding of the transformer is transferred to the secondary winding **151** in a manner that allows the diode **152** to conduct and to supply energy to the capacitor **153** and to supply energy to the capacitor **153** and to a load (not shown). Thus, electrical energy which is fed to the primary winding during the conducting period of transistor **103** is transferred to the capacitor **153** during the nonconducting period of transistor **103.** The entire action is cyclic for as the energy is removed from the transformer **150** the reverse bias on transistor **121** is removed allowing transistors **121** and **103** to turn ON and repeat the entire operation again. (About 800 to 2,000 Hz.)

As the energy stored in the capacitor reaches a predetermined level, the pulse generating circuit **5** begins generating trigger pulses. This occurs when the spark gap discharge device **170** reaches its breakdown potential. To assure that the energy stored in the capacitor is above the predetermined energy level but not in excess of a second and higher energy level, a voltage regulator circuit **2** is utilized. This eliminates excessive energy levels that cause adverse operation of the blasting machine.

Once the trigger pulses are present and the energy stored in the capacitor is within a preferred range depressing the firing switch **181** applies trigger pulses to transormers **182** which causes spark gap device **180** to conduct, thereby allowing the energy in capacitor **153** to discharge into the blasting caps (not shown) attached to the outputs **190** and detonate explosives.

In one satisfactorily operable system, the blasting machine described in FIG. **2** was powered by six 1½ volt D size batteries or one 12-volt Energizer battery No. S-121 and the circuit elements add the values or were of the types indicated below:

Capacitor **130**—3,300 microfarad, 30 Volts d.c.
Capacitor **165**—0.45 to 0.61 microfarad 3KV
Capacitor **177**—0.008 to 0.012 microfarad, 3.5KV
Capacitor **153**—400 microfarad 2.5KV
Capacitor **187**—0.025 to 0.03 microfarad 3KV
Resistor **122**—6.2 ohms, 11W
Resistor **123**—33 ohms ½W
Resistor **111**—100 ohms 2W
Resistor **112**—1,000 ohms, ½W
Resistor **113**—10K ohms ½W
Resistor **154**—3K ohms 10W
Resistor **167**—20K ohms 20W (two in series)
Resistor **163**—2 ohms 20W (two in parallel)
Resistor **175**—0.33 megohms 2W
Resistor **173**—1.36 megohms 4W (two in series)
Resistor **171**—500 ohms 10W
Resistor **186**—20 megohms 1W
Resistor **183**—1K ohms 5W
Resistor **189**—10K ohms 10W
Transistor **121**—Type MJE 341
Transistor **103**—Type 2N3055 Beta 20–35
Diodes **110,102,104,106**—GE A14F
Diode **152**—Motorola MR 995A

Discharge Device **160**—2,200 volts d.c. (breakdown)-Bendix Corp. Sidney, N.Y. Part No. 10-374105-21

Discharge Device **170**—2,000 volts d.c. (breakdown)-Bendix Corp. Sidney, N.Y. Part No. 10-374121-14

Three-electrode spark discharge device—3,750 volts d.c. (breakdown)-Bendix Corp. Sidney, N.Y. Part No. 1-28615-39

Transformer **150**—Core H177; 0.010 air gap in each leg primary 42T No. 15 120 volts; secondary 1500 T No. 29 8,000 volts

Transformer **182**—Ferramic Core ⅜ inch diameter primary 4T No. 20 secondary 32T No. 20

Switch **9** and **181**—4 Contact-Bendix Corp. Sidney, N.Y. Part No. 10-348773-1

While a preferred embodiment of the invention has been disclosed, it will be apparent to those skilled in the art that changes may be made to the invention as set forth in the appended claims, and in some cases, certain features of the invention may be used to advantage without corresponding use of other features. For example, different types of semi-conductors, or solid state control devices may be substituted for the types illustrated. Accordingly, it is intended that the illustrative and descriptive materials herein be used to illustrate the principles of the invention and not to limit the scope thereof.

Having described the invention, what is claimed is:

1. A blasting machine comprising in combination, an oscillator of the character comprising:

means for storing electrical energy;

means for supplying electrical energy to said energy storage means, said means for supplying electrical energy comprising:

a source of electrical energy;

a transformer having a primary winding connected to said source and a secondary winding;

a first diode means and said electrical energy storage means connected together in series across said secondary winding to store energy generated by the current flowing through said primary winding;

a solid state switch oscillator connected to said source and said transformer to periodically interrupt current flow from said source through said primary winding, said oscillator including:

a first transistor having collector and emitter terminals in series with said primary winding, said transistor having alternate conductive and nonconductive intervals to periodically interrupt the current flow from said primary winding;

a first voltage divider network connected across said first transistor and said primary winding, said first voltage divider network including second diode means connected to the junction between said primary winding and said first transistor to direct current from said winding in a predetermined manner; and

a secondary voltage divider network connected across said source of electrical energy, said second voltage divider network including a second transistor having alternate conductive and nonconductive intervals to respectively control the conductive and nonconductive intervals of said first transistor whereby the flow of current from said source to said primary winding is periodically interrupted causing current to flow in an oscillatory manner through said primary winding;

means for producing a plurality of electrical pulses when said energy storage means has reached a predetermined energy level; and

switching means being for receiving said pulses, said switching means operable to permit the discharge of said energy storage means only during the presence of said pulses, whereby said energy storage means cannot be discharged below said predetermined energy level.

2. A blasting machine as recited in claim **1** wherein said first voltage divider network comprises:

a diode having a first terminal connected to the junction between said primary winding and said source of electrical energy and a second terminal connected to the base of said second transistor;

a first resistor in series with the second terminal of said diode;

a second resistor in series with said first resistor; and a third resistor in series with said second resistor and having one terminal connected to the junction between said first transistor and said source of electrical energy.

3. A blasting machine as recited in claim **1** wherein the means for producing electrical pulses comprises:

a first normally nonconductive gaseous conductor which is rendered conductive when a predetermined voltage is applied thereto and a resistor-capacitor circuit in series with said first gaseous conductor so that when said first gaseous conductor is rendered conductive said capacitor lowers the voltage applied to said first gaseous conductor below said predetermined value and said second gaseous conductor is rendered nonconductive.

4. A blasting machine as recited in claim **2** wherein the means for producing electrical pulses comprises:

a first normally nonconductive gaseous conductor which is rendered conductive when a predetermined voltage is applied thereto and a resistor-capacitor circuit in series with said first gaseous conductor so that when said first gaseous conductor is rendered conductive said capacitor lowers the voltage applied to said first gaseous conductor below said predetermined value and said second gaseous conductor is rendered nonconductive.

5. The combination as recited in claim **3** wherein said switching means includes a second normally nonconductive gaseous conductor in circuit relationship with said pulse means, said second gaseous conductor being rendered conductive upon receiving said pulses whereby when pulses from said pulse means are transmitted to said second gaseous conductor, said second gaseous conductor is rendered conductive to permit said storage means to discharge.

6. The combination as recited in claim **4** wherein said switching means includes a second normally nonconductive gaseous conductor in circuit relationship with said pulse means, said second gaseous conductor being rendered conductive upon receiving said pulses whereby when pulses from said pulse means are transmitted to said second gaseous conductor, said second gaseous conductor is rendered conductive to permit said storage means to discharge.

7. A blasting machine comprising:

means for storing electrical energy;

a low voltage to high voltage dc converter means for supplying electrical energy to said storage means, said means for supplying electrical energy comprising:

a source of electrical energy;

a transformer having a primary winding connected to said source and a secondary winding;

a first diode means and said electrical energy storage means connected together in series across said secondary winding to store energy generated by the current flowing through said primary winding;

a solid state switch oscillator connected to said source and said transformer to periodically interrupt current flow from said source through said primary winding, said oscillator including:

a first transistor having collector and emitter terminals in series with said primary winding, said transistor having alternate conductive and nonconductive intervals to periodically interrupt the current flow from said primary winding;

a first voltage divider network connected across said first transistor and said primary winding, said first voltage divider network including second diode means connected to the junction between said primary winding and said first transistor to direct current from said winding in a predetermined manner; and

a second voltage divider network connected across said source of electrical energy, said second voltage divider network including a second transistor having alternate conductive and nonconductive intervals to respectively control the conductive and nonconductive intervals of said first transistor whereby the flow of current from said source to said primary winding is periodically interrupted causing current to flow in an oscillatory manner through said primary winding; in combination with:

means for producing at least one electrical pulse when said energy storage means has reached a predetermined energy level; and

means for discharging said energy storage means when said storage means has reached said predetermined energy level, said discharge means including a normally nonconductive circuit for receiving said electrical pulse from said pulse means, said circuit being rendered conductive by the occurrence of said pulse whereby said energy storage means discharges at said predetermined energy level.

8. A blasting machine as described in claim **7** wherein said first voltage divider network of said means for supplying electrical energy to said storage means comprises:

a diode having a first terminal connected to the junction between said primary winding and said source of electrical energy and a second terminal connected to the base of said second transistor;

a first resistor in series with the second terminal of said diode; a second resistor in series with said first resistor; and a third resistor in series with said second resistor and having one terminal connected to the junction between said first transistor and said source of electrical energy.

9. A blasting machine as recited in claim **7** wherein the normally nonconductive circuit of said discharge means including a first normally nonconductive gaseous conductor connected in circuit relationship with said pulse means, said first gaseous conductor operative to be conductive upon receiving said electrical pulse from said pulse means.

10. A blasting machine as recited in claim **8** wherein the normally nonconductive circuit of said discharge means including a first normally nonconductive gaseous conductor connected in circuit relationship with said pulse means, said first gaseous conductor operative to be conductive upon receiving said electrical pulse from said pulse means.

11. A blasting machine as recited in claim **7** wherein said pulse means includes a second normally nonconductive gaseous conductor that is rendered conductive when said storage means reaches said predetermined energy level.

12. A blasting machine as recited in claim **8** wherein said pulse means includes a second normally nonconductive gaseous conductor that is rendered conductive when said storage means reaches said predetermined energy level.

13. A blasting machine as recited in claim **9** wherein said pulse means includes a second normally nonconductive gaseous conductor that is rendered conductive when said storage means reaches said predetermined energy level.

14. A blasting machine as recited in claim **10** wherein said pulse means includes a second normally nonconductive gaseous conductor that is rendered conductive when said storage means reaches said predetermined energy level.

* * * * *