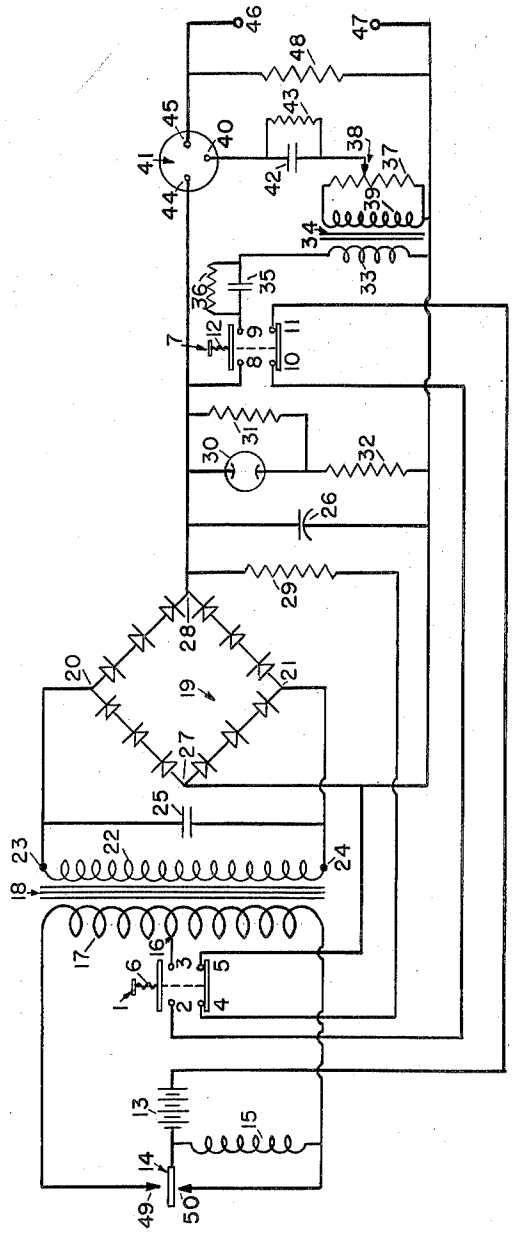
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BLASTING MACHINE

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BLASTING MACHINE

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This invention relates to a blasting machine and more particularly to a condenser type multiple shot machine whereby the ignition assemblies of large numbers of initiators may be simultaneously ignited.

In recent years there has been a trend toward firing increasing numbers of electric blasting initiators in a single shot. For a long time the standard blasting machine in the art has been the push-down or rack-bar, manually operated device which is limited to about 120 caps in a single shot. Where it became desirable to employ larger numbers of initiators in a single shot, it generally has been the practice to employ an engine driven generator or a service power line for the firing potential. Both of these techniques are inordinately complicated by the limited portability of the necessary equipment which, moreover, is simply not available in many cases.

More recently battery-operated condenser type machines have been developed which are capable of firing large numbers of caps. In these machines a charge is built up on a storage condenser which is manually or automatically released to the firing line. These machines have constituted a significant step forward in the art but still leave much to be desired from the standpoint of reliability, safety, and economy. Some of these machines have still lacked sufficient power to fire several hundred initiators. Others having sufficient power output have required such large and heavy batteries or hand generators for a power source that necessary portability has been sacrificed. Moreover, in all the prior condenser types there has been the possibility and danger of a condenser discharge to the firing circuit of a charge incapable of firing all the initiators. Such performance results in highly dangerous missed holes.

It is an object of the present invention therefore to provide an improved battery-operated condenser type machine which is capable of detonating simultaneously large numbers of electrical blasting caps whether connected in series, in parallel, or in series-in-parallel. It is a further object of the invention to provide such a blasting machine which is portable, durable, relatively inexpensive, and simple to operate. It is an additional object of the invention to provide a blasting machine which is safe to operate from the standpoint of the blasting engineer and is eminently reliable in that partial shots due to discharge of insufficient firing potential from the condenser are completely eliminated.

Generally described, the present invention is a blasting machine having in combination an input consisting of a source of low voltage D. C.; means associated with the input to interrupt the D. C. which comprises a reed vibrator, a charging switch connecting input and vibrator to the primary of a step-up transformer; a rectifier connected to the secondary of the transformer; a condenser connected to the output of the rectifier; a firing switch which in its operating position connects the condenser to an output through a triggering circuit and disconnects the D. C. source from the step-up transformer, said triggering

circuit comprising an interstage step-up transformer and a breakdown tube, said breakdown tube having a breakdown voltage higher than the maximum voltage to which the condenser can be charged.

In preferred embodiments of the blasting machine of the invention, a gas-filled glow tube is connected across the condenser to indicate the charge stored up therein. The rectifier may be a single rectifier tube or a plurality of such tubes arranged, for example, to form a bridge. High vacuum rectifier tubes or cold cathode tubes may be employed. Selenium rectifiers may also be employed and preferably the rectifier will be a bridge type selenium rectifier.

The presence of the triggering circuit is a special feature of the blasting machine in accordance with this invention which completely prevents discharging of the condenser through the firing circuit until adequate potential has been developed on the condenser to fire all of the initiators in the circuit. Thus, if a glow tube is connected across the condenser but functions improperly, a premature closing of the firing switch will not cause discharge of the condenser into the firing circuit. In like manner, the condenser will not discharge prematurely if the firing switch is accidentally depressed prior to the build-up of the desired charge. As set forth above, the breakdown tube employed in the triggering circuit always will have a breakdown voltage higher than the maximum voltage to which the condenser can possibly be charged, thus making it essential that a portion of the condenser charge be routed through the step-up transformer to generate a pulse high enough in potential to cause breakdown of the tube, thus allowing the condenser to discharge directly to the firing line. In order to conserve the firing potential built up on the condenser, it is preferred that a coupling condenser and resistor be disposed between the firing switch and the primary of the interstage step-up transformer, thus limiting the amount of the charge drained off from the condenser into the triggering circuit. It is also preferred that a resistor be connected across the secondary of the interstage step-up transformer and that this resistor be provided with an adjustable tap, thus permitting calibration of the triggering circuit to meet the demands of a particular breakdown tube.

Having generally described the invention, a preferred embodiment of a blasting machine in accordance therewith will be specifically illustrated in conjunction with the circuit diagram of the single figure shown in the drawing.

In the figure, a charging switch 1 is provided which has two sets of contacts 2 and 3 and 4 and 5, respectively. The switch is maintained in its normal or open position by spring 6 and in this open position connects contacts 4 and 5. In the closed or operated position the switch 1 connects contacts 2 and 3. A firing switch 7 is likewise provided with two sets of contacts 8 and 9 and 10 and 11, respectively. The switch 7 is maintained in the normal or open position by means of spring 12 and in this position connects contacts 10 and 11. In the operated or closed position the switch 7 connects contacts 8 and 9. A 6-volt dry-cell battery 13 is connected to vibrating reed 14 and magnetic coil 15 and to contact 2 of the charging switch 1 through contacts 10 and 11 and switch 7 when the firing switch 7 is in the open position as shown. Contact 3 of charging switch 1 is connected to the center tap 16 of the primary coil 17 of a step-up transformer 18. The vibrating reed 14 is positioned in a gap between contacts 49 and 50 which are connected across the primary 17 of the transformer 18. A bridge type selenium rectifier 19 is connected by means of terminals 20 and 21 across secondary 22 at terminals 23 and 24. A buffer condenser 25 is also connected across the secondary 22. The main storage con-

denser 26 is connected across the output of the rectifier 19 through output terminals 27 and 28. Terminal 28 of the rectifier 19 is connected with contact 4 of the charging switch 1 through resistor 29, while contact 5 of the charging switch 1 is connected to terminal 27 of rectifier 19 to discharge the condenser 26 when the charging switch 1 is in the open position as shown. A neon glow lamp 30 is connected across condenser 26 to indicate the charge on the condenser. Resistors 31 and 32 are provided to form a voltage dividing network which determines the potential at which the neon glow lamp 30 will glow. The primary 33 of an interstage step-up transformer 34 is connected to contact 9 of the firing switch 7 through coupling condenser 35. A resistor 36 is connected across the condenser 35 to discharge condenser 35 after switch 7 has been opened. A resistor 37 with an adjustable tap 38 is connected across the secondary 39 of the interstage step-up transformer 34. The adjustable tap 38 of the resistor 37 is connected to electrode 40 of breakdown tube 41 through a condenser 42. Resistor 43 is connected across the condenser 42 to maintain electrode 40 at the neutral potential except when the tube is being triggered. Terminal 44 of breakdown tube 41 is connected directly to positive plate of condenser 26 while electrode 45 of the breakdown tube 41 is connected to output terminal 46. Output terminal 47 is connected directly to the negative plate of the condenser 26. A resistor 48 is connected across output terminals 46 and 47 to provide a discharge path for condenser 26 in the event the machine is fired wihout an initiator circuit connecting terminals 46 and 47.

The blasting machine shown in Fig. 1 operates as follows: The switch 1 being in its normal open position leaves contacts 2 and 3 open, thus isolating the battery 13 from the principal blasting machine circuit. With switch 1 in the open position, contacts 4 and 5 are closed, thus placing resistor 29 in parallel with the condenser 26. This removes any residual charge which may be on the condenser as a result of previous use.

By closing the switch 1, contacts 2 and 3 are brought into conductive relationship and the low potential of the battery 13 is applied on part of the primary 17 of the transformer 18 and across the magnetic coil 15 of the reed vibrator. The reed 14 is magnetically attracted toward coil 15 and is drawn into engagement with contact 50. This engagement shorts out the coil 15 and removes the attraction allowing the reed 14 to swing back past its mid position to engage the contact 49. However, as soon as engagement between contact 50 and reed 14 is broken, attraction is again built up causing the reed 14 to swing back and again engage contact 50. As long as the switch 1 is closed, this cycle is repeated continuously. The frequency of vibration may be controlled by the design of the natural period of the reed 14. Thus, as the reed 14 engages first the contact 50 and then the contact 49 an alternating flux is set up in the primary winding 17 of the transformer 18 and an alternating voltage is induced across the terminals 23 and 24 of the secondary winding 22 of the transformer 18. The buffer condenser 25 which is connected across terminals 23 and 24 produces optimum wave form and increases the life of the vibrator.

The alternating voltage produced across the secondary terminals 23 and 24 of the transformer 18 is applied to terminals 20 and 21 of the selenium bridge rectifier 19. When terminal 24 of the transformer 18 is of negative polarity, with respect to the terminal 23 of the transformer, electrons will flow from terminal 24 to input terminal 21 of bridge rectifier 19, to output terminal 27 of the rectifier, to storage condenser 26, to output terminal 28 of the rectifier, to input terminal 20 of the rectifier, to terminal 23 of the transformer 18, and through the secondary winding of the transformer 18 to the terminal 24. By the nature of the rectifier electrons can flow through it in only one direction. Therefore, for the other half of the alternating voltage cycle terminal 24 of the transformer 18 becomes positive with respect to the terminal 23 and electrons then flow from the terminal 23 to input terminal 20 of the rectifier to output terminal 27 of the rectifier, to storage condenser 26, to output terminal 28 of the rectifier, to input terminal 21 of the rectifier, to terminal 24 of the transformer and through the secondary winding to terminal 23.

It will be seen that for both halves of the alternating voltage cycle the current flow with respect to the condenser 26 is toward the negative plate and away from the positive plate of the condenser. Thus, electrons are flowing away from the positive plate of condenser 26 causing a deficiency of electrons at the positive plate. At the same time, electrons are moving on to the negative plate of the condenser 26 causing a surplus of electrons at the negative plate. This process continues until the potential difference between the positive and negative plates of the condenser 26 is equal to that across terminals 27 and 28 of the rectifier 19. When condenser 26 is charged, neon lamp 30 will glow. The exact potential at which lamp 30 lights depends on the values of the resistors 31 and 32 which form a voltage dividing network. The tube 30 will give a visual indication that the potential on condenser 26 has reached the desired and predetermined value.

In order to release current to blasting initiators disposed between output terminals 46 and 47, the firing switch 7 is closed. The operation of the switch 7 opens contacts 10 and 11 and opens the line from the battery 13 to the center tap 16 of the primary winding 17 of the transformer 18. Contacts 8 and 9 are closed to connect the condenser 26 to condenser 35 and resistor 36. Condenser 35 acts as a coupling condenser between the condenser 26 and the primary 33 of the interstage transformer 34 and allows only an alternating voltage to pass. Resistor 36 acts as a bleeder for condenser 35 and is of sufficiently high value to allow only very limited direct current to flow therethrough. At the instant the firing switch 7 is closed, the potential on condenser 35 rises sharply from zero to the potential on the condenser 26. This rise in potential is a changing voltage and is readily passed by condenser 35 on to the primary 33 of the interstage step-up transformer 34. This voltage rise or pulse produces a rising flux in the primary 33 of the transformer 34, which flux induces a pulse in secondary winding 39 of the transformer 34. The resistor 37 which has an adjustable tap 38 allows a pulse similar in shape but greater in amplitude than that applied to the primary winding 33 to pass by condenser 42 to electrode 40 of breakdown tube 41. The secondary winding of transformer 34 is so connected that the triggering pulse on electrode 40 is of positive polarity. The presence of this pulse on the electrode 40 of the breakdown tube 41 places the electrode 40 at a higher potential than the electrode 45 and by the nature of the breakdown tube, the gaseous medium surrounding the electrodes 40, 44 and 45 becomes ionized. Once ionization occurs, a conductive path is formed between electrodes 44 and 45 of the breakdown tube 41 and condenser 26 discharges through the breakdown tube 41 to output terminal 46 and the detonators disposed between the terminals 46 and 47. The resistance of resistor 48 is sufficiently great that a negligible amount of the current flows through it.

By varying the position of the adjustable tap 38 of the resistor 37 the voltage of the pulse applied to electrode 40 of the breakdown tube 41 upon closing of the firing switch 7 can be varied. The voltage of the pulse at electrode 40 is also dependent on the voltage on condenser 26 at the instant switch 7 is closed. In practice, tap 38 will preferably be adjusted so that when condenser 26 is fully charged the voltage of the pulse on electrode 40 is just sufficient to cause ionization of the gas in the breakdown tube. When the condenser 26 is

less than fully charged, a breakdown of tube **41** will not occur even though the firing switch **7** is closed and the blasting machine will fail to function. It will be seen therefore that the blasting machine of the invention cannot be operated until the condenser **26** is fully charged to the firing potential predetermined as necessary to fire all of the initiators in the firing circuit. Thus, misfires due to insufficient firing voltage cannot occur unless the capacity of the machine is purposely exceeded.

In order to illustrate the performance of the blasting machine of the invention, the following examples are presented.

Example 1

Two thousand delay electric blasting caps were arranged in series-in-parallel. The caps were disposed in 50 series of 40 caps each with a 100-ohm resistor added to each series. A blasting machine similar to that of the drawing and powered by a 6-volt dry battery was employed as a power source. All caps shot.

Example 2

Two thousand caps were arranged in series-in-parallel as in Example 1, except that instantaneous caps were mixed throughout the circuit. The 50 series were divided into 5 groups of 10 series each. The first 10 series contained 40 delays each; the second 10 series contained 39 delays and one instantaneous cap; the third 38 delays and 2 instantaneous; the fourth 37 delays and 3 instantaneous; and the fifth 36 delays and 4 instantaneous. The same blasting machine was used as in Example 1. All caps shot.

Example 3

Although shooters are advised not to make unbalanced shots in the field, a badly unbalanced shot was made to test the capacity of the machine of the invention. Twenty-four series totaling 617 caps were arranged in parallel. The first series was a single delay cap while the second series was a single instantaneous cap. The remaining series were divided into 4 groups of 6 series each containing 10, 20, 35, and 40 delay caps, respectively, with each series also containing from 0–5 instantaneous caps in addition to the delays. The delay caps varied in delay period from 0.8 to 3.7 sec. A total of 617 caps were employed. The blasting machine of the previous examples was used. All caps shot.

As previously indicated, any desired battery of either the dry cell or storage type may be employed as the D. C. power source. The battery may be a single cell or may be composed of the requisite number of individual cells to produce the desired voltage. As the voltage is changed, of course, the characteristics of the vibrator and transformer will also be changed. As has been indicated, equivalent rectifying means may be substituted for the bridge rectifier illustrated in Fig. 1 which is made up of a number of low voltage selenium rectifiers connected in series. For example, high voltage selenium rectifiers may be connected in a bridge circuit or any commercially available rectifier may be substituted. Other types of semi-conductive rectifiers such as copper oxide, germanium, and silicon may also be employed as long as the components are made large enough to accommodate the voltage and current developed either by constructing a large unit or by wiring a number of small units together. Other rectifiers such as high vacuum rectifiers, mercury rectifiers, or cold cathode rectifiers may be used. The cold cathode type generally will not charge the condenser to as high a voltage as the selenium type due to the fact that cold cathode rectifiers cease to function at the low currents, which occur when the condensers approach full charge. Both the mercury and high vacuum type rectifiers generally require additional power from the battery to heat their cathodes. Therefore, from the standpoint of efficiency, economy, and performance the selenium type rectifier is preferred.

The number and capacitance of the main storage condenser **26** may be changed without altering the mode of operation of the blasting machine of the invention. Such condensers may be connected in parallel, in series, in series-in-parallel, or in parallel-in-series. Electrolytic condensers are preferred since they combine high capacitance with low weight and small physical size. Other types of condensers such as paper, oil, mica, or ceramic types may be substituted.

The breakdown tube employed in accordance with the invention will have at least three electrodes surrounded by an ionizable gas. The potential at which a particular tube will break down is determined largely by the distance separating the electrodes and the nature and pressure of the gas. Tubes containing more than three electrodes may be employed, but the extra electrodes do not enter into the operation of the machine.

The firing switch could be connected in ways other than that shown in Fig. 1 without changing the overall mode of operation of the blasting machine disclosed. However, the connection employed in the drawing is preferred since it avoids the passing of large firing currents through the switch itself.

Blasting machines built in accordance with the invention are safer to operate and more reliable in performance than any other condenser type, battery operated units available. If a 6-volt battery is employed as an input, the maximum voltage present in the unit when not in operation is 6 volts. Due to the presence of the triggering circuit and breakdown tube, it is impossible to discharge the condensers into the firing line accidentally or prior to their becoming fully charged. Machines in accordance with this invention are light in weight and readily portable. With a 6-volt battery as an input, firing voltages of 500 volts are readily obtainable. Such voltages have made it possible for machines in accordance with this invention to fire more than 2000 initiators in a single shot.

Since various modifications of the machine disclosed will occur to those skilled in the particular art without departing from the scope of the invention as disclosed, it is intended that the invention shall be limited only by the scope of the appended claims.

What we claim and desire to protect by Letters Patent is:

1. A blasting machine having in combination an input consisting of a source of low voltage D. C., means associated with the input to interrupt the D. C. comprising a reed vibrator, a charging switch connecting input and vibrator to the primary of a step-up transformer, a rectifier connected to the secondary of the transformer, a condenser connected across the output terminals of the rectifier, a firing switch in its operated position connecting the condenser to an output through a triggering circuit and-disconnecting the D. C. source from the step-up transformer, said triggering circuit comprising an interstage step-up transformer having an adjustable resistance connected across its secondary and a breakdown tube, said breakdown tube having a breakdown voltage higher than the maximum voltage to which the condenser can be charged.

2. A blasting machine in accordance with claim 1 in which a gas-filled glow tube is connected across the condenser.

3. A blasting machine in accordance with claim 1 in which the rectifier consists of at least one rectifier tube.

4. A blasting machine in acocrdance with claim 1 in which the rectifier is a selenium bridge rectifier connected across the secondary of the transformer.

5. A blasting machine having in combination a D. C. input, a reed vibrator connected to the D. C. input, a voltage multiplying means connected to the vibrator, a charging switch and a firing switch, said input and vibrator being connected to the voltage multiplying means

when the charging switch is closed and the firing switch is open, a rectifier connected to the secondary coil of the voltage multiplying means, at least one condenser connected in parallel with the output of the rectifier, a step-up transformer connected to the condenser when the firing switch is in closed position and a triode breakdown tube having a breakdown voltage higher than the maximum voltage to which the condenser can be charged, one electrode of which is connected to the firing switch, a second electrode of which is connected ot the output of the step-up transformer having an adjustable resistance connected across its secondary, and a third electrode of which is connected to the output of the machine, the output of the step-up transformer causing breakdown of the breakdown tube and permitting direct discharge of the condenser through the breakdown tube to the output of the machine.

6. A blasting machine having in combination an input consisting of a source of low voltage D. C., means associated with the input to interrupt the D. C. comprising a reed vibrator, a charging switch connecting input and vibrator to the primary of a step-up transformer, a selenium bridge rectifier connected to the secondary of the transformer, a condenser connected across the output terminals of the rectifier, a gas-filled glow tube connected across the condenser to indicate the charge thereof, a firing switch in its operating position connecting the condenser to an output through a triggering circuit and disconnecting the D. C. source from the step-up transformer having an adjustable resistance connected across its secondary, said triggering circuit comprising an interstage step-up transformer and a breakdown tube, said breakdown tube having a breakdown voltage higher than the maximum voltage to which the condenser can be charged.

7. A blasting machine in accordance with claim 5 in which a coupling condenser and a resistor are connected between the condenser and the interstage transformer, said resistor allowing only limited D. C. flow therethrough.

8. A blasting machine in accordance with claim 5 in which a resistor equipped with an adjustable tap is connected across the output of the interstage transformer and a condenser is connected between said resistor and the breakdown tube.

9. In a condenser type blasting machine a triggering circuit connected between the storage condenser and output which comprises an interstage step-up transformer having an adjustable resistance connected across its secondary and a breakdown tube, said breakdown tube having a breakdown voltage higher than the maximum voltage to which the storage condenser can be charged.

10. In a condenser type blasting machine, a triggering circuit connected between the storage condenser and output which comprises an interstage step-up transformer, a coupling condenser and resistor connected between the storage condenser and step-up transformer, a breakdown tube, and a resistor and a condenser connected between the step-up transformer and the breakdown tube, said breakdown tube having a breakdown voltage higher than the maximum voltage to which the storage condenser can be charged.

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