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MULTIPLE IGNITOR CAPACITOR IGNITION SYSTEM

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This invention relates to electric spark ignition apparatus, more specifically to ignition systems of capacitor discharge type, and has as its principal object the provision of capacitor discharge ignition apparatus capable of firing a plurality of ignitor plugs simultaneously and with substantially equal distribution of spark energy between all the ignitor plugs.

Multiple plug capacitor discharge type ignition systems have heretofore been proposed incorporating either a separate power supply and energy storage capacitor for each ignitor plug or a single energy storage capacitor discharging through all the ignitor plugs in parallel. Both these systems include means for electrically linking together the discharge circuits of the ignitor plugs to promote simultaneous firing thereof.

Those of the prior systems which include separate power supply and energy storage capacitor circuits for each ignitor plug are necessarily relatively complex, costly and inefficient in operation, and present serious insulation problems by reason of high potential differences existing between the several circuits. In systems wherein only a single capacitor is used, inequalities in distribution of spark energy at the plugs may occur because only for the ideal condition of electrically identical ignitor plugs is the energy of the storage capacitor divided equally between the plugs. With different environmental conditions and different degrees of erosion or unbalance of electrical characteristics of the ignitors, sometimes only one ignitor will ionize and discharge all of the stored energy, the other not firing at all. Thus the desired degree of certainty that all the ignitors always will fire, and that they will divide the stored energy equally between them, is difficult if not impossible to achieve in prior multiple plug systems.

Accordingly, the present invention has as another of its objects the provision of multiple plug capacitor discharge ignition apparatus wherein two or more energy storage capacitors are connected to fire a like number of ignitor elements simultaneously, in a manner to positively preclude all the stored energy being discharged through any one or less than all of the ignitor plugs. A further object of the invention is the provision of such systems wherein the energy storage capacitors all are charged through a common charging circuit affording maximum simplicity yet assuring equal distribution of stored energy in the several capacitors.

It is also an object of the invention to provide multiple plug capacitor discharge ignition systems characterized by minimum size and weight, good reliability of operation and economy of manufacture.

In carrying out the invention in one form, there is provided a plurality of ignitor plugs each connected in series circuit relation with one of a like plurality of main energy storage capacitors, one of a like plurality of control gaps, and one secondary winding of a pulse transformer having a plurality of secondary windings and a single primary winding. The primary winding is connected through triggering means to a small trigger capaci-

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tor charge simultaneously with the main energy storage capacitors. When this trigger capacitor reaches a predetermined voltage, the triggering means acts to discharge it through the primary of the pulse transformer to thus induce in each of the transformer secondary windings a high impulse voltage which is additive to the voltage on the main energy storage capacitors. The sum of these voltages is adequate to initiate discharge of each of the main energy storage capacitors through its respective control gap and ignition gap, with substantially equal distribution of energy between the gaps. In this system the main energy storage capacitors all are charged through a single charging circuit, which preferably is of cascade voltage doubler type providing accurate and loss-free control of capacitor charging rate.

In an alternative form of the invention adapted to use in systems wherein only two ignition gaps are necessary, each of the two ignition gaps is connected in series circuit relation with one winding of an inductor and with a main energy storage capacitor, both such main energy storage capacitors being charged by a common power supply which preferably is of the type described in the preceding paragraph. When either of the two ignition gaps breaks down and the ignition fires, the resultant current flow through the associated inductor winding gives rise to a voltage in the other inductor winding and this induced voltage initiates firing of the other ignitor.

The invention will itself be further understood and its various objects, features and advantages more fully appreciated by reference to the appended claims and the following detailed description when read in conjunction with the accompanying drawing, wherein:

Figure 1 is a schematic circuit diagram of electric spark ignition apparatus providing simultaneous firing of a plurality of ignitor plugs in accordance with the invention; and

Figure 2 is a schematic circuit diagram of similar apparatus adapted to provide simultaneous firing in systems embodying only two ignitor plugs.

With continued reference to the drawings, wherein like reference numerals have been used throughout to designate like elements, the ignition system of Figure 1 is shown as arranged for operation from an A.-C. power source 10 which may be of either alternator or D.-C. vibrator type depending on availability in the particular application.

Transformer 12 forms part of a capacitor charging circuit of cascade voltage doubler type as disclosed and claimed in the copending application filed on even date herewith by E. W. Lautenberger and assigned to the assignee of the present application. As fully explained in the copending Lautenberger application, the cascade voltage doubler type charging circuit disclosed therein affords important advantages for use in capacitor discharge ignition systems, because by proper selection of capacitor sizes it is readily possible to control sparking rates and to safely limit capacitor charging currents without power losses or adverse effect on system power factor.

As shown, the charging circuit comprises a relatively small capacitor 14 connected in series circuit relation with a rectifier 16 preferably of cold cathode gas tube type, one or more such tubes being employed as necessary to provide the necessary voltage rating. A second rectifier 18 also of cold cathode gas tube type, is connected in series circuit relation with the small capacitor 14 and with the main energy storage capacitors 20, 21 and 22, there being one energy storage capacitor for each ignitor plug in the system. A resistor 24 is included in the series circuit connection between each of the main energy storage capacitors 20—22 and the rectifier 18 to control peak surge back current through and

damage to the rectifiers during oscillatory discharge of the main energy storage capacitors, as more fully explained in the aforesaid Lautenberger application.

In the multiple plug ignition systems of the present invention, these resistors 24 serve also to partially isolate the energy storage capacitors 20—22 from each other so as to prevent discharge of all the capacitors to the one capacitor which is first to fire through its associated ignition gap, in event all do not fire precisely simultaneously. The resistors 24 do permit limited current flow between the capacitors, however, which is of advantage in that it tends to equalize the intensity and duration of the sparks produced at the several ignitor plugs.

Each of the three storage capacitors 20—22 is connected to form a discharge circuit including one control gap 26—28 and one of the three secondary windings of a pulse transformer 30 having a single common primary winding 32. All the secondary windings of pulse transformer 30 are of like hand with respect to each other and of opposite hand with respect to the primary winding 32, and all the windings are suitably insulated so that each is electrically independent of the others.

The transformer secondaries each are connected in series relation with one of the ignition gaps 34—36, each of which may be bridged as at 38 by a body or layer of semiconductive material for facilitating ionization of the ignition gaps and discharge therethrough at relatively low voltage, in well known manner.

The primary winding 32 of pulse transformer 30 is connected in a series circuit relation with a control or trigger gap 40 which, like the control gaps 26—28, comprises a pair of spaced apart spark electrodes disposed within a sealed envelope filled with an inert gas so as to provide substantially constant breakdown potential regardless of change in atmospheric conditions. The triggering gap 40 should have a breakdown potential at least slightly lower than the control gaps 26—28, for a reason which will later become apparent.

Triggering gap 40 is connected between a resistor 44 and a triggering capacitor 42 having a small capacitance value as compared to the main energy storage capacitors 20—22. The triggering capacitor 42, through its series resistor 44, is connected in parallel with the energy storage capacitors 20—22 so as to be charged therewith, the triggering capacitor rate of charge being made to correspond to that of the energy storage capacitors by proper selection of the value of resistor 44.

In operation, the cascade voltage doubler comprising capacitor 14, rectifiers 16 and 18, and resistors 24 provide a high voltage D.-C. output to the main energy storage capacitors 20—22 and, through resistor 44, to the triggering capacitor 42. During one portion of the cycle of transformer output voltage, capacitor 14 is charged through rectifier 16, and during another portion of the cycle it is connected through rectifier 18 to supply an increment of charge to each of the energy storage capacitors 20—22. The quantity of charge thus given the energy storage capacitors in each cycle of transformer output voltage is determined by the size of capacitor 14 as related to the total capacity of the energy storage capacitors, since the charging current all must pass through capacitor 14.

During charging of the main energy storage capacitors, current flow in the capacitor discharge circuits is prevented by the control gaps 26—28, one of which is interposed in each such circuit. Triggering gap 40 operates to delay discharge of triggering capacitor 42 until such time as the charge on the triggering capacitor reaches a predetermined voltage corresponding to the breakdown potential of the triggering gap.

When triggering capacitor 42 reaches this predetermined voltage, the triggering gap 40 then ionizes and the triggering capacitor discharges through the pulse

transformer primary 32 to ground, to thus induce in each of the transformer secondary windings a voltage which is additive to that on the associated energy storage capacitor 20—22. The sum of these voltages is sufficient to cause ionization of control gaps 26—28, which as noted above have substantially higher ionization potentials than the triggering gap. As each of control gaps 26—28 is ionized, it breaks down and permits discharge of the associated main energy storage capacitor 20—22 through its respective ignition gap 44—46, ionization of the ignition gaps being facilitated by their high resistance shunts 38 if used.

Thus, simultaneous discharge of all the main energy storage capacitors through the ignition gaps is positively assured, regardless of whether the number of ignition gaps included in the circuit is two, three or any other desired number. Substantially equal division of energy between the ignition gaps also is assured, by reason of the fact each ignition gap is provided with an independent energy storage capacitor and the several such capacitors all are charged from a common power supply to a common potential before discharge. If for any reason an unequal distribution of energy is desired, however, this may be obtained by proper selection of the sizes of energy storage capacitors 20—22.

It is to be understood that while the ignition system of Figure 1 is shown as being of low tension type, the system also is adapted to high tension operation in which the control gaps 26—28 and the high resistance shunts 38 across the ignitor gaps may be omitted. Similarly, while the charging circuit for the energy storage capacitors is shown as of cascade voltage doubler type, it will be understood that other charging circuits providing high voltage D.-C. output to the capacitors may instead be used if desired.

With reference now to Figure 2, the ignition circuit shown in this figure offers maximum simplicity but is limited to use in systems embodying only two ignitor plugs. Since in this system the charging circuit is of cascade voltage doubler type as already described with reference to Figure 1, no further description of the charging circuit of Figure 2 is necessary here.

A separate energy storage capacitor 46, 47 is provided for each of the two ignitor gaps 49 and 50, respectively, the two ignition gaps being bridged by high resistance shunts 52 if the system is to be of low tension type, or left unbridged for high tension operation. A control gap 54 controls discharge of main energy storage capacitor 46 through its associated ignitor gap 49, and a similar control gap 56 controls discharge of energy storage capacitor 47. In series circuit relation with each of the energy storage capacitors and its respective control and ignition gaps is connected one of the two windings 58 and 59 of an inductor, the two inductor windings being of opposite hand and wound on a common ferrite or other magnetizable core 61.

In operation, the rapid change of flux density in one of the windings and the core of the inductor which results from capacitor discharge current in whichever of the two discharge circuits is first to fire, induces a high impulse voltage in the other inductor winding. This impulse voltage is additive to the voltage on the energy storage capacitor in the still idle discharge circuit, and the combined voltage is applied across the associated control gap 54 or 56 causing it to ionize and to initiate discharge in the idle circuit. Thus, both ignitor plugs fire substantially simultaneously, with one following the other by a delay of approximately one to ten microseconds depending on component parameters.

While only certain preferred embodiments of the invention have been described and illustrated by way of example in the foregoing, many modifications will occur to those skilled in the art and it therefore should be understood that the appended claims are intended to cover

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all such modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In an electrical ignition system including a plurality of spark ignition devices; a like plurality of energy storage capacitors; unidirectional electric current supply means connected to charge said capacitors all to like polarity; a plurality of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough; and inductor means connected in said discharge circuits for effecting substantially simultaneous capacitor discharge therethrough.

2. In an electrical ignition system including a plurality of spark ignition devices, a plurality of energy storage capacitors, a capacitor charging circuit adapted when energized to provide a high voltage substantially unidirectional charge current output to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby all are charged to like polarity and to substantially the same potential, a plurality of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, and inductor means including windings connected in said discharge circuits and inductively coupling said discharge circuits so as to effect substantially simultaneous discharge of said capacitors each through its respective ignition device.

3. In an electrical ignition system including a plurality of spark ignition devices, a plurality of energy storage capacitors, a current limiting resistor in series relation with each of said capacitors, a capacitor charging circuit adapted when energized to provide a high voltage substantially unidirectional charge current output through said resistors to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby all are charged to like polarity and to substantially the same potential, a plurality of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, and inductor means including windings connected in said discharge circuits and inductively coupling said discharge circuits so as to effect substantially simultaneous discharge of said capacitors each through its respective ignition device.

4. In an electrical ignition system including a plurality of spark ignition devices, a plurality of energy storage capacitors, a capacitor charging circuit adapted when energized to provide a high voltage substantially unidirectional charge current output to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby all said capacitors are charged to like polarity and to substantially the same potential, a plurality of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, inductor means including windings connected in said discharge circuits and inductively coupling said discharge circuits so as to effect substantially simultaneous discharge of said capacitors each through its respective ignition device, and a control gap connected between the capacitor and inductor winding in each of said discharge circuits.

5. In an electrical ignition system for firing a plurality of spark ignition devices simultaneously, a plurality of energy storage capacitors, a capacitor charging circuit adapted when energized to provide a high voltage substantially unidirectional charge current output to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby all are charged to like polarity and to substantially the same potential, a plurality of dis-

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charge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, inductor means including a plurality of secondary windings each connected in a respective one of said discharge circuits and primary winding means inductively coupled to said secondary windings, and means for recurrently impressing on said inductor primary winding means a high impulse voltage thereby to induce in each of said secondary windings an impulse voltage effective to initiate simultaneous discharge of said capacitors each through its respective ignition device.

6. In an electrical ignition system for firing a pair of spark ignition devices simultaneously, a pair of energy storage capacitors, a capacitor charging circuit adapted when energized to provide a high voltage substantially unidirectional charge current output to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby both are charged to like polarity and to substantially the same potential, a pair of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, and inductor means including a pair of mutually inductively coupled windings each connected in one of said discharge circuits whereby capacitor discharge in either of said discharge circuits is effective to initiate substantially simultaneous capacitor discharge in the other.

7. In an electrical ignition system for firing a pair of spark ignition devices simultaneously, a pair of energy storage capacitors, unidirectional electric current supply means for charging said energy storage capacitors with said capacitors being connected in parallel circuit relation whereby both are charged to like polarity, a pair of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, inductor means including a pair of mutually inductively coupled windings each connected in one of said discharge circuits, and a pair of control gaps each connected between the capacitor and inductor winding in one of said discharge circuits.

8. In an electrical ignition system for firing a plurality of spark ignition devices simultaneously, a plurality of energy storage capacitors, a capacitor charging circuit adapted to provide a high voltage substantially unidirectional charge current output to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby all are charged to like polarity, a plurality of discharge circuits each connecting one of said capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor therethrough, inductor means including a plurality of secondary windings each connected in a respective one of said discharge circuits and primary winding means inductively coupled to said secondary windings, a trigger capacitor connected to be charged through said capacitor charging circuit, and a trigger gap connecting said trigger capacitor for discharge through said inductor primary winding means on breakdown of said trigger gap, whereby discharge of said trigger capacitor through said trigger gap recurrently impresses on said inductor primary winding means a high impulse voltage thereby to induce in each of said secondary windings an impulse voltage effective to initiate simultaneous discharge of said energy storage capacitors each through its respective ignition device.

9. In an electrical ignition system a plurality of spark ignition devices, a plurality of energy storage capacitors, a capacitor charging circuit adapted to provide a substantially unidirectional charge current output to said energy storage capacitors, said capacitors being connected into said charging circuit in parallel circuit relation with each other whereby all are charged to like polarity, a plurality of discharge circuits each connecting one of said

capacitors to a respective one of said spark ignition devices for recurrent discharge of the capacitor there-through; inductor means including a plurality of secondary windings each connected in one of said discharge circuits and primary winding means inductively coupled to said secondary windings, a control gap connected between the capacitor and inductor winding in each of said discharge circuits, charge through said capacitor charging circuit, and a trigger gap connecting said trigger capacitor for discharge through said inductor primary winding means on breakdown of said trigger gap, whereby discharge of said trigger capacitor through said trigger gap recurrently impresses on said inductor primary winding means a high impulse voltage thereby to induce in each

of said secondary windings an impulse voltage effective to initiate substantially simultaneous discharge of said capacitors each through its respective control gap and ignition device.

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