

Dec. 14, 1954

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ELECTRIC SPARK IGNITION APPARATUS

2,697,184

Filed Sept. 27, 1952

Fig. 1.

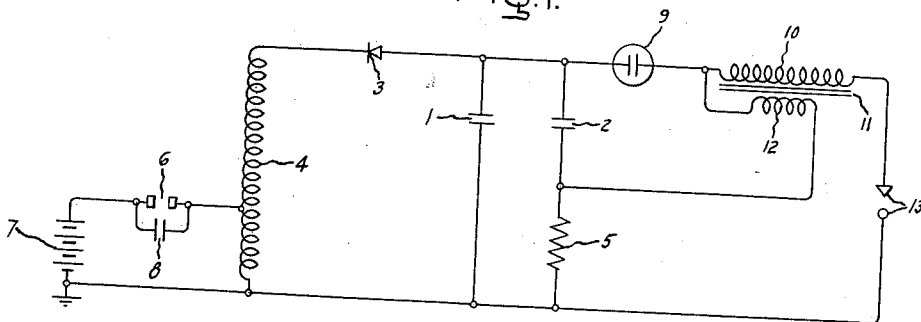


Fig. 2.

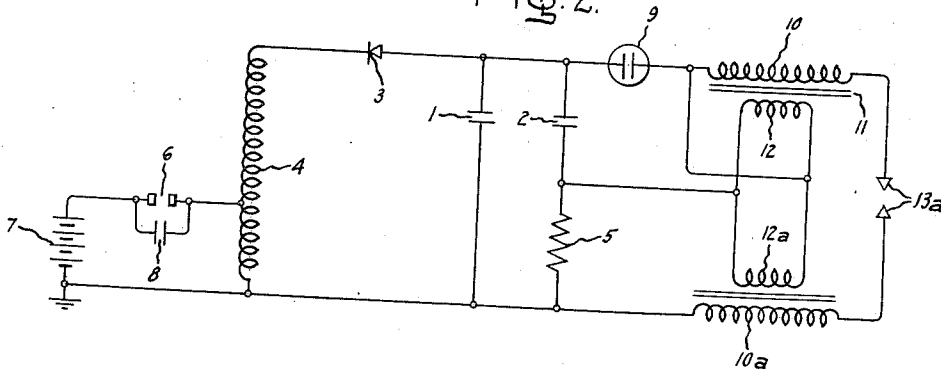
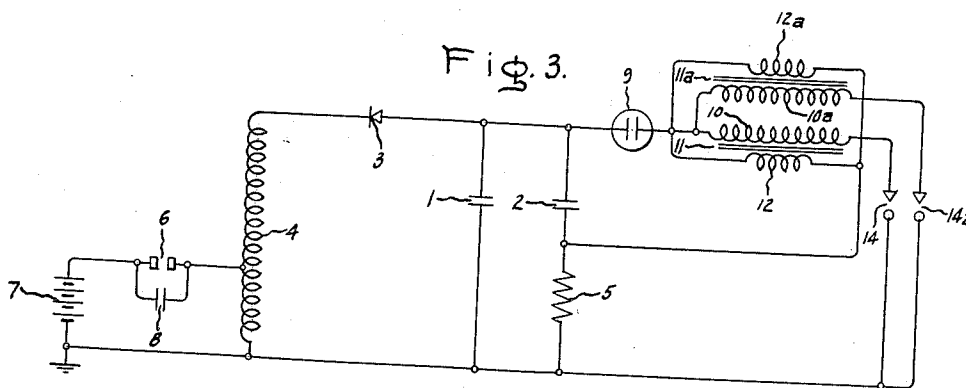


Fig. 3.



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ELECTRIC SPARK IGNITION APPARATUS

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Application September 27, 1952, Serial No. 311,934

14 Claims. (Cl. 315-177)

My invention relates to electric spark ignition apparatus, and more particularly to capacitive discharge ignition equipment for igniting combustible mixtures of air and fuel in apparatus where precise timing is not necessary. The present application is a continuation of my application Serial No. 256,484, filed November 15, 1951.

In aircraft gas turbines or jet engines, difficulty has heretofore been experienced in lighting or relighting burners at high altitudes and high air speed. It has been found that high energy capacitor discharge spark ignition is better suited to this use than are inductive spark ignition systems. The timing and repetition rate of the spark are not critical or even of any great significance, but the energy content of each discharge must be quite high and should be maintained substantially constant and independent of altitude and air speed.

Accordingly, therefore, it is a general object of my invention to provide new and improved electric spark ignition apparatus of the capacitor discharge type.

It is another object of my invention to provide electric spark ignition apparatus having a spark of high and substantially constant energy content.

It is a more specific object of my invention to provide a new and improved capacitor discharge spark ignition apparatus for aircraft gas turbines or jet engines which shall provide a high energy spark substantially independent of altitude and air speed, whereby the engine burners may be started or restarted readily at any altitude.

Another object of my invention is to provide a capacitor discharge ignition apparatus which shall comprehend a minimum number of parts and shall thus be light in weight and inexpensive, but shall nonetheless be dependable and durable in operation.

In carrying out my invention in one form I provide a main discharge or energy storage capacitor and an auxiliary triggering capacitor, both connected to be charged from any suitable source of electric current supply. The main discharge capacitor is provided with a discharge circuit including, in series circuit relation, a pair of spark ignition electrodes, the secondary winding of a step-up transformer and a sealed spark gap. The auxiliary triggering capacitor is provided with a triggering discharge circuit which includes, in series circuit relation, a primary winding of the step-up transformer and the same sealed discharge gap which is included in the discharge circuit of the main capacitor. In this circuit the sealed gap acts as a holdoff control which is independent of altitude and air speed, so that discharge cannot be initiated until the capacitors are charged to a predetermined voltage. When such predetermined voltage is attained, the sealed gap ionizes and the auxiliary capacitor discharges through the sealed gap and the transformer primary winding. This auxiliary discharge current induces in the transformer secondary winding a high impulse voltage. The high induced voltage adds to the main capacitor voltage in the main discharge circuit, and breaks down the ignition gap, thereby to release the main capacitor charge.

My invention itself will be further understood and its various objects and advantages more fully appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawing, in which Fig. 1 is a schematic circuit diagram of an electric spark ignition apparatus embodying my invention in one form; Fig. 2 is a schematic circuit diagram of a similar apparatus applied to a spark ignition system of the opposite polarity type; and Fig. 3 is a schematic circuit dia-

gram of a similar apparatus for simultaneous firing of a plurality of spark plugs.

Referring now to the drawing, and more particularly to Fig. 1, I have shown a main charge accumulating capacitor 1 and an auxiliary capacitor 2 connected to be charged in parallel circuit relation from a source of unidirectional current supply including a rectifier 3 and an autotransformer 4. The main capacitor 1 is connected directly across the charging source, the auxiliary capacitor 2 is connected across the source in series circuit relation with a current limiting resistor 5. The primary portion of the autotransformer winding is connected through a pair of vibrator contacts 6 to a battery 7. An arc suppressing capacitor 8 is connected across the vibrator contact points 6. It will be evident to those skilled in the art that through this charging circuit the capacitors 1 and 2 are simultaneously charged in a series of increments, the number of increments of course depending upon the capacity of the capacitors and the autotransformer output voltage.

Connected across the main capacitor 1 I provide a main discharge circuit comprising, in series circuit relation, a sealed spark discharge device 9, the high voltage secondary winding 10 of a step-up transformer 11 having a primary winding 12, and a pair of spaced apart ignition electrodes 13 which may, for example, be provided by a spark plug of any desired type. The sealed discharge device 9 comprises a pair of sparking electrodes disposed in spaced apart relation within a sealed envelope, and preferably the envelope is filled with an inert gas at a desired and substantially constant density. The breakdown voltage of such a gap is substantially constant despite temperature and resultant pressure changes in the inert gas. The ignition electrodes 13 are preferably the electrodes of an open jump gap type spark plug, such as is shown, for example, in Patent 2,465,092, issued to J. R. Harkness et al. on March 22, 1949. Preferably also, the fixed resistance of this main discharge circuit, i. e., exclusive of the arc paths therein, is considerably less than the critical value at which oscillatory discharge begins, so that discharge may be oscillatory. It will of course be appreciated by those skilled in the art that the degree of damping, and thus the nature of the discharge, depends upon the entire circuit resistance. The circuit resistance includes the ignition arc and the sealed gap arc, and these arcs vary in resistance during the discharge.

Across the auxiliary discharge capacitor 2 I connect an auxiliary discharge circuit which includes, in series circuit relation, the sealed spark discharge device 9 and the primary winding 12 of the step-up transformer 11. Preferably the fixed resistance of this auxiliary discharge circuit is also less than the critical value so that discharges there-through may be of an oscillatory nature, although the character of this discharge also depends upon the resistance of the sealed gap arc.

It will now be evident that in operation the capacitors 1 and 2 are charged in parallel circuit relation and in a series of charging increments from the unidirectional electric current supply source including the battery 7, the vibrator contact 6, the autotransformer 4 and the rectifier 3. When the voltage of the auxiliary or triggering capacitor 2 attains a predetermined desired value, such as for example, about 3 or 3.5 kilovolts, the sealed spark discharge device 9 breaks down or ionizes, and a discharge takes place through the auxiliary discharge circuit including the transformer primary winding 12. This discharge current induces in the transformer secondary winding 10 a high voltage impulse. This induced voltage may, for example, be of the order of 16 to 17 kilovolts, and is of high frequency if the discharge of capacitor 2 is oscillatory. Thus, the total voltage available for breaking down the spark plug gap between the ignition electrode 13 is of the order of 20 kilovolts. In this manner, discharge of the capacitor 2 through the auxiliary discharge circuit immediately and positively effects a discharge of the main capacitor 1 through the main discharge circuit including the ignition electrodes or spark plug 13. In this operation the current limiting resistor 5 serves to prevent discharge of the main capacitor 1 through the transformer primary winding 12 to ground after the gap has ionized.

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At Fig. 2 I have shown another embodiment of my invention similar to that shown at Fig. 1 but applied to an ignition system of the type known as an opposite polarity system. Those elements of the circuit of Fig. 2 which correspond to like elements in the circuit of Fig. 1 have been identified by the same reference numerals. At Fig. 2 I have shown a pair of spaced apart high voltage ignition electrodes 13a which may be the insulated high voltage electrodes of a pair of single-electrode spark plugs. The electrodes 13a are connected in the discharge circuit of the main discharge capacitor 1 in series circuit relation with the sealed spark discharge device 9 and the high voltage secondary windings 10 and 10a of two step-up transformers 11 and 11a. The transformers are provided respectively with primary windings 12 and 12a, and the primary windings are connected in parallel circuit in the discharge circuit of the auxiliary or triggering capacitor 2. The step-up transformer secondary windings 10 and 10a are so connected in the main discharge circuit that one terminal of each such secondary winding is directly connected to a separate one of the ignition electrodes 13a. The operation of the circuit shown at Fig. 2 is entirely similar to the operation of the circuit shown at Fig. 1, except that high triggering voltages are induced in the secondary windings of both the step-up transformers 11 and 11a, and these transformers are so disposed that the induced voltages are of opposite polarity thereby to increase the voltage available for discharge between the ignition electrodes 13a.

At Fig. 3 I have shown my new and improved ignition apparatus applied for simultaneous firing of more than one ignitor plug. The circuit of Fig. 3 is similar to that of Fig. 1, and like parts have been assigned the same reference numerals. At Fig. 3, however, I have shown two double electrode ignitor plugs 14 and 14a connected in parallel circuit relation in the main discharge circuit of the capacitor 1. Each branch of the parallel circuit includes also the secondary winding of a high frequency impulse transformer, the main capacitor 1 and sealed gap 9 being in the common part of the main discharge circuit. Thus, the plug 14 is in series with the secondary winding 10 of the transformer 11, and the plug 14a is in series with a secondary winding 10a of a transformer 11a, both these circuits being supplied in parallel from the capacitor 1 through the sealed gap 9. The transformer primary windings 12 and 12a are shown connected in parallel circuit relation in the triggering circuit. It will of course be understood by those skilled in the art that a single primary winding in inductive relation with each of a plurality of secondary windings could be utilized if desired. Similar parallel connections of transformer secondary windings may be multiplied to fire any desired number of ignitor plugs through a common main discharge circuit.

While I have described and illustrated only certain preferred embodiments of my invention by way of example, many modifications will occur to those skilled in the art, and I therefore wish to have it understood that I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

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

1. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of spark ignition electrodes, a pair of capacitors, unidirectional electric current supply means connected to charge said capacitors, a spark discharge device having a sealed envelope, a step-up transformer having a low voltage primary winding and a high voltage secondary winding, means for connecting said spark discharge device and said transformer secondary winding across one of said capacitors in a main series discharge circuit including said ignition electrodes, and means connecting said transformer primary winding and said spark discharge device across the other said capacitor in an auxiliary series discharge circuit, whereby discharge of said other capacitor through said auxiliary circuit triggers said main series discharge circuit through said transformer.

2. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of ignition electrodes, a pair of supply conductors, a main capacitor connected between said conductors, an auxiliary capacitor connected between said conductors in series circuit relation with a current limiting resistor, a spark discharge

device including a pair of sparking electrodes disposed in spaced apart relation in a sealed envelope, one said sparking electrode being connected to the common terminal of said capacitors, a step-up transformer having a low voltage primary winding and a high voltage secondary winding, means for connecting said spark discharge device and said transformer secondary winding across one of said capacitors in a main series discharge circuit including said ignition electrodes, and means connecting said primary winding and said spark discharge device across the other said capacitor in an auxiliary series discharge circuit, whereby discharge of said other capacitor through said auxiliary series discharge circuit triggers said main series discharge circuit through said transformer.

3. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of ignition electrodes, a pair of capacitors, means including a source of pulsating electric current supply for charging said capacitors in a series of increments, a spark discharge device having a sealed envelope, a step-up transformer having a low voltage primary winding and a high voltage secondary winding, means for connecting said spark discharge device and said transformer secondary winding across one of said capacitors in a main series discharge circuit including said ignition electrodes, the fixed resistance of said main discharge circuit being less than the critical value for preventing oscillation, and means connecting said transformer primary winding and said spark discharge device across the other said capacitor in an auxiliary series discharge circuit, the fixed resistance of said auxiliary discharge circuit being less than the critical value for oscillation, whereby discharge of said other capacitor through said auxiliary circuit triggers said main discharge circuit through said transformer.

4. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of ignition electrodes, a pair of capacitors, unidirectional electric current supply means connected to charge said capacitors, a spark discharge device having a sealed envelope, a pair of step-up transformers having low voltage primary windings and high voltage secondary windings, means for connecting said spark discharge device and said transformer secondary windings across one of said capacitors in a main series discharge circuit including said ignition electrodes, said ignition electrodes being adapted to be interposed between said secondary windings in said main series discharge circuit, and means connecting said primary windings in parallel circuit relation with each other and in series circuit relation with said spark discharge device across the other said capacitor thereby to provide an auxiliary series discharge circuit, whereby discharge of said other capacitor through said auxiliary circuit triggers said main discharge circuit through said transformers.

5. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of ignition electrodes, a pair of supply conductors, a main capacitor connected between said conductors, an auxiliary capacitor connected between said conductors in series circuit relation with a current limiting resistor, a spark discharge device including a pair of sparking electrodes disposed in spaced apart relation within a sealed envelope, one said sparking electrode being connected to the common terminal of said capacitors, a pair of step-up transformers each having a low voltage primary winding and a high voltage secondary winding, means for connecting said spark discharge device and said transformer secondary windings across said main capacitor in a main series discharge circuit including said ignition electrodes, said ignition electrodes being adapted to be interposed between said secondary windings in said main series discharge circuit, and means connecting said transformer primary windings in parallel circuit relation with each other and in series circuit relation with said spark discharge device across said auxiliary capacitor thereby to provide an auxiliary series discharge circuit, whereby discharge of said auxiliary capacitor triggers said main discharge circuit through said transformers.

6. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of spark ignition electrodes, a main energy storage capacitor, a source of unidirectional electric current supply connected to charge said capacitor, a spark discharge device having a sealed envelope, a step-up transformer having a low voltage primary winding and a high voltage secondary

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winding, means for connecting said spark discharge device and said transformer secondary winding across said energy storage capacitor in a main series discharge circuit including connections for said ignition electrodes, and means including said transformer primary winding and an auxiliary capacitor for recurrently inducing in said transformer secondary winding a high impulse voltage in response to recurrent conduction through said spark discharge device thereby recurrently to initiate current discharge through said main discharge circuit.

7. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of spark ignition electrodes, a main energy storage capacitor, a source of unidirectional electric current supply connected to charge said capacitor, a spark discharge device having a sealed envelope, a step-up transformer having a low voltage primary winding and a high voltage secondary winding, means for connecting said spark discharge device and said transformer secondary winding across said energy storage capacitor in a main series discharge circuit including connections for said ignition electrodes, an auxiliary capacitor, and means connecting said auxiliary capacitor in series circuit relation with said transformer primary winding and said spark discharge device thereby recurrently to induce in said transformer secondary winding a high impulse voltage in response to recurrent voltage breakdown of said spark discharge device, said high impulse voltage initiating a discharge current in said main discharge circuit.

8. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a plurality of cooperating pairs of spark ignition electrodes, a main energy storage capacitor, a source of unidirectional electric current supply connected to charge said capacitor, a spark discharge device having a sealed envelope, transformer means including a plurality of high voltage secondary windings and low voltage primary winding means inductively coupled with said secondary windings, means connecting said secondary windings in parallel circuit relation, each branch of said parallel circuit including connections for one said pair of said spark ignition electrodes, means connecting said parallel circuit in series circuit relation with said spark discharge device across said main capacitor thereby to provide a main discharge circuit, and means including said primary winding means and an auxiliary capacitor for recurrently inducing in said secondary windings high impulse voltages in response to recurrent conduction through said spark discharge device thereby recurrently to initiate parallel current discharge through said main circuit.

9. In an electric spark ignition apparatus for supplying recurrent arc discharges between a plurality of pairs of spark ignition electrodes, a pair of capacitors, unidirectional electric current supply means connected to charge said capacitors, a spark discharge device having a sealed envelope, transformer means including a plurality of high voltage transformer secondary windings and low voltage primary winding means inductively coupled with said secondary windings, means connecting said secondary windings in parallel circuit relation, each branch of the parallel circuit including connections for one pair of said spark ignition electrodes, means connecting said parallel circuit in series circuit relation with said spark discharge device across one of said capacitors thereby to provide a main discharge circuit, and means connecting said transformer primary winding means and said spark discharge device in series circuit relation across the other said capacitor, whereby discharge of said other capacitor induces high voltages in said secondary windings thereby to trigger said main discharge circuit.

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10. In an electric spark discharge apparatus, a plurality of spark plugs, a main energy storage capacitor and an auxiliary capacitor, a source of unidirectional electric current supply connected to charge said capacitors in parallel circuit relation, step-up transformer means including a plurality of secondary windings and primary winding means inductively coupled therewith, a single sealed spark discharge device connecting said spark plugs in parallel circuit relation across said main capacitor each in series with one said secondary winding, and means connecting said primary winding means and said sealed spark discharge device in series circuit relation across said auxiliary capacitor.

11. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of spark ignition electrodes, an energy storage capacitor adapted to be connected to discharge between said electrodes, a spark discharge device having a sealed envelope and adapted to be connected in circuit between said capacitors and said electrodes to control said discharge, and means including said device for recurrently impressing upon said circuit a high impulse voltage thereby recurrently to release said energy.

12. In an electric spark ignition apparatus for supplying a recurrent arc discharge between a pair of spark ignition electrodes connected in series circuit relation with a discharge device having a sealed envelope, means responsive to voltage breakdown of said device for impressing on said circuit a high impulse voltage thereby to initiate discharge between said electrodes.

13. In an electric spark ignition apparatus for supplying an arc discharge between a pair of spark ignition electrodes, main and auxiliary capacitors, unidirectional electric current supply means connected to charge said main capacitor, a single spark discharge device connected in charge changing circuit relationship with both of said capacitors, a step-up transformer having a low voltage primary winding connected in charge changing circuit relationship with said auxiliary capacitor and said discharge device, said transformer including a high voltage secondary winding connected in series with said discharge device and said electrodes across said main capacitor.

14. In an electric spark ignition apparatus for supplying an arc discharge between a pair of spark ignition electrodes, main and auxiliary capacitors, unidirectional electric current supply means connected to charge said main capacitor, a single spark discharge device connected in charge changing circuit relationship with both of said capacitors, a step-up transformer having a low voltage primary winding connected in charge changing circuit relationship with said auxiliary capacitor and said discharge device, said transformer including a high voltage secondary winding connected in series with said discharge device and said electrodes across said main capacitor, and an impedance connected to said auxiliary capacitor to control the charge state thereof prior to said arc discharge and to limit the dissipation of the charge energy of said main capacitor other than in said arc discharge.

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