This invention relates to a novel ignition system which provides a succession of spark gap discharging pulses to one or more spark gaps.

The invention has among its objects the provision of a novel ignition system particularly characterized by the certainty of its operation in supplying ignition sparks for an engine.

Another object of the invention lies in the provision of an ignition system which selectively supplies the ignition need of an engine or the like from either an intermittently operated direct current power source or from an alternating current source capable of continuous operation.

A further object of the invention lies in the provision of an ignition figure in the type indicated which automatically supplies a plurality of spark gaps with electrical energy of spark intensity when the system is powered by direct current, and which energizes a single spark gap when the system is powered by alternating current.

Yet other objects of the invention are the provision of a dual-powered ignition circuit of the type above indicated which incorporates means for preventing the transmission of electrical energy and pulses from the then operative part of the circuit to the part of the circuit which is not then operating, and the provision of an ignition circuit wherein in one mode of operation a plurality of spark gaps are operative, the circuit being so constructed and arranged that should one of the spark gaps become inoperative, the other or others of the spark gaps remain in operation.

The above and further objects and novel features of the invention will more fully appear from the following description in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is for the purpose of illustration only, and is not intended as a definition of the limits of the invention.

The single drawing is a circuit diagram of a preferred embodiment of ignition system in accordance with the invention.

Engines of the jet or ram jet type are customarily ignited by an ignition system which supplies a succession of spark gap discharging pulses to a spark gap device positioned within the engine. Although a jet engine will normally continue to operate when once ignited, even though the ignition system is then shut off, it is much safer to operate a jet aircraft with the ignition system thereof in continuous operation, since this guards against flame-out of the engine which may be dangerous at any time.

The present invention provides an ignition system in which electrical spark discharges are generated when desired, as during take-off and landing of an aircraft, and which further provides continuous stand-by spark discharge for the stand-by ignition system. If, therefore, flame-out should accidentally occur, the engine will readily be started again almost immediately by the stand-by ignition discharges. In the specific embodiment shown, the spark discharges for initial operation of the engine are provided from a direct current source such as a battery, and the stand-by discharges are provided by an alternating current source, such as an alternating current generator which may be either air driven or driven by the jet engine once it has started.

The ignition circuit shown in the drawing includes a first, alternating current powered section which, operating through step-up transformer 42, supplies the upper spark gap 47 with energy of spark discharge intensity. Ordinarily, such portion of the circuit remains in operation throughout the running of the engine once the latter has started. The circuit includes a further, direct current powered portion of the circuit which is preferably employed during the starting of the engine, while the alternating current powered section is not connected to the circuit. Such further circuit, functioning through both step-up transformers 42 and 87, supplies spark discharge devices 47 and 106, respectively, with electrical energy of spark discharge intensity. The circuit includes means which prevent the transmission of pulses from the alternating current powered section of the circuit into the direct current powered section thereof when the former is operating and the latter is not, and vice versa. The circuit also includes means whereby should one of spark discharge devices 47 and 106 become inoperative when the circuit is functioning with the direct current power source, the other spark discharge device continues to operate.

Turning now to the drawing, the circuit includes input terminals 10 and 11 to which a suitable source of alternating current may be connected. In a preferred embodiment of the system, a 115 volt, 400 cycle alternating current source is employed. Terminal 11 is connected to ground as shown. Terminal 10 is connected to a radio interference filter 12, the output of the filter being connected by a wire 14 to one end of the primary winding 15 of a step-up transformer 16. The other end of such winding is connected to ground. Transformer 16 may be, for example, of the type disclosed and claimed in the application of London, Serial No. 665,538, filed June 13, 1957, wherein the primary winding 15 and the secondary winding 17 of the transformer are loosely coupled with the core of the transformer.

Transformer 16 is of the so-called reactance-type having high secondary leakage reactance characteristics. In other words, the primary and the secondary of the transformer are loosely coupled, and there is a large leakage flux, the degree of which is governed by the secondary load conditions. In such transformer, as the secondary load current increases the secondary terminal voltage drops. The transformer 16 thus functions as a choke coil to determine to a material extent the rate of discharge of the storage condenser. In other words, loosely coupled reactance-type transformer 16 delivers only a limited amount of power due to its high secondary leakage inductance. Consequently, it effectively controls the charging rate of the condenser system and regulates the spark-producing rate of the apparatus, as well as reducing the magnitude of the peak current through the rectifiers and increasing the conduction time of such rectifiers. It has been found that, when such reactance-type transformer is used, no other regulating elements need be employed in the circuit.

The output from secondary winding 17 is rectified and is then led to a tank storage condenser system formed by the three condensers 24, 31, and 35. Specifically, a wire 19 leads from one end of secondary winding 17 to a first rectifier bank 20 and then to wire 21. The output of the first rectifier bank 20 is connected to a wire 25. A wire 22 having condenser 24 interposed therein extends from junction 34 to wire 21. A wire 26 extends from wire 19 through a second rectifier bank 27, which is connected in a manner which is the reverse of rectifier bank 20. The output of the second rectifier bank 27 is connected to a wire 29 having a resistor 30 interposed therein. Connected between junction 34 and wire 29 beyond resistor 30 is a wire 32 in which the condenser 31 is interposed.
The condenser 35 is connected across wires 21 and 29 beyond condensers 24 and 31, as shown. A resistor 36, connected in parallel with condenser 35, is also connected across wires 21 and 29.

The current pulses delivered to the tank condenser from the rectifier banks 20 and 27 function to charge condensers 24, 31, and 35, and in so doing double the voltage applied to the storage condenser system in the manner also disclosed and claimed in the above Lowden application. When the storage condenser system has been charged to a predetermined voltage, the discharge gap of a control gap device breaks down, thereby energizing transformer 42 and causing a spark discharge at device 47. The control gap, generally designated 37, has one electrode thereof connected to wire 29 and the other connected to ground through a wire 39.

The above-mentioned wire 21 is connected to a junction 38 from which there extends a wire 40 connected to a first end designated F of the primary winding 41 of transformer 42. The other end of primary 41, designated S, is connected by a wire 44 to the S end of the secondary winding 45 of transformer 42. The other, F, end, of the secondary winding is connected by a wire 46 to one electrode of spark gap 47, the other electrode of such gap being connected to ground through a wire 49. A condenser 51 and a resistor 52 are connected in parallel, such parallel circuit being connected at one end by wire 59 to wire 44 and at the other end by a wire 53 to a junction 54 which is connected to ground by a wire 55.

When a spark discharge occurs across the gap of device 37, a discharge loop for the tank storage condenser 24, 31, and 35 is formed by way of wire 21, wire 40, primary winding 41 of transformer 42, wires 44, 50, condenser 51, wires 53 and 55, ground, and wire 39. The surge of current thus produced through primary 41 induces a high voltage in secondary 45 of transformer 42, thereby forming a spark discharge across device 47. A safety discharge gap 56, having a breakdown voltage slightly greater than the maximum voltage demand of device 47, is connected between ground and wire 46 by a wire 57. The above-described cycle is repeated so long as the alternating current source remains connected to terminals 10 and 11.

Gap 56 is arranged to fire if there is an open circuit leading to device 47. It will be seen that the portion of the circuit thus far described, which is powered by alternating current, is connected to the remainder of the circuit at three points, the common ground, the junction 38, and the junction 54. As will appear in the following description of the portion of the circuit which is powered by direct current, means are incorporated in the circuit for preventing the feeding back of energy from the portion of the circuit which is then operating into the portion of the circuit which is then inoperative.

The direct current powered portion of the circuit includes some of the elements of the above-described alternating current powered portion of the circuit, including the transformer 42, a portion of the discharge loop permitting current flow through the primary of such transformer, and the spark discharge device 47. Terminals 59 and 60 are adapted to be connected to a source of direct current, as shown. Interposed in wire 62, leading from the positive terminal 59, is a radio frequency interference filter 61. Wire 62 is connected to one end of a first winding 65 of a coil 63 of vibrator device 64. The other end of winding 65 is connected to one end of the primary 74 of a step-up transformer 75. A second winding 71 of coil 63 has one end thereof connected to the other end of primary 74 by wire 72. The second end extending from winding 71 is connected to ground. The vibrator is provided with contacts 69, one contact being connected to ground by wire 70 and the other contact being connected to wire 65 and thence to ground through a condenser 67. When terminals 59 and 69 are connected to a source of direct current, the vibrator 64 is energized so as periodically to break the connection between contacts 69, thereby causing a series of current pulses through primary 74 of transformer 75.

Transformer 75 is provided with a secondary winding 76. One end of winding 76 is connected to a wire 77 in which there is interposed a rectifier bank 79. The other end of winding 76 is connected by a wire 80 to a junction 83; a condenser 85 interposed therein extends from junction 83 to wire 77 beyond the rectifier bank 79. A further wire 84 having a resistor 85 interposed therein extends from junction 83 to wire 77. Condenser 85, which is of relatively large capacity, functions as a storage condenser which discharges its energy into the firing portion of the circuit, the spark discharge gaps 47 and 106, both of which function when the ignition circuit is direct current powered.

The discharge portion of the circuit functioning in the manner to be described includes the previously described step-up transformer 42, which supplies gap device 47, and a second, similar step-up transformer 87 which supplies spark gap device 106. Transformer 87 has the S end of its primary winding 85 connected to junction 83 by wire 81. The F end of primary winding 85 is connected to a wire 99 through wire 89; the S end of secondary 104 of transformer 87 is connected to wire 90 by wire 103. The F end of secondary 104 is connected to one electrode at one end by wire 109 and at the other end by wire 105. The other electrode of such spark discharge device is connected to ground through wire 107. A safety spark discharge device 121 is connected between wire 105 and ground by a wire 120. The discharge circuit includes a triggered control gap 97 and energy discharge loops acting in conjunction therewith so that when the voltage of the charge on storage condenser 82 reaches a predetermined value simultaneous spark discharges occur at spark discharge devices 47 and 106.

The triggered control gap device 97 may be, for example, of the type disclosed and claimed in the application of Linkron, Serial No. 142,198, filed October 2, 1961. Such device, which employs a gas filled envelope, has three spaced electrodes within the envelope forming a first main longer gap and a second shorter triggering gap. Upon discharge of the triggering gap, the gas between the electrodes forming the main gap becomes highly ionized and thus permits the discharge of energy across the main gap. In the circuit shown the wire 77 is connected to one electrode 108 of the triggering gap of device 97. A wire 94 is connected to a second electrode 99 of device 97. Shunted across wires 77 and 94 is a wire 96 having a condenser 95 interposed therein. Condenser 95, which has a capacity appreciably smaller than that of condenser 82, is charged to the same voltage as condenser 82. When such voltage reaches a predetermined value, condenser 95 discharges its charge across electrodes 99 and 100, thereby initiating discharge of the main gap of device 97.

The third electrode, designated 109, of device 97, is connected to the previously described junction 38 by a wire 110. Wire 94, connected to electrode 99, is connected to wire 90 leading from transformer 87 through a loop consisting of parallel wires 91 and 102 having a resistor 93 and a condenser 101 interposed therein, respectively. There is thus formed a discharge loop for storage condenser 82 through wire 77, gap 100, wire 94, condenser 101, wire 90, wire 89, the primary winding 86 of transformer 87, and wire 81.

The discharge portion of the circuit, when powered with direct current, is completed by a loop having parallel connected condenser 112 and resistor 114 connected to junction 54 at one end and, by wire 111, to wire 81 at the other end. Connected between wires 59 and 111, specifically to junctions 116 and 115, respectively, is a wire 117 having a condenser 119 interposed therein. It will be seen that the parallel circuit, including condenser 112 and resistor 114, is, in effect, connected
in series with the previously described parallel circuit consisting of condenser 51 and resistor 52, the junction 54 between such two circuits being grounded. The parallel circuit consisting of condenser 51 and resistor 52 foregoing, is connected in series with the previously described parallel circuit consisting of condenser 82, such second discharge loop including the primary winding 41 of step-up transformer 42. The serially connected parallel circuits are connected across the S end of each of the primary windings of step-up transformers 42 and 87.

A spark gap device, in accordance with the present invention employs circuit components having the following values: Storage condenser 82 has a capacity of approximately 5.5 U.F. Each of resistors 56 and 85 has a resistance of 20 megohms. Each of condensers 95, 51, and 112 has a capacity on the order of .05 U.F. Each of condensers 101 and 119 has a capacity on the order of .10 U.F. Spark gap devices 47 and 106 are supplied with energy at a maximum of 27,000 volts when the circuit is powered with direct current, and device 47 is supplied with energy at the same voltage when the circuit is powered by alternating current. The triggering gap 99, 100 and 109 of control gap device 97 has a break down voltage of 3,000-3,100 volts. The gap between electrodes 100 and 109 of such device has a breakdown voltage of 4,000-4,600 volts. Control gap device 37 has a breakdown voltage of 3,500-3,600 volts. Safety gap devices 123 and 124, which bridge gap 37, has a capacity of 2,000-2,050 ohms. Resistor 92 has a resistance of 100,000 ohms. Each of condensers 24 and 31 has a capacity on the order of .05 U.F. Condenser 35 has a capacity on the order of .06 U.F. Resistor 30 has a resistance of 1,000 ohms. A source of 115 volts, 400 cycle alternating current is adapted to be connected to terminals 10 and 11. A source of 14-30 volts direct current is adapted to be connected to terminals 59 and 60. The parts of the above-described circuit powered by alternating current and by direct current can be operated simultaneously with no damage to either, but separate operation of each of such parts of the circuit is preferred.

The circuit of the present invention functions as follows: Under steady operating conditions the terminals 10 and 11 are connected to a source of alternating current, whereas the terminals 59 and 60 are disconnected from the source of direct current. This may be done, for example, by means of two 2-pole switches 122 and 124, respectively, which may be interconnected as indicated so that when the circuit through one of them is open, the circuit through the other of them is closed. When switch 122 is open, and switch 124 is closed, current may flow through the filter 12 and the primary 15 of transformer 16. A step-up voltage then occurs at the secondary 17 of such transformer. When such voltage is negative at the upper end of the primary 17, the rectifier bank 25 conducts current to charge condenser 31. When the voltage is positive at the upper end of secondary 17, rectifier bank 25 conducts current to charge condenser 24. The voltages of the charges on condensers 24 and 31 are additive, thus doubling the voltage of the charge on condenser 35. Condenser 35 is charged to progressively higher voltages as time proceeds, until such point a threshold voltage of control gap 27 is reached. When this occurs, condenser 35 discharges through a loop composed of wire 21, wire 40, primary 41 of transformer 42, wires 44, 59, condenser 51, and wires 53 and 55 to ground. The surge of current thus produced in primary 41 causes a part of a second discharge loop for storage taken with the charging of condenser 51, causes the gap of device 47 to become ionized. Since condenser 51 has a capacity which is small compared to that of condenser 35, condenser 35 still has a substantial amount of stored energy. Consequently, condenser 35 now discharges through wire 21, primary 41, secondary 45, spark gap device 47, ground, and control gap 37. This causes the ignition spark at device 47. After condenser 35 has been discharged, the above-described cycle repeats itself so long as alternating current is applied to terminals 10 and 11. Resistor 56 discharges condenser 35 when the alternating current supplied to the circuit is interrupted. When the circuit is powered by alternating current as described, voltages are formed at the F end of primary 41, and thus at junction 38 and at electrode 109 of the triggered gap device 97. The impulse voltage breakdown between terminals 100 and 109, however, substantially exceeds the voltages attained at junction 38 during A.C. operation of the circuit, and so device 97 functions as a barrier between the then operative portion of the circuit and the other portion of the circuit, which is not then employed.

When the ignition circuit of the invention is operated with a direct current source, as during the starting of the engine, the A.C. supply is disconnected from terminals 10 and 11 and the D.C. supply is connected to terminals 59 and 60. Current then flows through filter 61, thereafter taking three paths. One path is through coil 65 and through contacts 69 and ground when the contacts 69 are closed.

When the vibrator 64 is energized, there are produced current pulses in primary 74 of transformer 75. The stepped up voltage appearing across secondary 76 of such transformer is rectified and flows in the form of direct current pulses to charge storage condenser 82. The smaller condenser 35 is effectively connected in parallel with condenser 82 in a circuit including resistor 92 and primary 86 of transformer 87. When the charge on condenser 95 reaches the breakdown voltage of the gap between electrodes 99 and 100 of device 97, condenser 95 discharges directly into the arc formed across the electrodes 99 and 100. Upon the formation of such initial discharge across electrodes 99 and 100, storage condenser 82 discharges through the same gap into condenser 101, the discharge loop being completed through wire 90, primary 86 of transformer 87, and wire 81. The consequent change in current through primary 86 causes a step-up voltage to occur in secondary 104 of transformer 87, such step-up voltage causing ionization of the gap of device 106.

Simultaneously, the current flow between electrodes 99 and 100 of device 97 ionizes the gap between electrodes 100 and 109 of such device. This causes current to flow from storage condenser 82 through primary 41 of transformer 42 to condensers 51 and 112, which are connected in series. The current flow through primary 41 causes a step-up voltage to occur across secondary 45, thereby bridging condenser 35, and then discharging through device 47. The gap between electrodes 100 and 109 of device 97, and the gaps of devices 47 and 106 are now all ionized at the same instant.

Since the capacities of condensers 51, 101, 112, and 119 are small compared to that of storage condenser 82, only a portion of the energy stored in condenser 82 is dissipated in the above-described circuits or loops. The remainder of the energy flows from condenser 82 across the gap formed by electrodes 100 and 109 through primary 41, secondary 45, the gap of device 47 to ground, through wire 107, the gap of device 106, secondary 104, primary 86, and wire 81 back to the low side of condenser 82. This current flow causes a high energy spark discharge to occur at both of devices 47 and 106. The above-described cycle is rapidly repeated, storage condenser 82 being charged as described following each discharge thereof. Resistors 123 and 124 allow the current in condensers 51 and 112 to be returned to uncharged condition before each discharge of the devices 47 and 106.

The safety gaps 56 and 121, as described, are, in effect, connected in parallel with the gaps of the respective devices 47 and 106. Should either of devices 47 and 106 become inoperative, the respective safety gap functions to preserve continuity of the final discharge circuit. The control gap 37, employed as an element of the alter-
nating current powered portion of the circuit, functions as a barrier between the circuit portions when the circuit is powered with direct current. Thus the breakdown voltage of device 37 is sufficiently high to prevent flow of current from ground to wire 29 when the circuit is functioning with direct current power. The breakdown voltage of device 37 is greater than the breakdown voltage of device 30; consequently, feedback can not occur from the direct current powered portion of the circuit to the alternating current powered portion thereof. The breakdown value of the gap 100, 109 is also greater than the breakdown voltage value of control gap 37. As a result, feedback can not occur from the alternating current powered portion of the circuit to the direct current powered portion thereof.

Although only one embodiment of the invention has been illustrated in the accompanying drawings and described in the foregoing specification, it is to be especially understood that various changes, such as in the relative dimensions of the parts, materials used, and the like, as well as the suggested manner of use of the apparatus of the invention, may be made therein without departing from the spirit and scope of the invention as will now be apparent to those skilled in the art.

What is claimed is:

1. Electrical apparatus comprising a first source of electrical energy including a first storage condenser, a sparking circuit connected across the first storage condenser, the sparking circuit comprising a hold-off gap having a first and a second electrode, the first electrode of the hold-off gap being connected to the second storage condenser, and an igniter gap having a first electrode connected to the second electrode of the hold-off gap and a second electrode connected to a common conductor, and means responsive to and automatically operable when the charge on said first storage condenser attains a predetermined voltage below the normal spark-over voltage of said hold-off gap for rendering the latter conductive to said charge, said last named means comprising a first circuit means connected to said first storage condenser, said first circuit means including a timing device for delaying the triggering of said circuit means for a predetermined time period following the initiation of discharge of said storage condenser.

2. Electrical apparatus as defined in claim 1, wherein the breakdown voltage of the control gap is markedly greater than the breakdown voltage of the triggering gap, and the breakdown voltage of the hold-off gap is markedly greater than the breakdown voltage of the control gap.

3. Electrical apparatus comprising a first source of electrical energy including a first storage condenser, a sparking circuit connected across the first storage condenser, the sparking circuit comprising a delay element for delaying the initiation of discharge following the initiation of discharge of said storage condenser, a timing device for delaying the triggering of said circuit means for a predetermined time period following the initiation of discharge of said storage condenser, and an igniter gap having a first and a second electrode, the first electrode of the igniter gap being connected to the second electrode of the hold-off gap and the second electrode of the igniter gap being connected to a common conductor, and means responsive to and automatically operable when the charge on said first storage condenser attains a predetermined voltage below the normal spark-over voltage of said hold-off gap for rendering the latter conductive to said charge, said last named means comprising a second circuit means connected to said first storage condenser, said second circuit means including a third condenser connected between the second electrode of the hold-off gap and the second electrode of the igniter gap to said common conductor, a second source of electrical energy including a second storage condenser, a fourth circuit means connecting one side of the second storage condenser to the second electrode of the hold-off gap, and a central gap connected between said common conductor and the other side of the second storage condenser, whereby the sparking circuit may be automatically energized by the first and second sources of electrical energy.

4. Electrical apparatus as defined in claim 3, wherein the breakdown voltage of the control gap is markedly greater than the breakdown voltage of the triggering gap, and the breakdown voltage of the hold-off gap is markedly greater than the breakdown voltage of the control gap.

5. Electrical apparatus comprising a first source of electrical energy including a first storage condenser, a sparking circuit connected across the first storage condenser, the sparking circuit comprising the following serially connected elements: a hold-off gap having a first and a second electrode, the first electrode of the hold-off gap being connected to the first storage condenser, a first igniter gap, a common conductor, and a second igniter gap, and means responsive to and automatically operable when the charge on said first storage condenser attains a predetermined voltage below the normal spark-over voltage of said hold-off gap for rendering the latter conductive to said charge, said last named means comprising a first circuit means connected to said first storage condenser, said first circuit means including a triggering gap having a first and a second electrode adjacent said hold-off gap for effecting ignition of the latter, a first electrode of the triggering gap being connected to one side of the first storage condenser, said first circuit means further including a second condenser connected across the electrodes of the triggering gap and adapted to be charged by the first storage condenser to create a discharge across said triggering gap to ionize said hold-off gap, a second circuit means, including a third condenser, connected in series with the second electrode of the triggering gap and the first storage condenser, said second circuit means forming a loop for initiating the discharge of the triggering gap by partial discharge of the first storage condenser therethrough, a third circuit means including a fourth condenser connected from between the second electrode of the hold-off gap and the first electrode of the first igniter gap to the said common conductor, a second source of electrical energy including a second storage condenser, a fourth circuit means connecting one side of the second storage condenser to the second electrode of the hold-off gap, and a control gap connected between said common conductor and the other side of the second storage condenser, whereby the sparking circuit may be alternatively energized by the first source of energy to discharge both igniter gaps and by the second source of energy to discharge the first igniter gap.

6. Electrical apparatus as defined in claim 5, wherein the breakdown voltage of the control gap is markedly greater than the breakdown voltage of the triggering gap, and the breakdown voltage of the hold-off gap is markedly greater than the breakdown voltage of the control gap.
for initiating the discharge of the triggering gap by par-

tial discharge of the first storage condenser thereto, a third circuit means, said third circuit means connecting similar ends of the primary windings of the first and second transformers to said common conductor, said third circuit means including sub-circuits each having a further, fourth condenser connected between the primary winding of the respective transformer and the common conductor, a second source of electrical energy including a second storage condenser, a fourth circuit means connecting one side of the second storage con-
denser to the second electrode of the hold-off gap, and a control gap connected between said second common con-
ductor and said second source of energy, to provide a second discharge gap to ionize said hold-off gap when said storage condenser is charged to a predetermined level, and a second circuit means including first coupling means wherein the primary winding of said second transformer, said trigger-
ging gap and said storage condenser are in series coupling relationship when said triggering gap is ionized and dis-
charging, the discharging current in said first coupling means being sufficient to ionize and break down said second igniter gap, and said second circuit means in-
cluding further second coupling means wherein the pri-
mary winding of said first transformer, said hold-off gap and said storage condenser are in series coupling relationship when said hold-off gap is ionized and dis-
charging, the discharging current in said second cou-
pling means being sufficient to ionize and break down said first igniter gap, said storage condenser being sub-
stantially discharged through said serially connected first and second igniter gaps to provide ignition spark dis-
charge thereon when said first and second igniter gaps are simultaneously ionized and in breakdown condition.

12. Electrical apparatus as defined in claim 11, com-
prising a third condenser serially connected in said sec-
ond circuit means.

13. Electrical apparatus as defined in claim 12, com-
prising a resistor connected in parallel with the third con-
denser in said second circuit means.

14. Electrical apparatus as defined in claim 13, where-
in the second circuit means includes the primary wind-
ing of the second transformer connected therein in series 
with the parallel connected third condenser and resistor.

15. In electrical apparatus comprising a source of elec-
trical energy including a storage condenser, the combi-
nation therewith of a sparking circuit connected across 
the storage condenser, the sparking circuit comprising a hold-off gap having a first and a second electrode, one of said electrodes of the hold-off gap being connected to one side of the storage condenser, an igniter gap, means for coupling said igniter gap to the other of said electrodes in a series coupling relationship, first circuit means including a triggering gap having a first and a second electrode adjacent said hold-off gap for effecting ionization of the latter, a first electrode of the triggering gap being connected to one side of the storage con-
denser, said first circuit means further including a second condenser connected across the electrodes of the trigger-
ging gap and adapted to be charged by said source to a level sufficient to provide a discharge across said trigger-
ging gap to ionize said hold-off gap when said storage condenser is charged to a predetermined level, and a second circuit means including means for coupling the second electrode of said hold-off gap to said storage condenser, the sparking circuit comprising a discharge loop for said storage condenser when said hold-off gap is ionized and said storage condenser is charged to a level sufficient to provide a discharge thereac-
cross, said second circuit means further including means responsive to the discharge therethrough to ionize said igniter gap to provide substantial discharge of said stor-
age condenser therethrough and thereby provide ignition spark discharge thereon.

9. Electrical apparatus as defined in claim 8, where-
in said hold-off gap and said triggering gap have a common electric center.

10. Electrical apparatus as defined in claim 8, com-
prising the combination of a resistor connected in par-
allel with a third condenser, said combination being 
serially connected in said second circuit means.

11. In electrical apparatus comprising a source of elec-
trical energy including a storage condenser, the combi-
nation therewith of a sparking circuit connected across 
the storage condenser, the sparking circuit comprising a hold-off gap having a first and a second electrode, the first electrode being connected to the storage condenser, a first voltage step-up transformer having primary and secondary windings, the primary winding being con-
nected to the second electrode of the hold-off gap, a first igniter gap connected to the secondary winding of the first transformer, a second igniter gap and a second voltage step-up transformer having primary and secondary windings, the second igniter gap being connected to the secondary winding of the second transformer, means for coupling said first and second igniter gaps in a series coupling relationship, first circuit means con-
ected to said storage condenser, said first circuit means including a triggering gap having a first and a second 
electrode adjacent said hold-off gap for effecting ioniza-
tion of the latter, a first electrode of the triggering gap being connected to one side of the storage condenser, said first circuit means further including a second con-
denser connected across the electrodes of the triggering gap and adapted to be charged by said source to a level sufficient to provide a second discharge gap to ionize said hold-off gap when said storage condenser is charged to a predetermined level, and a second circuit means including first coupling means wherein the primary winding of said second transformer, said trigger-
ging gap and said storage condenser are in series coupling relationship when said triggering gap is ionized and dis-
charging, the discharging current in said first coupling means being sufficient to ionize and break down said second igniter gap, and said second circuit means in-
cluding further second coupling means wherein the pri-
mary winding of said first transformer, said hold-off gap and said storage condenser are in series coupling relationship when said hold-off gap is ionized and dis-
charging, the discharging current in said second cou-
pling means being sufficient to ionize and break down said first igniter gap, said storage condenser being sub-
stantially discharged through said serially connected first and second igniter gaps to provide ignition spark dis-
charge thereon when said first and second igniter gaps are simultaneously ionized and in breakdown condition.

12. Electrical apparatus as defined in claim 11, com-
prising a third condenser serially connected in said sec-
ond circuit means.
nistor serially connected to the primary winding of the second transformer, said second circuit means being connected in series with the second electrode of the triggering gap and storage condenser to form a loop for initiating the discharge of the triggering gap by partial discharge of the storage condenser thereon and whereby in one electrode of each of the igniter gaps is connected to the output side of the secondary winding of the respective transformer, the other electrode of each of the igniter gaps is connected to a common conductor, and a third circuit means connecting the primary windings of the first and second transformers to the common conductor, said circuit means including sub-circuits each having a further, fourth condenser connected between the primary windings of the respective transformer and the common conductor.

16. Electrical apparatus as defined in claim 15, wherein the third circuit means includes a fifth condenser connected between the primary windings of the transformers and in parallel with the said sub-circuits.

17. Electrical apparatus as defined in claim 15, wherein the common conductor is ground, and wherein both sides of the storage condenser are ungrounded.

18. Electrical apparatus as defined in claim 15, wherein the fifth condenser, the fourth condenser of each of the sub-circuits, and the fifth condenser have capacities which are small compared to the capacity of the storage condenser, whereby a large portion of the energy stored in the storage condenser is dissipated at the igniter gaps.

19. Electrical apparatus as defined in claim 15, comprising two alternative, safety gaps connected in parallel with the respective igniter gaps, the breakdown voltages of the safety gaps being on the same order as but slightly greater than that of the igniter gaps, whereby upon failure of an igniter gap the sparking circuit is completed through the corresponding safety gap.

20. Electrical apparatus comprising a source of electrical energy including a storage condenser, the combination therewith of a sparking circuit connected across the storage condenser, the sparking circuit comprising a hold-off gap having a first and a second electrode, the first electrode being connected to the storage condenser, and an igniter gap connected to the second electrode, and means responsive to and automatically operable when the charge on said storage condenser attains a predetermined voltage below the normal spark-over voltage of said hold-off gap for rendering the latter conductive to said charge, said last-named means comprising a first circuit means connected to said storage condenser and to said incircuit means including a triggering gap having a first and a second electrode adjacent said hold-off gap for effecting ionization of the latter, said first electrode of the triggering gap being connected to one side of the storage condenser, said first circuit means further including a second condenser connected across the electrodes of the triggering gap and adapted to be charged by said source to a level sufficient to provide a discharge across said triggering gap to ionize said hold-off gap when said storage condenser is charged to a predetermined level, and a second circuit means, including a third condenser connected in series with the triggering gap and storage condenser, said second circuit means forming a loop for conducting a partial discharge of the storage condenser into said third condenser, said storage condenser being charged to a sufficient level to break down said hold-off gap when ionized by said triggering gap and being partially discharged through a third circuit means connected to said storage condenser, said third circuit means including means responsive to the discharge current therethrough to cause ionization of said igniter gap, said storage condenser being substantially discharged through the ionized and broken down serially connected hold-off gap and igniter gap to provide ignition spark discharge at the latter.

21. Electrical apparatus comprising a source of electrical energy including a storage condenser and means for charging said condenser, a sparking circuit connected across said condenser comprising in series a hold-off gap and two igniter gaps, a triggering gap coupled to said storage condenser and disposed adjacent to and having a spark-over voltage of lower hold-off gap, and said storage condenser being ionized at a predetermined level of said second main condenser to effect ionization of said other igniter gap, and second circuit means including said hold-off gap for conducting a partial discharge of said storage condenser to effect ionization of said other igniter gap, and said storage condenser being substantially discharged through said serially connected igniter gaps when the latter are simultaneously ionized to provide ignition spark discharge thereat.

22. Electrical apparatus as defined in claim 21 further comprising a second sparking circuit comprising a second source of electrical energy including a second storage condenser, second means for charging said second condenser, means for connecting said second storage condenser to said first sparking circuit beyond said hold-off gap, and a control gap in connection with said second storage condenser for varying said control discharge voltage thereof to first effect ionization of said other igniter gap and to thereafter discharge said second condenser across said other igniter gap, said control gap having a spark-over voltage below that of said hold-off gap.

23. An ignition system comprising main ignition condenser means, a spark discharge dual gap device having respective main and control gaps associated therewith, an igniter gap device having an igniter gap associated therewith, first circuit means for coupling said main condenser means, said main gap and said igniter gap in a series coupling relationship, second circuit means for coupling said main condenser means and said main gap in a series coupling relationship, third circuit means for coupling said main condenser means and said control gap in a series coupling relationship, a source of energy coupled to said main condenser means and adapted to charge said main condenser means, and means for ionizing said control gap when said main condenser means is charged to a predetermined level to discharge partially said main condenser means through said third circuit means to ionize said main gap, said main condenser means being adapted to be partially discharged through said second circuit means when said main gap is ionized and said control gap is uncharged, and said main condenser means being further adapted to be discharged substantially through said first circuit means to provide spark discharge at said igniter gap when said igniter gap is ionized.

24. An ignition system according to claim 23 wherein said means for ionizing said control gap comprises a condenser coupled across said control gap and adapted to be charged by said source of energy.

25. An ignition system according to claim 23 further comprising second main ignition condenser means, a second control spark discharge device having a main gap associated with said spark gap and the storage condenser said second main condenser means, the main gap of said second control spark discharge device and said igniter gap in a series coupling relationship, a fifth circuit means for coupling said second main condenser means and the main gap of said second control spark discharge device and said igniter gap in a series coupling relationship, a fifth circuit means for coupling said second main condenser means and the main gap of said second control spark discharge device and the storage condenser said second main condenser means, the main gap of said second main condenser means to be adapted to be discharged when said second main control means is charged to said predetermined level to discharge partially said main condenser means through said fifth circuit means, and fifth circuit means having further means responsive to the partial discharge therethrough and adapted to ionize said
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Igniter gap to discharge substantially said second main condenser means through said igniter gap and provide ignition spark discharges thereat, and switching means for selectively coupling said first main condenser means and said second main condenser means to said first and second sources of energy, respectively.

26. An ignition system according to claim 25 wherein said means for ionizing said control gap comprises a condenser coupled across said control gap and adapted to be charged by said first source of energy.

27. An ignition system comprising main ignition condenser means, a spark discharge dual gap device having respective main and control gaps associated therewith, first and second igniter gap devices having respective first and second igniter gaps associated therewith, first circuit means for coupling said main condenser means, said main gap and said first and second igniter gaps in a series coupling relationship, second circuit means for coupling said main condenser means and said main gap in a series coupling relationship, a third circuit means for coupling said main condenser means and said control gap in a series coupling relationship, a first source of energy coupled to said main condenser means and adapted to charge said main condenser means, and means for ionizing said control gap when said main condenser means is charged to a predetermined level to discharge partially said main condenser means through said third circuit means to ionize said main gap, said main condenser means being adapted to be partially discharged simultaneously through said second circuit means when said main gap is ionized to cause ionization of said first igniter gap and through said third circuit means to cause ionization of said second igniter gap, and said main condenser means being further adapted to be discharged substantially through said first circuit means to provide spark discharge at said igniter gaps when said igniter gaps are simultaneously ionized.

28. An ignition system according to claim 27 wherein said means for ionizing said control gap comprises a condenser coupled across said control gap and adapted to be charged by said source of energy.

29. An ignition system according to claim 27 further comprising second main ignition condenser means, a second control spark discharge device having a main gap associated therewith, a fourth circuit means for coupling said second main condenser means, the main gap of said second second spark discharge device and said first igniter gap in a series coupling relationship, a fifth circuit means for coupling said second main condenser means and the main gap of said second control spark discharge device in a series coupling relationship, a second source of energy coupled to said second main condenser means and adapted to charge said second main condenser means, the main gap of said second control spark discharge device being ionized at a predetermined level of said second main ignition condenser means to discharge partially said second main condenser means through said fifth circuit means, said fifth circuit means having further means responsive to the partial discharge therethrough and adapted to ionize said first igniter gap to discharge substantially said second main condenser means through said first igniter gap and provide ignition spark discharges thereat, and switching means for selectively coupling said first main condenser means and said second main condenser means to said first and second sources of energy, respectively.

30. An ignition system according to claim 29 wherein said means for ionizing said control gap comprises a condenser coupled across said control gap and adapted to be charged by said first source of energy.

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