

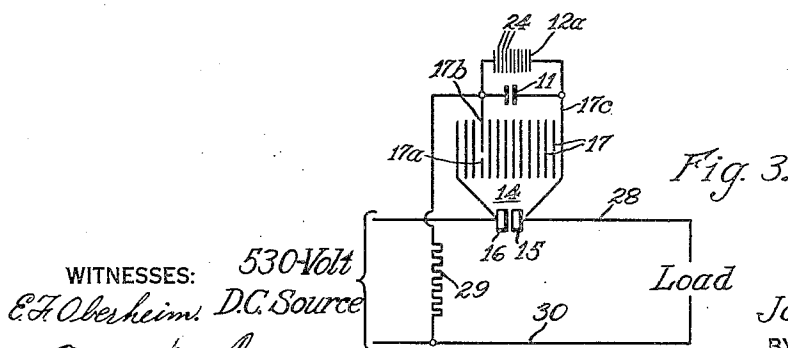
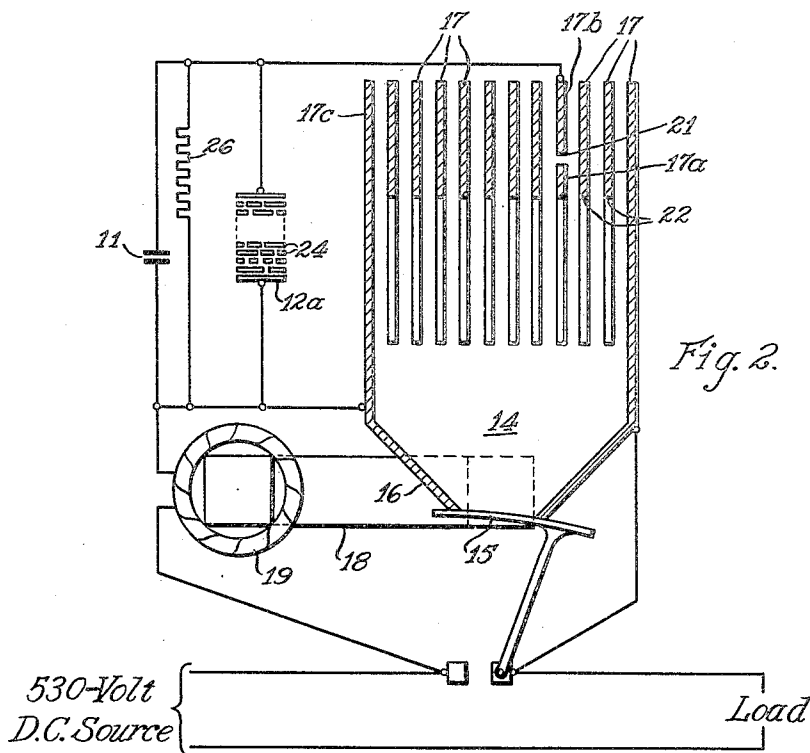
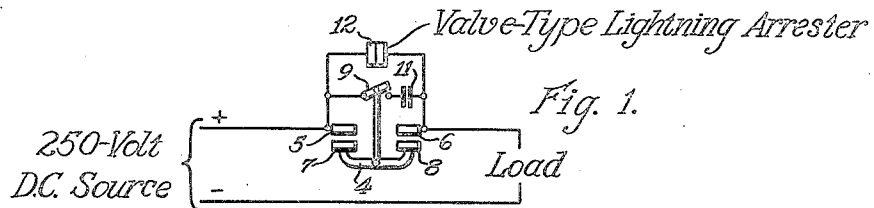
July 16, 1940.

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2,208,399

ELECTRIC SWITCH

Filed May 27, 1939



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2,208,399

ELECTRIC SWITCH

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Application May 27, 1939, Serial No. 276,054

14 Claims. (Cl. 175-294)

My invention relates to electric switches, and it has particular relation to that type of switch in which the circuit is interrupted by the formation of a plurality of serially connected short arcs, in which current-flow is quenched at the first current-zero.

The principal object of my invention is to provide such a subdivided-arc switch with means for connecting a capacitor across at least a portion of said subdivided arcs in such manner that the charging current of the capacitor introduces an artificial current-zero, or at least reduces the arcing current to such a low value that the arc is extinguished. Heretofore, the subdivided-arc switch has been confined to use on alternating-current circuits, in order to take advantage of the current-zeros which occur twice every cycle. It will readily be observed that my present invention introduces an artificial current-zero, rendering this subdivided-arc type of switch applicable to direct-current circuits, as well as making it possible to cause the switch to interrupt the current without waiting for the alternating-current current-zero when operating the improved switch on an alternating-current circuit.

A still further object of my invention is to utilize, with the shunting capacitor, a shunt connected valve-type lightning arrester or excess-voltage-discharging means which limits the recovery voltage tending to restrike the arc, and which also serves to harmlessly dissipate the stored energy in the circuit in which the current is being interrupted.

A still further object of my invention is to associate, with the shunting capacitor, a resistance-means which insures a receptive electrostatic condition of the capacitor, previous to the application of the arc-voltage thereto. This may be accomplished either by utilizing the resistor as a discharge-resistance connected in shunt to the capacitor, or as a serially connected high-resistance means for normally connecting the capacitor across the supply-line, so that, prior to the connection of the capacitor in shunt to the serially connected arcs, the capacitor is charged to the potential opposite to the arcing voltage, so that the capacitor will be in a condition ready to discharge through the arc, so as to establish an artificial current-zero therein, or even to tend to momentarily reverse the current therein.

With the foregoing and other objects in view, my invention consists in the methods, systems, apparatus, combinations and structures herein-

after described and claimed, and illustrated in the accompanying drawing, wherein:

Figure 1 is a diagrammatic view of circuits and apparatus embodying my invention in a construction utilizing mechanical means for effecting the necessary sequential operations,

Fig. 2 is a partly diagrammatic structural view illustrating my invention in a form of embodiment utilizing automatic means for effecting the sequential operations, and

Fig. 3 is a diagrammatic view illustrating a modification of the embodiment shown in Fig. 2.

In Figure 1, my invention is illustrated as being applied to one conductor of a 250-volt direct-current source which is supplying electric current to a load, as indicated. The invention is illustrated as being embodied in a double-pole switch 4 having two stationary main contacts 5 and 6, and two serially connected movable contacts 7 and 8 cooperating with the respective main contacts 5 and 6. The switch 4 is also provided with an auxiliary contact-mechanism 9 which is closed after the movable contacts 7 and 8 have opened, away from their respective stationary contacts 5 and 6, for a predetermined distance. The stationary contacts 5 and 6 are connected in series with the load, so that, in the closed position of the switch, the load circuit will be completed through the serially connected movable contacts 7 and 8. When the switch 4 is opened, arcs will be drawn between the contact-members 5 and 7, and between the contact-members 6 and 8, and after these arcs have been drawn, the auxiliary switch 9 will be closed.

In accordance with my invention, the auxiliary switch 9 is utilized to connect a capacitor 11 across the two serially connected arcs 5-7 and 6-8, and this capacitor is of such size that the charging-current thereof will be sufficient to instantly divert the current from the arcs 5-7 and 6-8, introducing, in said arcs, a momentary artificial current-zero, or at least reducing the arc-current to such a low value that the arcs will be extinguished, or the capacitor may be sufficiently large to tend to momentarily reverse the arc-current.

In accordance with my invention, as shown in Fig. 1, I also utilize a valve-type lightning arrester 12, which is connected in shunt across the two serially connected arc-devices 5-7 and 6-8 for the purpose of preventing the appearance of an excess-voltage surge across the terminals of the arc-gap devices after the arcs have been extinguished, thus insuring that the arcs shall not restrike, and also harmlessly absorbing the

stored energy in the direct-current circuit. In other words, the lightning arrester 12 has a sufficiently low breakdown-voltage and a sufficiently high discharge-current capacity so that it will effectively by-pass the arc-gaps 5-7 and 8-6 after the arcs have been interrupted by the charging-current of the capacitor 11, and at the same time said lightning arrester has a discharge-interrupting capacity sufficient to substantially interrupt its own discharge after the abatement of the excess-current surge which initiated said discharge. In other words, the lightning arrester has a valve-characteristic, or a discharge-interrupting characteristic.

While my invention is not limited to the production of an artificial current-zero in an arc, or a plurality of serially-connected arcs, which are produced in air, it has been illustrated in application to open-air arcs, and the general theory of the invention can be readily understood by a consideration of its application to open-air arcs, with the understanding that suitable adjustments in the theory can be made when other types of arcs are utilized.

An electric arc in air is a gaseous conductor in which the current is carried by the motion of positive and negative ions, the energy for the formation of these ions being furnished by the current in the arc and the voltage across the arc. If, for any reason, the arc-current is reduced to zero, there can be no energy for the formation of new ions as long as the current remains zero. If, immediately after a momentary current-zero, a recovery voltage is applied across the arc-terminals, tending to re-establish the arc in either direction of current-flow, the arc will not be reestablished if the rate of increase of this recovery-voltage is less than the rate of increase of the dielectric strength of the arcing space. If this condition is fulfilled, the arc is said to be extinguished. The rate of increase of the dielectric strength of the arcing space, after a current-zero, is dependent upon the rate of deionization of the air within this space.

For short, unconfined arcs in air, this deionization of a previously active arcing-space, after a current-zero, occurs in three principal ways. First, ionization is lost by recombination of positive and negative ions within the arc-space; second, ions are dissipated to the surrounding air and to the electrode-surfaces; and third, as soon as any magnitude of recovery-voltage is applied, negative ions, which are largely electrons, are driven away from the surface of the cathode by electrostatic repulsion, leaving a thin layer, or space-charge region, containing only positive ions. Because of the relatively small mass of the electrons, this insulating cathode-enveloping layer forms extremely rapidly upon the application of a recovery-voltage to the arc-terminals, so rapidly in fact, that its appearance may be practically considered as instantaneous, and its potential-gradient such that at least 250 volts may be borne by it. There is evidence that the ability to withstand the first 250 volts of recovery-voltage seems to be acquired by the arc-space in less than 10^{-7} seconds, or one-tenth of a micro-second.

It will be noted that this initial dielectric strength of the arcing space is the result of the third way in which deionization occurs, namely the repulsion of electrons from the cathode-surface. The two first-mentioned methods of deionization, namely recombination and dissipa-

tion of ions, do not begin to account for an appreciable part of the increasing dielectric strength until after several microseconds have elapsed, and since the time available for extinguishing an arc in most practical circuits is only a few microseconds, the cathode-drop of 250 volts or more must be relied upon to accomplish the extinction of an arc which is short, such as one which is of the order of a fraction of an inch in length.

In Fig. 1, there are two arc-gaps 5-7 and 8-6 in series. Within less than 10^{-7} seconds after the establishment of current-zero in these arcs, by reason of the discharge of the capacitor 11, said arcs are capable of withstanding a total recovery-voltage of 500 volts or more. The inductance of the interrupted direct-current circuit will, in general, be sufficient to tend to establish a momentary high-voltage surge tending to momentarily maintain the current in the direct-current circuit after the extinction of the arcs 5-7 and 8-6. If the lightning arrester 12 is of a type which will prevent the total voltage from building up to more than 350 or 400 volts, then this momentary surge-voltage may be bypassed around the arc-terminal 5-7 and 8-6, without imposing, on the arc-spaces, a recovery-voltage sufficiently high to re-establish the arcs. Such an arrangement is suitable for direct-current circuits of less than 300 volts. For higher voltages, several such gap-devices may be connected in series.

In Fig. 2, I show means whereby the capacitor may be automatically connected in shunt across some or all of the serially connected short gaps, by electrical means, rather than by reason of the mechanical movement of a switch contact-member. In this form of embodiment of my invention, I utilize a modification of the form of divided-arc circuit-breaker which is shown in my Patent 1,932,090, granted October 24, 1933, in which an arc is formed, in an initial arcing-chamber 14, between a movable electrode 15 and a stationary electrode 16, after which the arc is blown, or caused to move, into the spaces between a plurality of spaced conducting plates 17 having edges thereof presented towards said initial arcing-chamber 14, so as to cause the initial arc to be subdivided into a plurality of serially connected short arcs between the successive plates 17, and so as to cause the arc to continue to move, away from said initial arcing-chamber 14, within said spaces between the plates 17. The arc-blowing means is shown in the form of a magnetizable circuit 18 which is energized by a coil 19, the circuits for which are only diagrammatically illustrated, the practical details being shown, for example, in my aforesaid Patent No. 1,932,090.

In accordance with my invention, the nest of spaced plates 17 is modified by causing one of said plates to be subdivided into two parts 17a and 17b, the partial-plate 17a being disposed closest to the arcing-chamber 14, so that the moving arc first plays on the plate 17a and then on the plate 17b. Considering the relation of the plate 17b to the remaining plates 17 of the series, it will be noted that the edge 21 of the plate 17b, which is presented toward the initial arcing-chamber 14, is further away from said initial arcing-chamber than the corresponding edges 22 of a plurality of the other plates 17. The result of the foregoing construction is that the initially-produced single-arc between the electrodes 16 and 15 is converted or subdivided into a plurality of serially connected short arcs between

the successive plates 17, and these serially-connected arcs are well established before the plate 17b becomes energized by becoming the terminal of one of these short arcs.

5 In accordance with the form of my invention which is illustrated in Fig. 2, the short plate 17b is utilized to connect the capacitor 11 across a plurality of spaced plates 17, one terminal of the capacitor 11 being connected to the plate 17b and the other terminal of the capacitor being connected to an end plate 17c which is removed from the plate 17b by a plurality of spaces between the plates 17, so that the plate 17c is, say the eighth plate over from the plate 17b.

15 In the form of embodiment of my invention which is shown in Fig. 2, the valve-type lightning-arrester 12a is illustrated as being in the form of a large number of thin, lightly contacting carbon plates 24 of different irregular sizes, stacked up in light overlapping contact with each other, as described and claimed in an application of William E. Berkey and myself, Serial No. 206,342, filed May 6, 1938. Although this is a particularly desirable form of arrester, for the voltage of the switch which is illustrated in Fig. 2, wherein the switch is applied to a 530-volt direct-current circuit, I am, of course, not limited to any particular arrester. In Fig. 2, the arrester 12a is connected permanently in shunt to the capacitor 11.

30 In practicing my invention, it is necessary to make sure that the capacitor 11 shall be in such an electrostatic condition that it is capable of drawing a heavy momentary charging-current when the arcing-voltage is first applied thereto. For this purpose, it may be assumed that there is sufficient leakage in the dielectric of the capacitor itself, or in the shunt-connected lightning arrester 12a, to accomplish this function, or, as shown in Fig. 2, a separate discharging resistor 26 may be connected in parallel across the terminals of the capacitor 11. This resistor may be of any convenient size which, so far as I have been able to deduce, is not at all critical in the device.

45 In Fig. 3, I show a slight modification in the means for insuring a receptive electrostatic condition of the capacitor 11 previous to the application of the arc-voltage thereto. In Fig. 3, one terminal of the capacitor 11 is connected, as in Fig. 2, to the plate 17c which is connected to one conductor 28 of the electric circuit. The second terminal of the capacitor 11 is connected, as in Fig. 2, to the intermediate plate 17b. In Fig. 3, however, this second terminal of the capacitor 11 is also connected, by means of a high resistance 29, to the other conductor 30 of the electrical circuit, so that the capacitor is normally fully charged in the direction opposite to the arc-voltage, the word "normally" referring to the operating conditions when the switch-contacts 16 and 15 are closed.

When the switch-contacts 16—15 are opened, in Fig. 3, an arc is formed, which is blown into the plates 17 and thence onto the plate 17b, which connects the capacitor 11 across the major portion of the entire arcing voltage, thus extinguishing the arc in the manner explained in connection with Fig. 1. It will be understood that the discharging-voltage of the lightning arrester 12a must be properly coordinated with the cathode-drop dielectric strengths of the serially connected arc-spaces which are shunted by the lightning arrester, as well as being coordinated with the voltage of the direct-current circuit on

which the switching-device is utilized, as explained in connection with Fig. 1.

While I have shown my invention in several preferred forms of embodiment, I wish it to be understood that such showing and explanation are to be taken in an illustrative sense, rather than as indicating limits to the form and scope of my invention, since many changes may be made by those skilled in the art without departing from some of the essential general features of my invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language and the prior art.

I claim as my invention:

1. A device for interrupting a circuit, carrying an electric current, comprising means operative to cause said current to be carried by a plurality of serially connected arcs, means operative, subsequently to the establishment of the serially connected arcs, to thereafter cause at least a portion of the total arc-voltage to be suddenly applied to a capacitor of a size at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, and a valve-type lightning-arrester means in shunt-relation to said capacitor for limiting the excess-voltage surge of recovery-voltage to a value insufficient to restrike the extinguished arcs under predetermined operating-conditions of the device, said valve-type lightning-arrester means having a sufficiently marked cut-off characteristic to cause a substantially complete interruption of said current after the abatement of the excess-voltage surge.

2. A device for interrupting a circuit, carrying an electric current, comprising means operative to cause said current to be carried by a plurality of serially connected arcs, means operative, subsequently to the establishment of the serially connected arcs, to thereafter cause at least a portion of the total arc-voltage to be suddenly applied to a capacitor of a size at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, and a valve-type lightning-arrester means in shunt-relation to at least a portion of said serially connected arcs.

3. An arc-type circuit-interrupting device comprising means for establishing a plurality of serially connected arcs, means for subsequently applying at least a portion of the total arc-voltage to a shunting circuit having a predominating capacitance which is at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, and resistance-means permanently associated with said capacitance in such manner as to insure a receptive electrostatic condition of said capacitance, previous to the application of the arc-voltage thereto.

4. A device for interrupting the flow of electric current in a first conductor of an electric circuit, comprising, in combination, a capacitor having a first terminal connected to said first conductor of the electric circuit, a resistor connecting a second terminal of the capacitor to a second conductor of the electric circuit, an arc-type circuit-interrupting device associated with said first conductor and comprising means for establishing a plurality of serially connected arcs for carry-

ing the current flowing in said conductor, and means operative subsequently to the establishment of said arcs for effecting a connection between said arc-type circuit-interrupting device and said second terminal of the capacitor for applying at least a portion of the total arc-voltage across said capacitor, said capacitor being of a size at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device.

5. An arc-type circuit-interrupting device comprising means for establishing a plurality of serially connected arcs and for subsequently applying at least a portion of the total arc-voltage to a shunting circuit having a predominating capacitance which is at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, a valve-type lightning-arrester means in shunt-relation to said capacitor for limiting the excess-voltage surge of recovery-voltage to a value insufficient to restrike the extinguished arcs under predetermined operating-conditions of the device, said valve-type lightning-arrester means having a sufficiently marked cut-off characteristic to cause a substantially complete interruption of said current after the abatement of the excess-voltage surge, and resistance-means permanently associated with said capacitance in such manner as to insure a receptive electrostatic condition of said capacitance, previous to the application of the arc-voltage thereto.

6. An arc-type circuit-interrupting device comprising means for establishing a plurality of serially connected arcs and for subsequently applying at least a portion of the total arc-voltage to a shunting circuit having a predominating capacitance which is at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, and a valve-type lightning-arrester means in shunt-relation to at least a portion of said serially connected arcs.

7. A device for interrupting the flow of electric current in a first conductor of an electric circuit, comprising, in combination, a capacitor having a first terminal connected to said first conductor of the electric circuit, a resistor connecting a second terminal of the capacitor to a second conductor of the electric circuit, an arc-type circuit-interrupting device associated with said first conductor and comprising means for establishing a plurality of serially connected arcs for carrying the current flowing in said conductor, means operative subsequently to the establishment of said arcs for effecting a connection between said arc-type circuit-interrupting device and said second terminal of the capacitor for applying at least a portion of the total arc-voltage across said capacitor, said capacitor being of a size at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, and a valve-type lightning-arrester means in shunt-relation to said capacitor for limiting the excess-voltage surge of recovery-voltage to a value insufficient to restrike the extinguished arcs under predetermined operating-conditions of the device, said valve-type lightning-arrester means having a sufficiently marked cut-off char-

acteristic to cause a substantially complete interruption of said current after the abatement of the excess-voltage surge.

8. A device for interrupting the flow of electric current in a first conductor of an electric circuit, comprising, in combination, a capacitor having a first terminal connected to said first conductor of the electric circuit, a resistor connecting a second terminal of the capacitor to a second conductor of the electric circuit, an arc-type circuit-interrupting device associated with said first conductor and comprising means for establishing a plurality of serially connected arcs for carrying the current flowing in said conductor, means operative subsequently to the establishment of said arcs for effecting a connection between said arc-type circuit-interrupting device and said second terminal of the capacitor for applying at least a portion of the total arc-voltage across said capacitor, said capacitor being of a size at least sufficient to reduce the corresponding arc-current to a value sufficiently small to extinguish the corresponding arcs under predetermined operating-conditions of the device, and a valve-type lightning-arrester means in shunt-relation to at least a portion of said serially connected arcs.

9. An arc-type circuit-interrupting device comprising an initial arcing-chamber, a plurality of spaced conducting plates having edges thereof presented towards said initial arcing-chamber, means for establishing an arc in said initial arcing-chamber, arc-moving means for causing said arc to move from said initial arcing-chamber into the spaces between said plates and to continue to move away from said initial arcing-chamber within said spaces, one of said plates being, in effect, a two-part plate, having a first arcing-member against which the moving arc first plays, and a second arcing-member spaced from the first arcing-member further away from the initial arcing-chamber, and a capacitive-impedance means permanently connected in parallel between said second arcing-member and another plate which is a plurality of plates removed therefrom, said capacitive-impedance means being such as to draw a predetermined charging-current when the moving arc strikes the second arcing-member, said predetermined charging-current being at least sufficient to reduce the current in the arcs between the shunted plates to a value sufficiently small to extinguish the last-mentioned arcs under predetermined operating-conditions of the device.

10. An arc-type circuit-interrupting means comprising an initial arcing-chamber, a plurality of spaced conducting plates having edges thereof presented towards said initial arcing-chamber, means for establishing an arc in said initial arcing-chamber, arc-moving means for causing said arc to move from said initial arcing-chamber into the spaces between said plates and to continue to move away from said initial arcing-chamber within said spaces, one of said plates being, in effect, a two-part plate, having a first arcing-member against which the moving arc first plays, and a second arcing-member spaced from the first arcing-member further away from the initial arcing-chamber, a capacitive-impedance means permanently connected in parallel between said second arcing-member and another plate which is a plurality of plates removed therefrom, said capacitive-impedance means being such as to draw a predetermined charging-current when the moving arc strikes the second arcing-member,

said predetermined charging-current being at least sufficient to reduce the current in the arcs between the shunted plates to a value sufficiently small to extinguish the last-mentioned arcs under predetermined operating-conditions of the device, and an excess-voltage-discharging means in shunt-relation to said capacitive-impedance means, said excess-voltage-discharging means having a sufficiently low breakdown-voltage and a sufficiently high discharge-current capacity to limit the excess-voltage surge of recovery-voltage to a value insufficient to restrike the extinguished arcs under predetermined operating-conditions of the device, and said excess-voltage-discharging means having a discharge-interrupting capacity sufficient to substantially interrupt its discharge after the abatement of the excess-voltage surge.

11. An arc-type circuit-interrupting device comprising an initial arcing-chamber, a plurality of spaced conducting plates having edges thereof presented towards said initial arcing-chamber, means for establishing an arc in said initial arcing-chamber, arc-moving means for causing said arc to move from said initial arcing-chamber into the spaces between said plates and to continue to move away from said initial arcing-chamber within said spaces, one of said plates being, in effect, a two-part plate, having a first arcing-member against which the moving arc first plays, and a second arcing-member spaced from the first arcing-member further away from the initial arcing-chamber, a capacitive-impedance means permanently connected in parallel between said second arcing-member and another plate which is a plurality of plates removed therefrom, said capacitive-impedance means being such as to draw a predetermined charging-current when the moving arc strikes the second arcing-member, said predetermined charging-current being at least sufficient to reduce the current in the arcs between the shunted plates to a value sufficiently small to extinguish the last-mentioned arcs under predetermined operating-conditions of the device, and an excess-voltage-discharging means in shunt-relation to at least a portion of said plurality of plates.

12. An arc-type circuit-interrupting device comprising an initial arcing-chamber, a plurality of spaced conducting plates having edges thereof presented towards said initial arcing-chamber, one of said plates having its presented edge further away from said initial arcing-chamber than a plurality of others of said plates, means for establishing an arc in said initial arcing-chamber, arc-moving means for causing said arc to move from said initial arcing-chamber into the spaces between said plates and to continue to move away from said initial arcing-chamber within said spaces, and a capacitive-impedance means permanently connected in parallel between said one of said plates and another plate which is a plurality of plates removed therefrom, said capacitive-impedance means being such as to draw a predetermined charging-current when the moving arc strikes the presented edge of said one of the plates, said predetermined charging-current being at least sufficient to reduce the current in the arcs between the shunted plates to a

value sufficiently small to extinguish the last-mentioned arcs under predetermined operating-conditions of the device.

13. An arc-type circuit-interrupting device comprising an initial arcing-chamber, a plurality of spaced conducting plates having edges thereof presented towards said initial arcing-chamber, one of said plates having its presented edge further away from said initial arcing-chamber than a plurality of others of said plates, means for establishing an arc in said initial arcing-chamber, arc-moving means for causing said arc to move from said initial arcing-chamber into the spaces between said plates and to continue to move away from said initial arcing-chamber within said spaces, a capacitive-impedance means permanently connected in parallel between said one of said plates and another plate which is a plurality of plates removed therefrom, said capacitive-impedance means being such as to draw a predetermined charging-current when the moving arc strikes the presented edge of said one of the plates, said predetermined charging-current being at least sufficient to reduce the current in the arcs between the shunted plates to a value sufficiently small to extinguish the last-mentioned arcs under predetermined operating-conditions of the device, and an excess-voltage-discharging means in shunt-relation to said capacitive-impedance means, said excess-voltage-discharging means having a sufficiently low breakdown-voltage and a sufficiently high discharge-current capacity to limit the excess-voltage surge of recovery-voltage to a value insufficient to restrike the extinguished arcs under predetermined operating-conditions of the device, and said excess-voltage-discharging means having a discharge-interrupting capacity sufficient to substantially interrupt its discharge after the abatement of the excess-voltage surge.

14. An arc-type circuit-interrupting device comprising an initial arcing-chamber, a plurality of spaced conducting plates having edges thereof presented towards said initial arcing-chamber, one of said plates having its presented edge further away from said initial arcing-chamber than a plurality of others of said plates, means for establishing an arc in said initial arcing-chamber, arc-moving means for causing said arc to move from said initial arcing-chamber into the spaces between said plates and to continue to move away from said initial arcing-chamber within said spaces, a capacitive-impedance means permanently connected in parallel between said one of said plates and another plate which is a plurality of plates removed therefrom, said capacitive-impedance means being such as to draw a predetermined charging-current when the moving arc strikes the presented edge of said one of the plates, said predetermined charging-current being at least sufficient to reduce the current in the arcs between the shunted plates to a value sufficiently small to extinguish the last-mentioned arcs under predetermined operating-conditions of the device, and an excess-voltage-discharging means in shunt-relation to at least a portion of said plurality of plates.

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