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SERIES GAP DEVICE FOR LIGHTNING ARRESTERS

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Fig. 1.

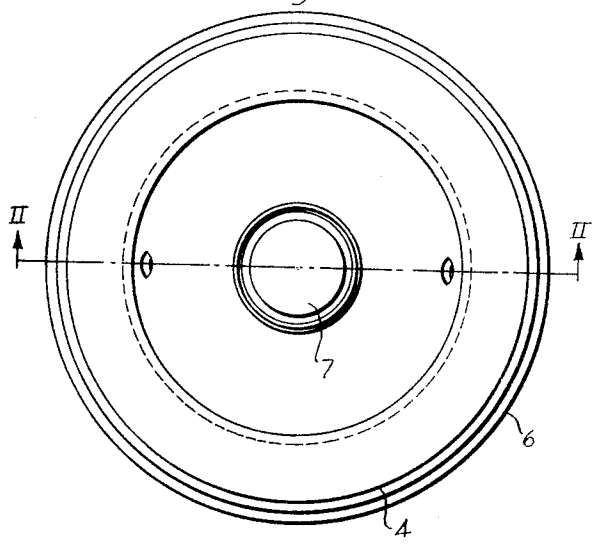
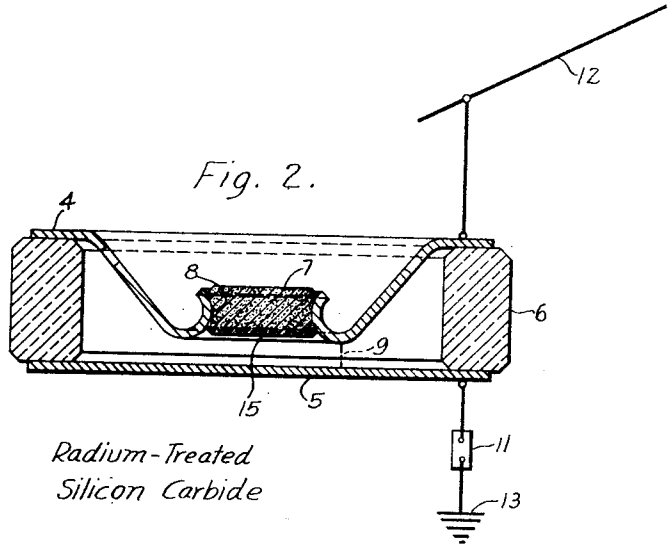


Fig. 2.



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SERIES GAP DEVICE FOR LIGHTNING ARRESTERS

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20 Claims. (Cl. 175—30)

My invention relates to protective discharge gaps, and it has particular relation to series-gap devices for lightning arresters. A lightning arrester has the property of changing from substantially an insulator, or at least from a very high resistance, to a fairly good conductor of electricity in response to a predetermined over-voltage, and of returning to its initial state, or at least reducing the discharge-current to a relatively small value, upon restoration of predetermined normal voltage conditions.

The function of the series-gap device to which my present invention applies is threefold: first, under normal conditions it keeps voltage from appearing across the arrester element; second, when a surge of predetermined over-voltage is applied, the series gap breaks down, allowing the passage of surge-current through the arrester; and third, after the surge-voltage has disappeared, the series gap interrupts the residual, or so-called power-follow, current flowing through the arrester, which is the aforesaid relatively small value of discharge-current which tends to flow in the arrester after the restoration of normal voltage-conditions. Accordingly, the series-gap device which would afford the greatest degree of protection to the electrical circuit or conductor to which the combined series gap and arrester is applied would be a gap which would consistently have the lowest possible breakdown-voltage when a surge is applied to it and which would still consistently have a sufficiently high 60-cycle, or normal-frequency, breakdown to prevent breakdown on the application of the normal line-voltage. In addition, the series-gap device must have adequate arc-interrupting or "quenching" ability.

Prior to my present invention, it has been common to utilize one or more series gaps having electrodes of brass or similar materials, in connection with lightning arresters. These gaps have adequate quenching or so-called "non-arcing" properties, but they have an undesirably high impulse-ratio, or ratio of surge-voltage breakdown to 60-cycle breakdown; and their surge-breakdown voltage has been inconsistent, making it difficult to predict the operation of the gap under various conditions.

Heretofore, any efforts made to reduce the impulse-breakdown of a gap have involved the difficulty of obtaining adequate arc-quenching properties, because a gap-electrode material which will break down at relatively low voltage will, in general, also tenaciously hold onto the arc after the arc has once formed, thus having poor arc-quenching qualities. There are a number of such substances which have been known to produce a gap-device having a relatively low impulse-breakdown voltage, such substances including crystalline substances such as silicon carbide, either with or without a binder, and radium-treated substances.

The object of my present invention is to make use of the desirable properties of such low-breakdown gap-electrode substances, while still retaining the required quenching ability of the series-gap device such as that which has been commonly in use in connection with lightning arresters prior to my present invention. I accomplish this by causing the low-breakdown substance to be utilized in a high-resistance form, and in close juxtaposition to a low-resistance gap-electrode material having good arc-quenching properties. The result of this combination is that the breakdown will occur according to the properties of the low-breakdown, high-resistance material, where the arc will first be initiated, but because of the high resistance of the material, the arc will be spread out over this material and transferred to the adjacent low-resistance electrode-member, so that a concentrated arc-discharge or arc is finally carried substantially only by the low-resistance electrode-member. This transfer of the arc occurs substantially instantaneously, or in an extremely short period of time, as the voltage of the arc which terminates on the low resistance electrode-material will be lower than the voltage necessary to maintain an arc terminating on the high-resistance electrode-material, so that the arc of the initial breakdown is extinguished, and the series-gap device has the same arc-interrupting properties as if the low-breakdown material had not been present.

With the foregoing and other objects in view, my invention consists in the combinations, structures and methods hereinafter described and claimed and illustrated in the accompanying drawing, wherein

Figure 1 is a plan view of a series-gap device in accordance with my invention, and

Fig. 2 is a cross-sectional view thereof, with a diagrammatic representation of electrical circuits and apparatus illustrating the application and use of my invention in connection with a lightning arrester for providing an excess-voltage protective device for an electrical circuit or conductor.

As shown in the drawing, my series-gap device comprises two main electrodes 4 and 5 which are made of brass or other low-resistance material

having good quenching or non-arcing properties. These electrodes are separated by annular or ring-shaped porcelain insulators 6.

One or both of the main electrodes 4 and 5 are provided with a closely associated auxiliary electrode 7 of low-breakdown properties but of such high resistivity that any arc formed thereon will immediately be transferred to its associated main electrode. In the particular embodiment of my invention which is shown in the drawing, only one of the main electrodes is provided with an auxiliary electrode 7, but it will readily be understood that the two main electrodes may be similar to each other.

In the form of my invention which is shown in the drawing, the central portion of the main electrode 4 is provided with a hole or perforation 8, into which is molded, under pressure, a plug 7 of high-resistance material which may consist of a large number of closely spaced silicon-carbide crystals or other conducting particles stuck together and to the electrode by a suitable binding material of fairly insulating qualities. The silicon-carbide plug 7 may also be radium-treated, or treated with a radio-active substance, or the radium treatment may be utilized without the utilization of silicon-carbide crystals, the latter being replaced by any substance or ingredient for giving the plug its desired high-resistance electrical conductivity. This high-resistance plug 7 is closely associated with its main gap-electrode 4, so that both elements are spaced from the other main electrode 5 by approximately the same gap or distance 9, although the gap-length or spacing between the high-resistance plug 7 and the other main electrode 5 from which it is spaced is preferably slightly greater than the main-electrode gap-spacing 9, as shown on the drawing.

It is usually desirable that the height or axial length of the spacer-ring 6 shall be considerably greater than the gap-spacing 9, and to this end one or both of the main electrodes are dished inwardly. In the embodiment shown, the main electrode 4 which carries the silicon-carbide plug 7 is centrally dished, so as to approach to the distance 9 from the other main electrode 5, which is flat. In the center of this dished portion the hole 8 is punched, and the material surrounding the edges of the hole is punched backwardly, away from the other main electrode 5, so as to leave a rounded annular portion of the main electrode 4, surrounding the plug 7, for providing the main gap 9.

One or more of the above-described series-gap devices are utilized in series with one or more lightning-arrester elements as diagrammatically indicated at 11, the whole being connected between the electrical circuit or conductor 12 which is to be protected, and the ground 13, the number of serially connected devices depending upon the voltage.

When a voltage is applied to the series-gap device, and increased in magnitude, the material of the plug 7 will give off free electrons at a lower average voltage-gradient than the material of the main electrode-portions 4 and 5, and the presence of these electrons affects the breakdown of the gap. It has been found that this effect is most noticeable on the breakdown characteristics of the gap under surge-conditions, resulting in a uniformly low breakdown of the gap under surge conditions. When voltage is first applied to the series-gap device, the plug 7, prior to the breakdown of the gap, assumes substantially the same potential as the main electrode 4 with which it is associated. The rising potential on this electrode causes capacitive charging-current to flow across the gap 9 between the plug 7 and the other main electrode 5, and it is necessary for this charging current to pass from the main electrode 4 through the interior of the plug 7 to the gap-terminal surface thereof. This passage of current through the plug 7 may produce high potential-gradients between the conducting particles or crystals, and these potential-gradients liberate electrons which influence the breakdown-voltage of the gap and cause it to be consistently low in comparison to the breakdown-voltage of a gap made altogether with the material of the two main electrodes 4 and 5 without the plug-insert 7.

Once the arc has been formed, there will be a considerable resistance-drop caused by the flow of any arc-current through the high-resistance material of the plug 7, and moreover the high resistivity of the arc-terminal surface 15 of the plug 7 will cause the terminal of the arc to spread out on this surface, rather than concentrating in a small area thereof, so that any arc which is formed on the surface of the plug 7 will immediately transfer to the adjacent surface of the associated electrode 4, this transfer being facilitated by the slight difference between the gap-spacings of the main and auxiliary electrodes. This not only prevents excessive heating of the high-resistance plug 7, but it causes the series gap device to retain the same arc-quenching ability which it would have had if the auxiliary plug 7 had not been utilized.

Comparative tests with my new gap-devices, as compared to previous gap-devices, has shown that none of the gaps, new or old, has an absolutely fixed breakdown-voltage which is the same for all gaps which, so far as can be determined without a breakdown-test, are identical with each other. Like most other physical properties of materials, the breakdown-values of a large number of apparently similar gaps are scattered, some high and some low. With the old gaps, not only is the average breakdown-value higher, but the range between high and low values is greater, than in my new gaps. I have found that my new gaps with radium-treated silicon-carbide plugs have a somewhat less scattered range of surge-breakdown-values, or a more consistently predictable breakdown, for a given gap-spacing, than my new gaps with non-radium-treated silicon-carbide plugs; while the surge-breakdown-values of the latter are, in turn, enormously less scattered, or more consistent, and also much lower in average value, than the old gaps without any silicon-carbide plugs.

When I refer to an arc-initiating function or operation, I mean to include also a spark-initiating function or operation, without fine discriminations as to whether the initial discharge is a spark or an arc.

I claim as my invention:

1. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of said main electrode, said relatively poor-conducting material containing a radio-active substance and having such poor con-

ductivity as to be incapable of maintaining an arc on its surface in the presence of the main electrode.

2. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of said main electrode, said relatively poor-conducting material comprising a small amount of radio-active substance, a binding material of fairly insulating qualities, and a large number of closely spaced conducting particles dispsersed therein.

3. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of said main electrode, said relatively poor-conducting material comprising a small amount of radio-active substance, a binding material of fairly insulating qualities, and a large number of closely spaced silicon-carbide particles dispersed therein.

4. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression, said arc-initiating substance comprising relatively poor-conducting material containing a radio-active substance and having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of the main electrode.

5. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression, said arc-initiating substance comprising relatively poor-conducting material comprising a small amount of radio-active substance, a binding material of fairly insulating qualities, and a large number of closely spaced conducting particles dispersed therein.

6. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression, said arc-initiating substance comprising a small amount of radio-active substance, a binding material of fairly insulating qualities, and a large number of closely spaced silicon-carbide particles dispersed therein.

7. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of, and in electrical connection to, said associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said relatively poor-conducting material having better discharge-initiating qualities than the material of said associated main electrode but having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

8. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of, and in electrical connection to, said main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said relatively poor-conducting material having an exposed discharge-gap surface which emits electrons at a lower average voltage-gradient than said associated main electrode but having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

9. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of, and in electrical connection to, said associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said relatively poor-conducting material comprising a binding material of fairly insulating qualities and a large number of closely spaced conducting particles dispersed therein, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

10. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of, and in electrical connection to, said associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said relatively poor-conducting material comprising a binding material of fairly insulating qualities and a large number of closely spaced silicon-carbide particles dispersed therein, whereby the arc after initiation

is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

11. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said arc-initiating substance comprising relatively poor-conducting material having better discharge-initiating qualities than the material of said associated main electrode but having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

12. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said arc-initiating substance comprising relatively poor-conducting material having an exposed discharge-gap surface which emits electrons at a lower voltage than said associated main electrode but having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

13. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said arc-initiating substance comprising a binding material of fairly insulating qualities and a large number of closely spaced conducting particles dispersed therein, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

14. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said arc-initiating substance comprising a binding material of fairly insulating qualities and a large number of closely spaced silicon-carbide particles dispersed therein, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

15. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of, and in electrical connection to, said associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, the gap-length between said relatively poor-conducting material and said other electrode from which it is spaced being greater than the gap-length between the spaced main electrodes of the device, said relatively poor-conducting material having sufficiently better discharge-initiating qualities than the material of said associated main electrode to cause the arc to be initiated on said relatively poor-conducting material in spite of its relatively greater gap-length, said relatively poor-conducting material having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

16. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, and arc-initiating means associated with at least one of said main electrodes; said arc-initiating means comprising an auxiliary electrode of relatively poor-conducting material alongside of, and in electrical connection to, said associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, the gap-length between said relatively poor-conducting material and said other electrode from which it is spaced being greater than the gap-length between the spaced main electrodes of the device, said relatively poor-conducting material having an exposed discharge-gap surface which emits electrons at a sufficiently lower average voltage-gradient than said associated main electrode to cause the arc to be initiated on said relatively poor-conducting material in spite of its relatively greater gap-length, said exposed discharge-gap surface of the relatively poor-conducting material having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

17. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a

concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, the gap-length between said arc-initiating substance and said other electrode from which it is spaced being greater than the gap-length between the spaced main electrodes of the device, said arc-initiating substance comprising relatively poor-conducting material having sufficiently better discharge-initiating qualities than the material of said associated main electrode to cause the arc to be initiated on said relatively poor-conducting material in spite of its relatively greater gap-length, said relatively poor-conducting material having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

18. A series-gap device, comprising spaced main electrodes of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central depression therein, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, the gap-length between said arc-initiating substance and said other electrode from which it is spaced being greater than the gap-length between the spaced main electrodes of the device, said arc-initiating substance comprising relatively poor-conducting material having an exposed discharge-gap surface which emits electrons at a sufficiently lower average voltage-gradient than said associated main electrode to cause the arc to be initiated on said relatively poor-conducting material in spite of its relatively greater gap-length, said exposed discharge-gap surface of the relatively poor-conducting material having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

19. A series-gap device, comprising a spacer-ring, and a pair of spaced main electrodes disposed one on either side of said spacer-ring, said main electrodes being of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central dished portion approaching the other main electrode and having a central depression in said dished portion, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said arc-initiating substance comprising relatively poor-conducting material having better discharge-initiating qualities than the material of said associated main electrode but having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

20. A series-gap device, comprising a spacer-ring, and a pair of spaced main electrodes disposed one on either side of said spacer-ring, said main electrodes being of relatively good-conducting material capable of becoming the terminal of a concentrated arc-discharge and having adequate quenching properties, at least one of said main electrodes having a central dished portion approaching the other main electrode and having a central depression in said dished portion, and an arc-initiating substance disposed within said depression in electrical-contact relation to the associated main electrode and spaced entirely in non-contacting, discharge-gap relation to the other electrode, said arc-initiating substance comprising relatively poor-conducting material having an exposed discharge-gap surface which emits electrons at a lower voltage than said associated main electrode but having such poor conductivity as to be incapable of maintaining an arc on its surface in the presence of said associated main electrode, whereby the arc after initiation is transferred to said associated main electrode, and means for conducting current directly to and from the terminal main electrodes during the continuance of said arc.

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