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James

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[54] **ELECTRICAL SWITCHING ARRANGEMENTS**

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[30] **Foreign Application Priority Data**

July 21, 1970 Great Britain 35,388/70

[52] **U.S. Cl.** **313/325,** 313/217
[51] **Int. Cl.** **H01j 17/04**
[58] **Field of Search** 313/217, 325; 315/36

[56] **References Cited**

UNITED STATES PATENTS

2,290,526 7/1942 Berkey et al. 313/217
3,230,410 1/1966 Hafkemeyer et al. 313/217

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Assistant Examiner—Darwin R. Hostetter
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[57] **ABSTRACT**

Various spark gap switches are disclosed in which an arc is caused to be struck, at a desired switching instant, between two electrodes. The electrodes are constructed so that a surface of one electrode faces an annular edge of the other, and a pronounced change in inter-electrode spacing occurs at this annular edge. The resultant magnetic forces produced at the annular edge when the arc is struck tend to hold the arc in a desired position. In some forms of the switches, the electrodes are generally planar. In others, one electrode is at least partially embraced by the other so as to define a semi-enclosed region within which the magnetic forces retain the arc.

6 Claims, 10 Drawing Figures

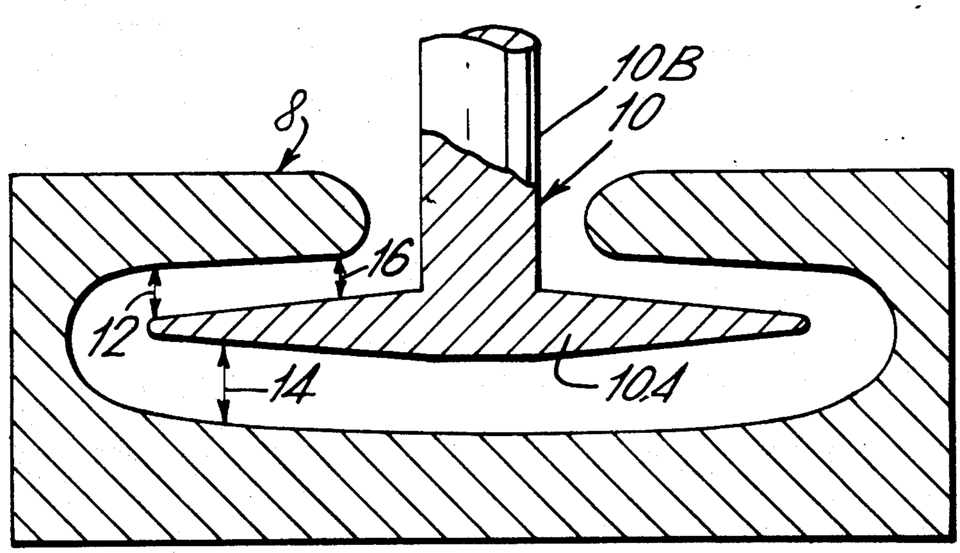


Fig. 1.

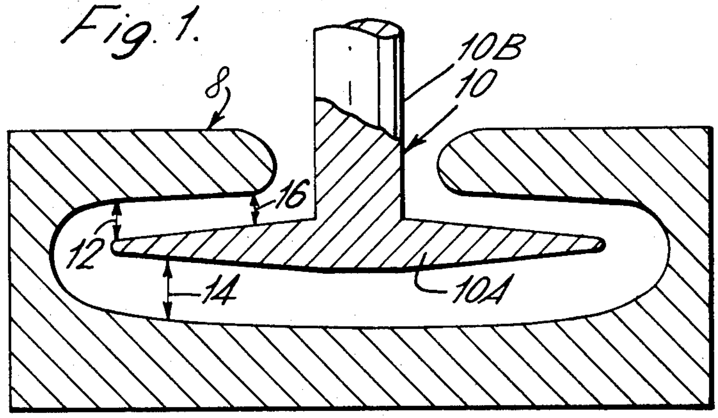


Fig. 2A.

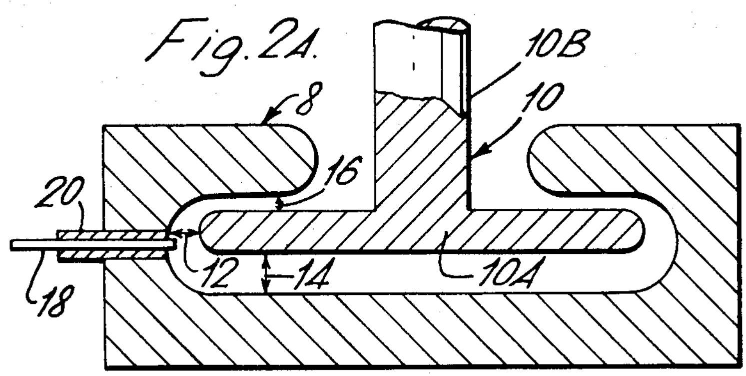


Fig. 2B.

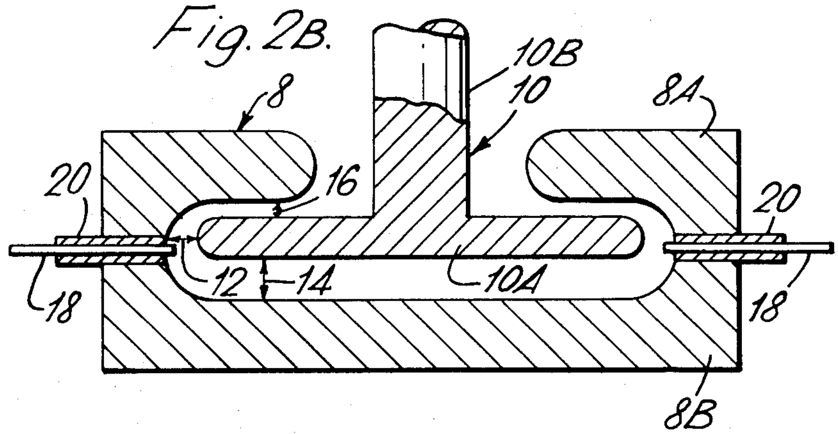


Fig. 2c.

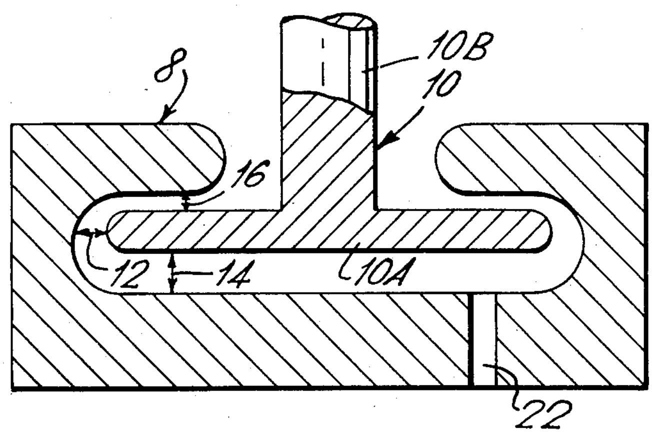


Fig. 2D.

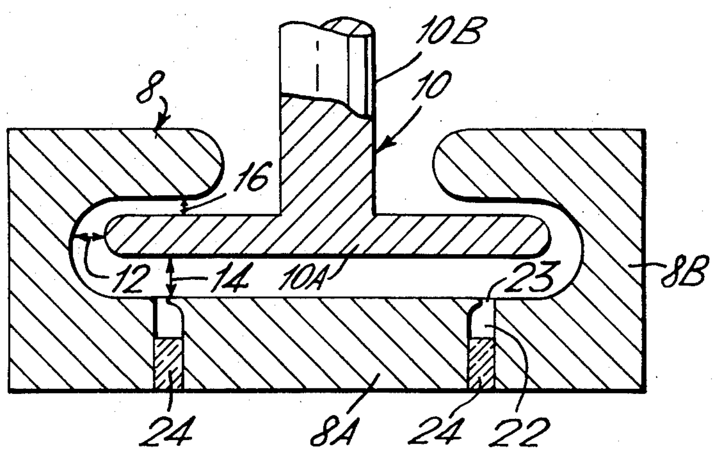


Fig. 3A.

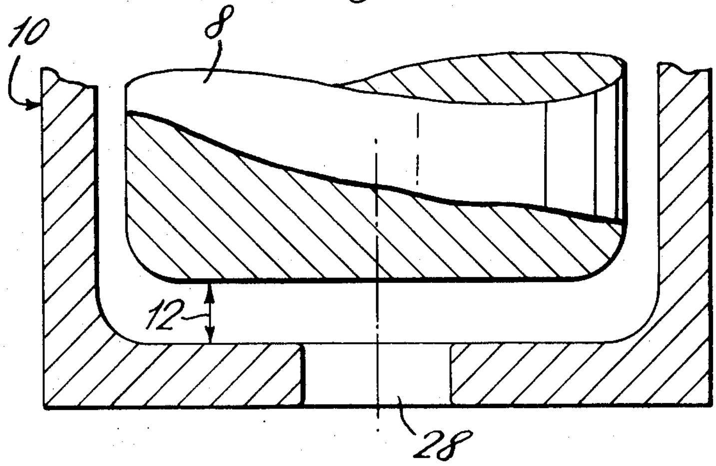


Fig. 3B.

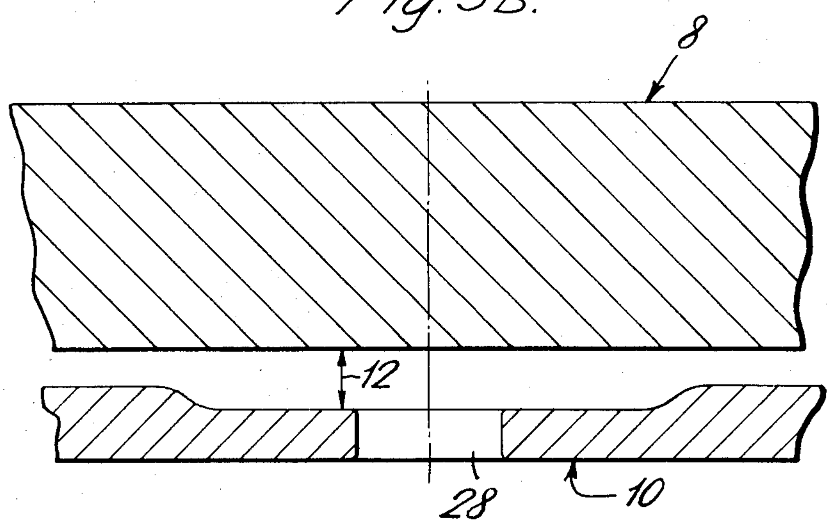


Fig. 4.

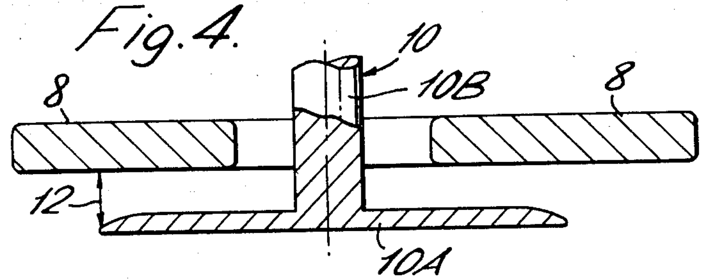


Fig. 5A.

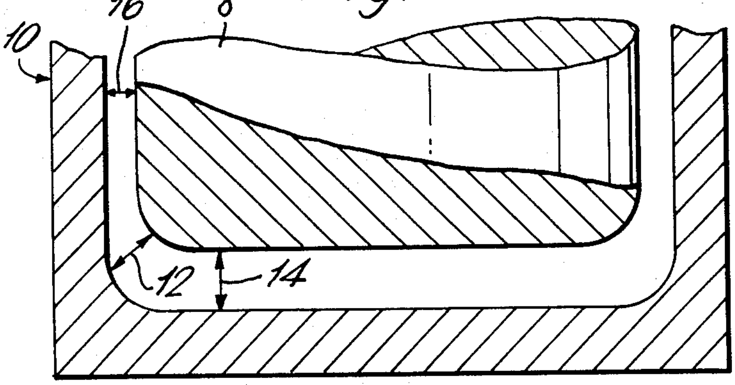
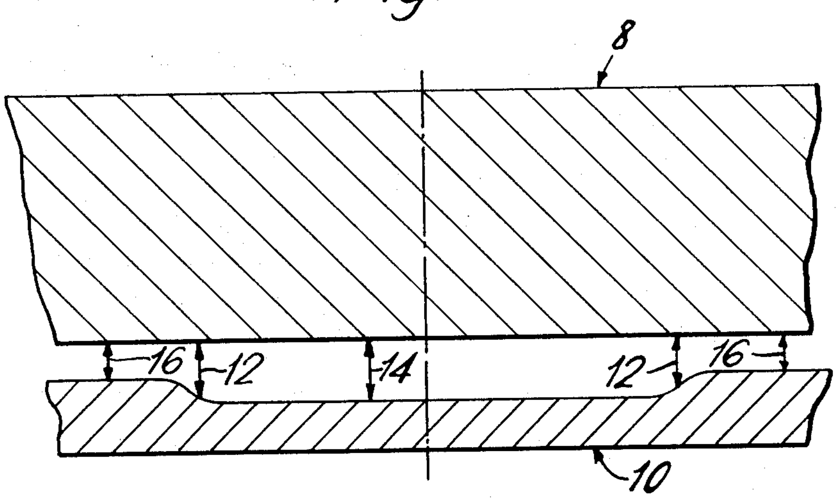


Fig. 5B.



ELECTRICAL SWITCHING ARRANGEMENTS

BACKGROUND OF THE INVENTION

The invention relates to spark gap apparatus, and more particularly to spark gap switches in which an arc is struck, at a desired switching instant, between two electrodes.

BRIEF SUMMARY OF THE INVENTION

According to the invention, there is provided spark gap apparatus, comprising first and second electrodes in which a surface of the first electrode faces an annular edge on the second electrode which edge defines a pronounced change in inter-electrode spacing, and means for applying an electrical potential difference between the electrodes such that the magnetic forces acting on an arc produced therebetween at the annular edge tend to limit the directions of movement of the arc.

According to the invention, there is further provided spark gap switch apparatus, comprising first and second electrodes having a pronounced and symmetrical change in spacing between them so as to define a semi-enclosed region between them, whereby magnetic forces acting on an arc set up between the electrodes tend to retain the arc within the said region.

BRIEF DESCRIPTION OF THE DRAWINGS

Spark gap switches embodying the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic cross-section through one spark gap embodying the invention;

FIG. 2A to 2D are diagrammatic cross-sections through variants of a further spark gap switch embodying the invention;

FIGS. 3A and 3B are diagrammatic cross-sections through two variants of another spark gap switch embodying the invention; and

FIGS. 4, 5A and 5B are diagrammatic cross-sections through further spark gap switches embodying the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The spark gap switches to be discussed are for switching high currents for long pulse times and, if required, with high accuracy of timing. In each case, a gap is provided between two electrodes, and, in a manner to be described, the current is caused to flow across the gap, at the instant required, in the form of an arc.

In the spark gap switch of FIG. 1, two electrodes 8 and 10 are provided. Electrode 10 is in the form of a disc-shaped portion 10A and a supporting rod 10B. The rod 10B is fixedly mounted relative to the electrode 8 and separated therefrom by electrical insulation not shown. The spacing between the electrodes is non-uniform, such that the length of the gap 12 between them is less than the length of the gap 14 and preferably greater than the length of the gap 16. In addition, the peripheral edge of the disc 10A is of reduced thickness to give a non-uniform electric field in the gap when a potential difference exists between the electrodes, the thickness of the edge being small compared to the inter-electrode spacing.

In operation, a discharge between the electrode 8, 10 can be initiated in one of a number of ways. For example, a high potential difference may suddenly be applied between the electrodes 8 and 10. This high potential can be applied by suddenly raising one of the electrodes from zero volts; instead a steady potential difference, not quite sufficient to break down the gap between the electrodes can be applied between them, a voltage pulse then being applied to one of the electrodes sufficient to raise the potential difference to the breakdown value. Alternatively, a steady potential difference, again not quite sufficient to cause breakdown, can be applied between the electrodes and then the spacing or gas pressure between the electrodes can be suddenly reduced to cause breakdown to occur, or the actual gas can be changed from one having a relatively good resistance to electrical breakdown to one having a relatively poorer resistance to electrical breakdown (e.g. from compressed air to argon or from SF_6 to air) so as to cause breakdown to occur; these methods are not so satisfactory when very high timing accuracy is required.

Whichever method is used, the intense non-uniform electric field set up at the edge of the disc 10A causes breakdown to occur across the gap 12, so that an arc is struck here. The resultant magnetic force produced by the arc and the electrode currents is such that, provided the arc current and the lengths of time for which it is maintained are sufficient, the arc is caused to shift around the peripheral edge of the disc 10A until it reaches the gap 14, this being the position of maximum inductance, that is, maximum arc length. If the arc current and/or its time of existence is not sufficient to cause the arc to move round to the gap 14, it will remain in the gap 12. In either case, however, it will not move to or through the narrow gap 16.

Thus, the arc is held in a confined position remote from the electrical insulation separating electrodes, and the damage to the insulation by the arc will thus be minimised. Furthermore, the position in which the arc is initially maintained traps erosion products within the inter-electrode space.

The shape of the disc 10A is such that erosion caused by the arc initiation is spread round the periphery of the disc 10A. The life of the electrode 10 can therefore be made as long as necessary by choosing a sufficiently large diameter for the disc 10A. Erosion of the disc 10A merely reduces the diameter of the disc while maintaining approximately the same gap dimensions, and the life of the electrode 8 is also prolonged. Thus, triggering performance, voltage hold-off, and arc voltage will not vary as a result of erosion until the disc diameter becomes very small. These factors combine to increase the life of the switch.

The spark gap switch FIGS. 2A to 2D is generally similar to that of FIG. 1, and similar parts are similarly referenced; as shown, the disc 10A of FIGS. 2A to 2D arrangement has a fatter cross-section than that in FIG. 1. FIG. 2A shows one method by which an arc discharge can be initiated. Here, an additional electrode 18, which is electrically insulated by insulation 20 from the electrode 8, is used. A potential difference (which may be zero), insufficient to cause breakdown, is applied between the electrode 8 and 10. At the desired switching instant, a potential is suddenly applied to electrode 18, and causes breakdown to occur initially either between electrode 18 and electrode 10 or between 18 and electrode 8 and subsequently between the electrode 8 and 10.

FIG. 2B shows a modification in which two or more auxiliary electrodes 18 are provided. This may be advantageous in that it prolongs the life of disc 10A and the electrode 18 by initiating breakdown at more than one point around the periphery of the disc. Instead of the two electrodes 18 in FIG.2B being separate, they may be in the form of a single annular ring electrode which physically divides electrode 8 into two parts 8A and 8B.

FIG. 2C shows another variant. Again, a potential difference (which may be zero) insufficient to cause breakdown is applied between electrodes 8 and 10. At the desired switching instant, a plasma jet is injected through an orifice 22, and breaks down the gap 14 causing an arc to be established between electrodes 8 and 10. More than one orifice 22 may be provided and this may be advantageous in that breakdown can be initiated at a number of points around the disc 10A thus prolonging electrode life.

FIG. 2D illustrates a further way in which an arc can be struck. If the orifice 22 is made annular in form, the electrode 8 is separated into two electrically isolated electrodes 8A and 8B. An arc can thus be struck between these two electrodes across the gap provided by the orifice. This is achieved by connecting a capacitor of the required energy between parts 8A and 8B, and applying a voltage pulse to either electrode 8A or 8B. The resultant magnetic force on the auxiliary arc moves it towards disc 10A so that if a potential difference is applied between electrodes 8 and 10, breakdown will occur across gap 14. To ensure that the auxiliary arc is initiated at gap 23 after erosion has taken place, it may be advantageous to have a disc-shaped outer edge to either electrode 8A or 8B at gap 23 as shown or place an insulator 24 between parts 8A and 8B, or both the disc-shaped edge and the insulator can be used together. Alternatively, an auxiliary annular electrode placed between electrodes 8A and 8B, as for example shown in FIG. 2B by electrode 18, will ensure that the auxiliary arc is struck across gap 23. In this case, breakdown is initiated between electrode 8A and 8B by applying a voltage pulse to electrode 18.

FIGS. 3A and 3B show two variants of a further spark gap switch, and again parts similar to those in FIG. 1 are similarly referenced. In the variant of FIG. 3A, the electrode 10 does not have a disc-shaped portion but is cup-shaped with a hole 28 whose annular edge faces the electrode 8, which is in the form of a cylindrical solid, and produces a pronounced change in inter-electrode spacing. When an arc is struck at the gap 12, using one of the methods previously described, the effect of the annular edge is to create magnetic forces which tend to drive the arc towards the centre of the hole; the arc is therefore prevented from damaging the insulation (not shown) separating the upper parts of the electrodes. The configuration of the variant of FIG. 3A, however, is such that erosion products are not so well retained within the gap as in the embodiments of FIGS. 2A and 2B.

In the variant of FIG. 3B, the two electrodes simply comprise two generally flat plates as shown with electrode 10 being provided with a hole 28 whose annular edge faces the electrode 8 across the gap 12 and has the same effect as in FIG. 3A. Again, the arc is struck across the gap 8 at the desired switching instant, by any one of the methods described above, and the configuration retains the arc at the centre of the spacing. Here, the erosion products are also more or less retained within the spacing.

In FIGS. 3A and 3B, the holes 28 can be replaced by circular recesses facing the lower ends of the electrodes 8.

The embodiment of FIG. 3B can be modified by inserting a rod upwardly through the hole 28 to provide electrical connection to the electrode 8. In a further modification, a plurality of holes 28 can be formed in the electrode 10, each such hole facing the electrode 8. Each such hole can have a rod through it.

In FIG. 4, the electrode portion 10A is of disc-like form with a thickness less than the inter-electrode spacing, while the electrode 8 is of planar form. As before, the arc is struck across the inter-electrode gap 12 by one of the methods described above, and the non-uniform field existing at the annular edge of priphery of the disc 10A helps to give a rapid striking action and reduces erosion of the two electrodes. As shown, the electrode 8 is annular in form, and again the magnetic forces set up on the arc ensure that the end of the arc on electrode 8 tends to move outwardly along electrode 8. The spacing between electrode 8 and disc portion 10A can be uniform or can increase in a radially outward direction.

FIGS. 5A and 5B respectively show variants of the further spark gap switches of FIGS. 3A and 3B; parts similar to those in FIGS. 3A and 3B are similarly referenced. In the variant of FIG. 5A, the spacing between the electrodes is uniform along the horizontal and is also uniform, but smaller, along the vertical. At the desired switching instant, an arc is struck at the gap 14 using one of the methods previously described. Because of the small size of the gap 16 as compared with the gaps 12 and 14, the arc is prevented from moving to or through the gap 16; the arc is therefore prevented from damaging the insulation (not shown) separating the upper parts of the electrodes.

In the variant of FIG.5B, the horizontal spacing between the electrodes 8 and 10 is not uniform. In this variant, the two electrodes may simply comprise two generally flat plates as shown. Again the arc is struck across the gaps 12 or 14, at the desired switching instant, by any one of the methods described above, and the configuration of the inter-electrode spacing retains the arc at the centre of the spacing. Here, the erosion products are also more or less retained within the spacing.

It will be appreciated that the semi-enclosed configuration shown in FIGS. 1 to 2D and 5A and 5B and in the versions of FIGS. 3A and 3B in which the holes 28 are replaced by recesses are advantageous over the open forms of FIG. 4, in that they provide a predetermined maximum impedance for the arc and lend themselves to operation under pressurized conditions.

What is claimed is:

1. Spark gap switch apparatus, comprising
   - a first electrode of a disc shape defining first and second opposed surfaces,
   - a second electrode including an annular surface defining a hole therein.
   - the first electrode being mounted with one of said surfaces facing and overlapping the said annular surface and hole of the second electrode with the periphery of said one surface defining a pronounced change in inter-electrode spacing, and

means for applying an electrical potential difference between the electrodes to produce an arc therebetween, said means including a conductive rod connected to the first electrode and directed transversely of said one surface of the first electrode to pass through the hole in the second electrode with the current flow in the arc and electrode surfaces producing magnetic forces acting on the arc which tend to keep the arc away from the said hole.

2. Apparatus according to claim 1, in which the second electrode at least partially embraces the first electrode.

3. Apparatus according to claim 2, in which the inter-electrode gap increases in a direction away from the periphery of the hole in the second electrode, so as to tend to move the arc away from the rod.

4. Apparatus according to claim 1, in which the periphery of said first electrode has a thickness which is small compared to the inter-electrode gap.

5. Apparatus according to claim 1, including striking means for striking the said arc at a desired switching instant.

6. Spark gap switch apparatus, comprising

a first disc-shaped electrode,

a second generally cup-shaped electrode, a curved upper end portion of the side wall of the cup extending transversely to the cup axis so as to partially close off and top of the cup and to define a hole through which the said cup axis passes,

an electrically conductive rod attached to the first electrode and extending transversely to the surface thereof and supporting the first electrode inside the cup defined by the second electrode with a major surface of the disc-shaped first electrode overlapping the upper end portion of the second electrode and with the rod extending out through the said hole defined by the second electrode such that the inter-electrode gap increases towards the periphery of the first electrode, and

means for striking an arc between the electrodes which produces magnetic forces tending to retain the arc inside the cup and away from the said hole.

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