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Rich

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[54] **SHIELD STRUCTURE FOR VACUUM ARC DISCHARGE DEVICES**

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[52] **U.S. Cl.** **313/240,** 313/174, 313/188, 313/241, 313/242

[51] **Int. Cl.** **H01j 1/53**

[58] **Field of Search** 313/174, 188, 196, 242, 313/243, 282, 290, 241, 240

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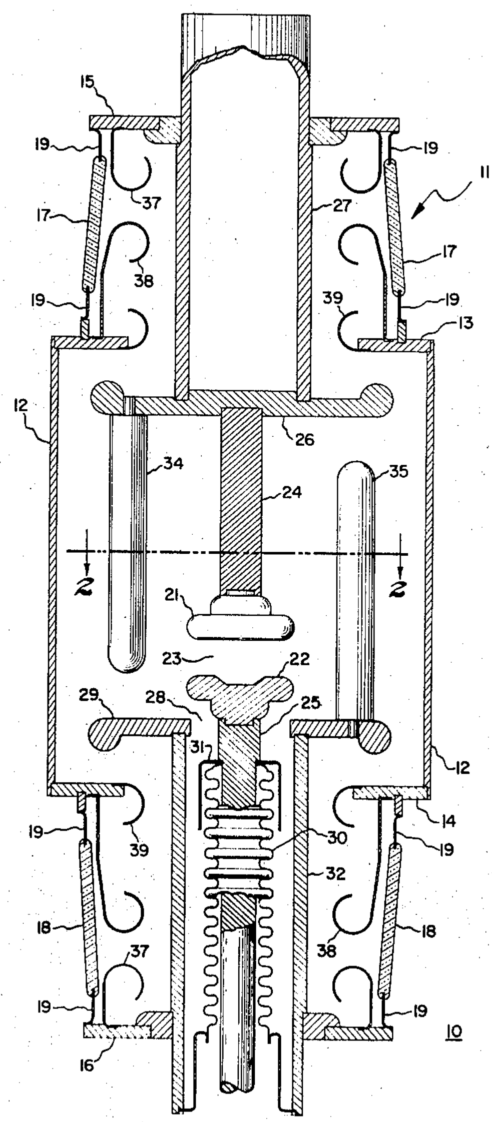
[57] **ABSTRACT**

Vacuum arc discharge devices having improved arc shielding characteristics are disclosed. Such improved devices comprise a vacuum sealed envelope comprising a cylindrical metallic member which functions not only as a part of the vacuum envelope, but as a shield for collecting molten metallic particles produced during high current arcing. Various embodiments of interleaved arcing electrodes which provide high current and high voltage capabilities in a fixed diameter envelope are also disclosed.

9 Claims, 6 Drawing Figures



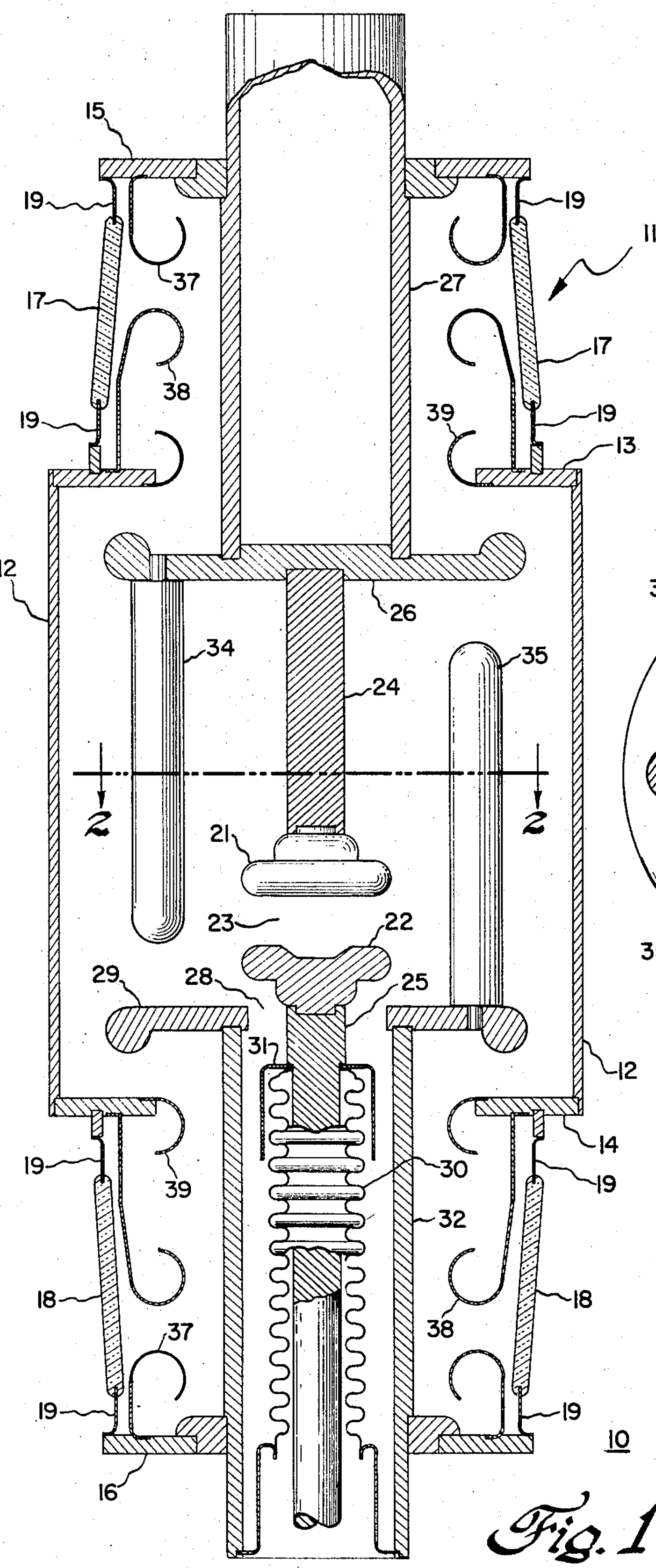

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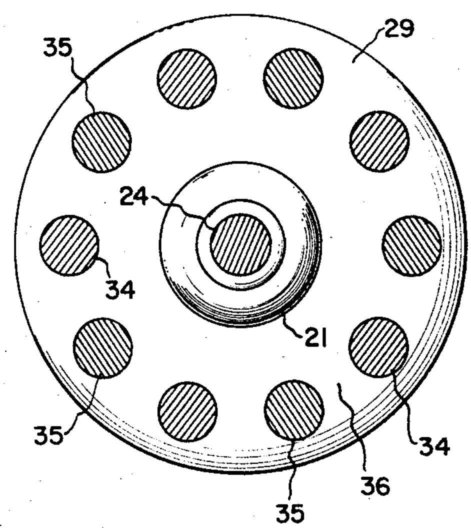
Fig. 1

Fig. 2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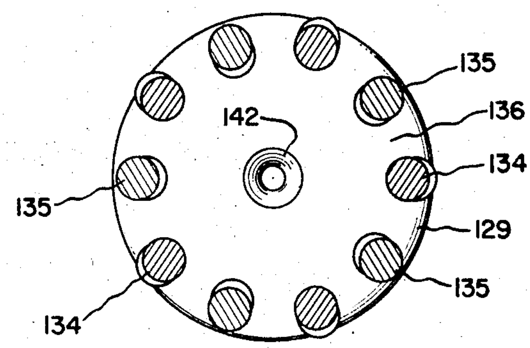
135
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142
134
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Fig. 4

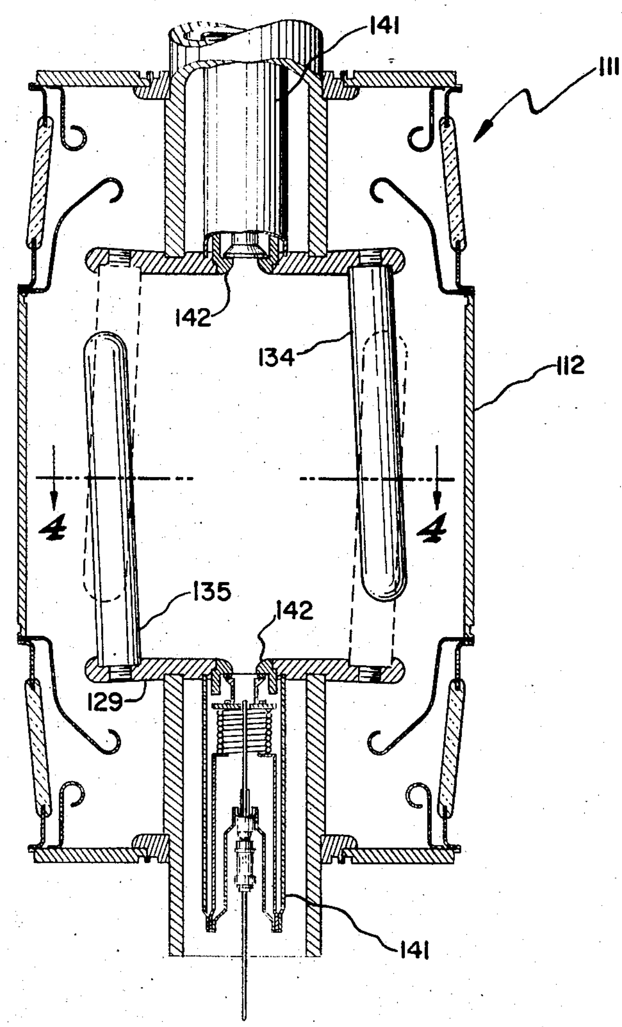
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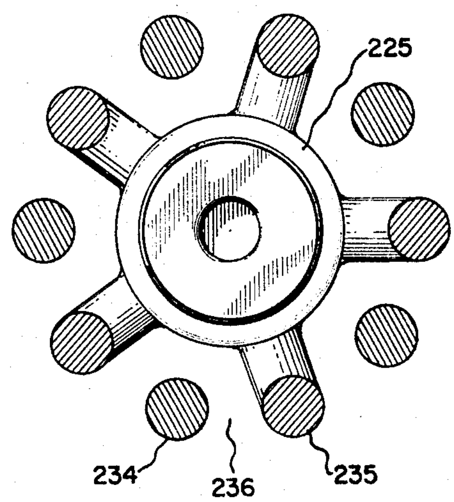
Fig. 3

Fig. 6



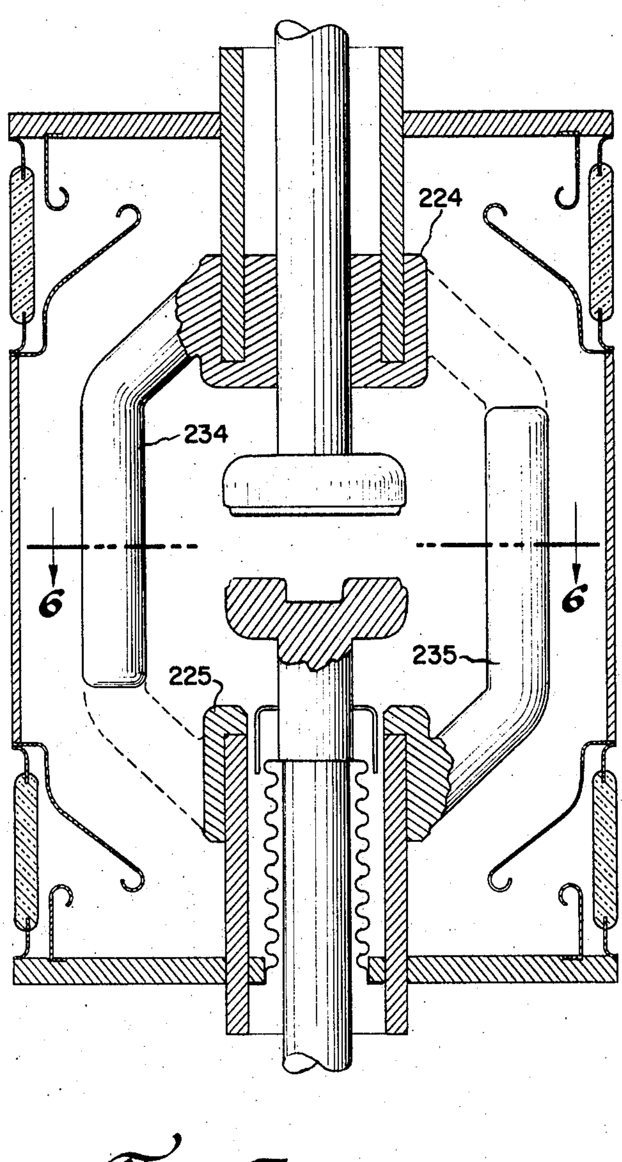


Fig. 5

SHIELD STRUCTURE FOR VACUUM ARC DISCHARGE DEVICES

The present invention relates to improved vacuum arc devices utilized to protect electrical apparatus by the interruption of current with a high current electric arc. More particularly, the invention relates to such improved devices as vacuum gaps, triggerable vacuum gaps, vacuum switches, and the like, wherein a rod array structure of interleaved individual arc electrode members presents a large arcing surface for the attainment of high current and low current density power arcing characteristics.

In the field of vacuum arc devices, there is a continuing effort to develop vacuum gap devices which are capable of conducting arcing currents in excess of 200,000 amperes (peak) during overload conditions with the additional requirement of providing such arcing currents at voltages in excess of 38 kV. Superimposed on these requirements are the elements of cost and size. In general, it has been found that the cost of a vacuum arc device increases in proportion to the square of the diameter and, hence, it is essential to minimize the diameter of the structure to provide an economical vacuum arc device. However, this requirement conflicts with the requirement for high voltage capability which necessarily requires wide spacing between electrodes to prevent undesired arcing therebetween. In my copending application Ser. No. 347,071, filed Apr. 2, 1973, now U.S. Pat. No. 3,798,484, and of common assignee as the instant invention, an improved vacuum arc discharge device adapted to carry high currents at increased voltage levels is made possible through the use of series-connected arc-electrode assemblies each comprising interleaved electrodes for providing uniform current conduction during the arcing time. In one embodiment of that invention, two pairs of coaxially aligned switch contacts are provided for interrupting the current flow in a high voltage electrical circuit. The two pairs of electrical contacts provide the increased spacing between electrodes to provide the necessary voltage breakdown protection.

While the apparatus described in the aforementioned patent application has proved to be a substantial advance over the prior art, a further improvement in its capability is desirable. In particular, increased current-carrying capability during the arcing period is clearly desirable. However, since the current-carrying capability of electrical contacts of a particular type material is a function of the mating surface areas, larger electrical contacts are required. This requirement, however, is not easily met within the constraints of a fixed diameter apparatus. Accordingly, by the invention herein disclosed, the voltage and current capacities of a vacuum arc device are increased without increasing the diameter of the apparatus.

It is, therefore, an object of this invention to provide increased voltage and current capacities of vacuum arc discharge devices while simultaneously limiting the diameter of the envelopes enclosing such devices.

It is a further object of this invention to provide increased voltage and current-carrying characteristics of vacuum arc discharge devices of both the vacuum switch type and the triggered gap.

It is also an object of this invention to provide vacuum arc discharge devices of low cost, improved cooling characteristics and in the case of a vacuum switch

type device, increased steady-state current-carrying capabilities.

Briefly, these and other objects of my invention are achieved in accord with one embodiment thereof wherein an improved vacuum arc discharge device is adapted to carry high currents at increased voltage levels without increasing the envelope diameter of such devices. That improved vacuum arc discharge device comprises a hermetically sealed, evacuated envelope having a pair of base plates disposed at opposite ends of the envelope. Within the envelope is a pair of primary arc-electrode assemblies each comprising a spaced circular array of cylindrical primary electrode members having smooth cylindrical arcing surfaces. Each assembly is supported at one of its ends by a support plate. The primary arc-electrode assemblies extending from each support plate are interleaved with one another to form a plurality of electrically parallel arcing paths, each of which is substantially free from magnetic fields transverse to the path of current conduction between the individual electrode members. In accord with the novel features of the present invention, the major portion of the envelope enclosing the interleaved primary arc-electrode assemblies comprises a cylindrical metallic member which functions not only as a part of the vacuum envelope, but as a shield for collecting molten metallic particles produced during the high current arcing times and as a heat sink for the device. By the elimination of the prior art insulating sidewall members and a concentrically located shield within said members, a larger volume is available within the evacuated envelope for the primary arc-electrode assemblies and for larger contacting electrodes for handling high "momentary" fault currents without suffering excessive erosion or damage.

In further accord with other novel features of my invention, selected primary arc-electrode configurations and selected location of the butt electrical contacts for vacuum switch configurations provide substantial improvements in performance at low cost.

The novel features believed characteristic of the present invention are set forth in the appended claims. The invention itself, together with further objects and advantages thereof, can best be understood with reference to the following detailed description, taken in connection with the accompanying drawings in which:

FIG. 1 is a vertical cross-sectional view, with parts broken away, of a vacuum switch constructed in accord with one embodiment of the present invention;

FIG. 2 is a horizontal sectional view taken along the lines 2—2 in FIG. 1;

FIG. 3 is a vertical cross-sectional view, with parts broken away, of a triggerable vacuum gap device constructed in accord with another embodiment of my invention;

FIG. 4 is a horizontal sectional view taken along the lines 4—4 of FIG. 3;

FIG. 5 is a vertical cross-sectional view of a vacuum switch device in accord with still another embodiment of my invention; and

FIG. 6 is a horizontal sectional view taken along the lines 6—6 of FIG. 5.

FIG. 1 illustrates a vacuum switch device constructed in accord with one embodiment of the present invention. In FIG. 1, a switch **10** comprises an evacuable envelope **11** including a metallic sidewall member **12** which is hermetically sealed to upper and lower flange members **13** and **14**, respectively. Spaced apart from the upper and lower flange members **13** and **14**, respectively, are upper and lower endwall members **15** and **16**. The endwall members **15** and **16** are connected to flanges **13** and **14** respectively, with insulating sidewall members **17** and **18**. The insulating sidewall members **17** and **18** are hermetically sealed to the respective upper and lower flanges **13** and **14** at one end and to the upper and lower endwall members **15** and **16** at the other end with metallic flanges **19** which are suitably welded, brazed, or otherwise affixed to flange members **13** and **14** and endwall members **15** and **16**. These flanges are embedded in suitable matching thermal coefficient of expansion seals within the respective ends of the insulating sidewall members **17** and **18** to provide a hermetically sealed envelope.

Within the envelope, a pair of primary arc-electrodes **21** and **22** which define an arcing gap **23** therebetween (when the primary arc-electrodes are in open circuit position), are supported upon respective arc-electrode support members **24** and **25**. Electrode support member **24** is fixed and is electrically and mechanically affixed to a metallic support plate **26** which in turn is supported from the upper endwall member **15** by a cylindrical support member **27**. Electrode support member **25** is reciprocally movable through an aperture **28** in a metallic support plate **29**. Vacuum integrity within the envelope **11** is maintained while permitting reciprocal mobility to arc-electrode support member **25** by means of a bellows assembly **30** affixed at flange **31** to electrode support member **25** and to cylindrical support member **32**. Support member **32** provides the main current conduction path during arcing, i.e., after arc initiation at the contacts and subsequent transfer to the secondary electrode assemblies **34** and **35**. During steady-state current flow, the current is carried through support member **27**, support plate **26**, electrode support **24**, contacts **21** and **22**, and electrode support **25**. An electrical connection, not shown, via a flexible conducting braid, for example, between electrode support **25** and cylindrical support member **32** serve as terminals to which the external power cables are connected.

Metallic support member **26** includes a plurality of downwardly-depending electrode members **34** and metallic support plate **29** includes a plurality of upwardly-depending electrode members **35**. Each of the electrode members **34** and **35** are smooth surfaced cylindrical rod-like members, preferably of solid construction, but may be hollow if desired. Each of the electrode members is arranged in a circular array so that an alternating ring-shaped structure produced by the alternation of downwardly-depending electrode members **34** and upwardly-depending electrode members **35** creates a plurality of interelectrode gaps **36**, illustrated more clearly in FIG. **2**. FIG. **2** is a cross-sectional view of FIG. **1** taken along the lines **2—2** of FIG. **1**.

The materials for contacts **21** and **22** are prepared from a high purity, high vapor pressure material, such as, for example, copper or any of the materials set forth in U.S. Pat. No. 2,975,256 to Lee et al. U.S. Pat. Nos. 2,975,255 and 3,016,436 to Lafferty, and U.S. Pat. No. 3,140,373 to Horn, and similar materials, alloys and intermetallic compounds which are operative to provide a copious quantity of metallic particles during arcing for supplying conduction carriers during operation of the device. The electrode materials for electrodes **34** and **35** are preferably hardened ferrous materials such as those described in U.S. Pat. No. 3,769,538 to L.P. Harris. Additionally, useful materials for the metallic sidewall member may be such materials as stainless steel, copper, nickel, or other weldable or bondable metals.

In operation of vacuum switch devices in accord with my invention, during steady-state current conditions, current is conducted centrally through the vacuum switch along the path defined by central support member **27**, arc-electrode support member **24**, butt contacts **21** and **22** which are in abutting relationship and support member **25**. When an overload condition occurs, the mating butt contacts are separated by the support member **25** and an arc is struck in the gap **23**. When the butt contacts **21** and **22** are a sufficient distance apart, the arc is transferred from the but contacts **21** and **22** to the rod electrodes **34** and **35**. This transfer is initially achieved by suitably shaping the butt contacts so as to obtain a "magnetic blow out" of the arc plasma. Once the arc is transferred to the rod electrodes **34** and **35**, it burns them preferentially because of the substantially lower arc drop across the rod array relative to the arc voltage drop across the butt contacts.

The plurality of high current arcs sustained by the overload current passing through the array of electrode members is sustained by a conductive plasma, comprising metallic particles from the electrode members **34** and **35**. This plasma permits the arcs to be transferred across the gaps **36** in each parallel conductive path until the value of arcing current passes through a zero value and conduction ceases, giving the specie of the plasma an opportunity to cool and condense upon the relatively cool surface of the sidewall member **12**. When the next cycle of alternating voltage is applied across the open contact electrodes, the high dielectric strength of the vacuum within the device prevents reestablishment of the current.

One of the significant advantages of constructing vacuum switch devices in accord with my invention is the dual function performed by the metallic sidewall member **12**. More specifically, the sidewall member **12** functions as part of the enclosure for the vacuum switch device and as a shield for collecting vaporized metallic particles produced during arcing. In prior art devices, the sidewall member is of an insulating material with a metallic shield placed between the insulating sidewall member and the electrode members **34** and **35**. However, in accord with my invention, the use of a metallic sidewall member eliminates the need for a costly insulating sidewall member. Further, the metallic sidewall member provides much better cooling than the insulating sidewall member which has comparatively poorer thermal conductivity characteristics.

Still another advantage of the use of a metallic sidewall member is the increased volume available within the evacuated envelope for larger diameter butt contacts. As pointed out previously, larger butt contacts permit higher current-carrying capabilities than smaller contacts. Still further, the increased volume permits greater spacing between primary electrode members **34** and **35**, thereby increasing the voltage breakdown capabilities of the device. Hence, vacuum switch devices constructed in accord with my invention provide increased voltage and current carrying capabilities without increasing the diameter of the device.

Still another feature of my invention is the dual function provided by the metallic support plates **26** and **29.** These plates, in addition to providing support for the electrode members **34** and **35,** also provide shielding between the arcing region and the insulating sidewall members **17** and **18.** These support members prevent molten metal particles and/or metal vapor emitted in the arcing region from adhering to the insulating sidewall members and producing electrical short-circuits. Additional shield members **37, 38** and **39** with large radii of curvature provide additional shielding for the insulating members without undesirably reducing the voltage breakdown capabilities of the vacuum switch device. Further, the metallic sidewall (which eliminates an insulating vapor shield) permits the metal vapor shields **37, 38** and **39** to be constructed with large radii of curvature. This results in an appreciable increase in the voltage breakdown characteristics without increasing the diameter of the vacuum device.

FIG. **3** illustrates a triggerable vacuum gap device **110** which incorporates the basic concept of the invention by employing a metallic sidewall and utilizing metallic support plates for the electrode members which provide shielding for the insulating sidewall members near the extremities of the device.

The structure of the triggerable vacuum gap device **110** is similar to that of the vacuum switch **10** except that there are no butt-type starter electrode contacts to operate during steady-state conditions, since this device is purely an overload responsive mechanism. The electrode structure comprises a pair of primary arc-electrode assemblies having primary electrode members **134** and **135** arranged to form a circular array similar to those of the vacuum switch shown in FIGS. **1** and **2.** The electrode structure defines a plurality of parallel conductive paths through the envelope **111** of this device and a plurality of gaps **136** (see FIG. **4**) disposed in each of the parallel conductive paths.

To trigger the triggerable vacuum device to a conductive state requires triggering electrode assembly means shown as **141,** well known in the prior art and shown, for example, in U.S. Pat. Nos. 3,465,192 and 3,465,206. The triggering means electrode assembly injects a cloud of an electron-ion plasma into the interelectrode gaps between the electrode members. An aperture **142** is disposed in the metal support plate **129** so that the trigger electrode assembly can inject plasma into the interelectrode region. Trigger electrode assembly **141** is energized directly or indirectly by overload voltages applied to the lines which device **110** is connected with or designed to protect. Overload currents conducted from the load circuit to the electrode members of the device will, because of the presence of the injected conductive plasma, instantaneously be short-circuited through a high current arc in the interelectrode gaps between adjacent electrode members. As illustrated, the electrode members **135** and **134** in this embodiment of my invention are inclined or canted outwardly toward the metallic sidewall member. This slight inclination, which is generally of the order of approximately 5°, produces a more compact device having voltage breakdown capabilities similar to those of the embodiments of my invention illustrated in FIG. **1,** but with a reduced length of the vacuum device, than devices having electrode assemblies parallel with the sidewall member.

FIGS. **5** and **6** illustrate yet another alternative embodiment of a vacuum switch device in accord with my invention wherein electrode members **234** and **235** have a "dogleg" configuration such that the portions of the electrodes surrounded by the sidewall member are substantially parallel to the sidewall member but then curve toward the arc electrode support members **224** and **225,** respectively. The primary reason for contouring the electrode members in this way is to accommodate larger diameter butt contacts. Another desirable characteristic of this embodiment of my invention is the reduced length of the support members for the butt contacts. This reduced length permits a larger steady-state current flow without an undue rise in ambient temperature of the device. Obviously, those skilled in the art can readily appreciate that the butt-electrode contacts may be removed if desired, and replaced with a trigger-electrode assembly, thus converting the vacuum switch device to a triggerable vacuum gap device.

From the foregoing description, those skilled in the art readily appreciate the numerous advantages flowing from this invention. In particular, by the elimination of the prior art insulating wall member, a substantial reduction in cost is achieved. Further, the use of a metallic sidewall member enhances the cooling capability of the vacuum device. And, the elimination of the insulating sidewall member increases the volume available within the device for increasing the voltage and current-carrying capabilities of the device. In particular, the spacing between the arc-electrode members can be made much greater and the size of butt contacts, where employed, can also be made much greater to handle higher currents. Still further, the dual functions provided by the metallic sidewall member and the electrode support plates enhance the operation of these devices while reducing the number of components in the device.

While I have shown and described various embodiments of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention. Thus, for example, while some embodiments of my invention are illustrated as vacuum switch devices, and some as triggerable vacuum gap devices, each of these embodiments can be made to operate as vacuum switch devices or as triggerable vacuum gap devices. It is, therefore, intended in the appended claims to cover all such changes and modifications that fall within the true spirit and scope of this invention.

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

1. An improved vacuum arc discharge device for carrying high currents at increased voltage levels comprising:

a hermetically sealed evacuated envelope, said envelope including a metallic cylindrical sidewall member, a pair of insulating sidewall members and a pair of oppositely disposed endwall members, each endwall member connected to one of said insulating sidewall members and said insulating sidewall members connected to the ends of said metallic sidewall member in a vacuum-tight seal;

a pair of support plates disposed in said envelope intermediate the ends thereof and supported by said endwall members;

a first plurality of spaced electrode members extending from one of said support plates;

a second plurality of spaced electrode members extending from the other of said support plates, said first and second plurality of spaced electrode members being substantially normal to said support plates and interleaved in alternating sequence to form a spaced circular array of electrodes;

means for causing an electric arc breakdown to be established between adjacently spaced arc-electrode members; and

means for connecting said arc-electrode members in circuit with an electric load.

2. The device of claim **1** wherein said device is a triggerable vacuum gap device and said means for causing an electric arc breakdown comprises a trigger electrode assembly for supplying electron-ion plasma.

3. The device of claim **1** wherein said device is a vacuum switch and said means for causing an electric arc breakdown comprises normally closed butt electrode contacts.

4. The device of claim **3** wherein said butt electrode contacts are disposed centrally within said circular array of electrodes.

5. The device of claim **1** wherein said spaced electrode members are substantially parallel to cylindrical sidewall member and have smooth cylindrical arcing surfaces.

6. The device of claim **1** wherein said spaced electrode members comprise smooth cylindrical members which are inclined outwardly toward said metallic cylindrical sidewall for providing increased voltage breakdown capability in a fixed diameter envelope with reduced length.

7. The device of claim **1** wherein said spaced electrode members are contoured in the shape of a dogleg which extends outwardly from said support plates toward said sidewall member and then substantially parallel to said sidewall member for accommodating a pair of butt electrical contacts within said array of electrodes; and

a pair of butt electrical contacts disposed within said array of electrodes with one of said contacts supported by one support plate and the other of said contacts reciprocally movable through an aperture in said other support plate.

8. The device of claim **1** wherein said metallic cylindrical sidewall member comprises stainless steel.

9. The device of claim **1** wherein said metallic cylindrical sidewall member is selected from the group consisting of stainless steel, copper and nickel.

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