

Dec. 5, 1967

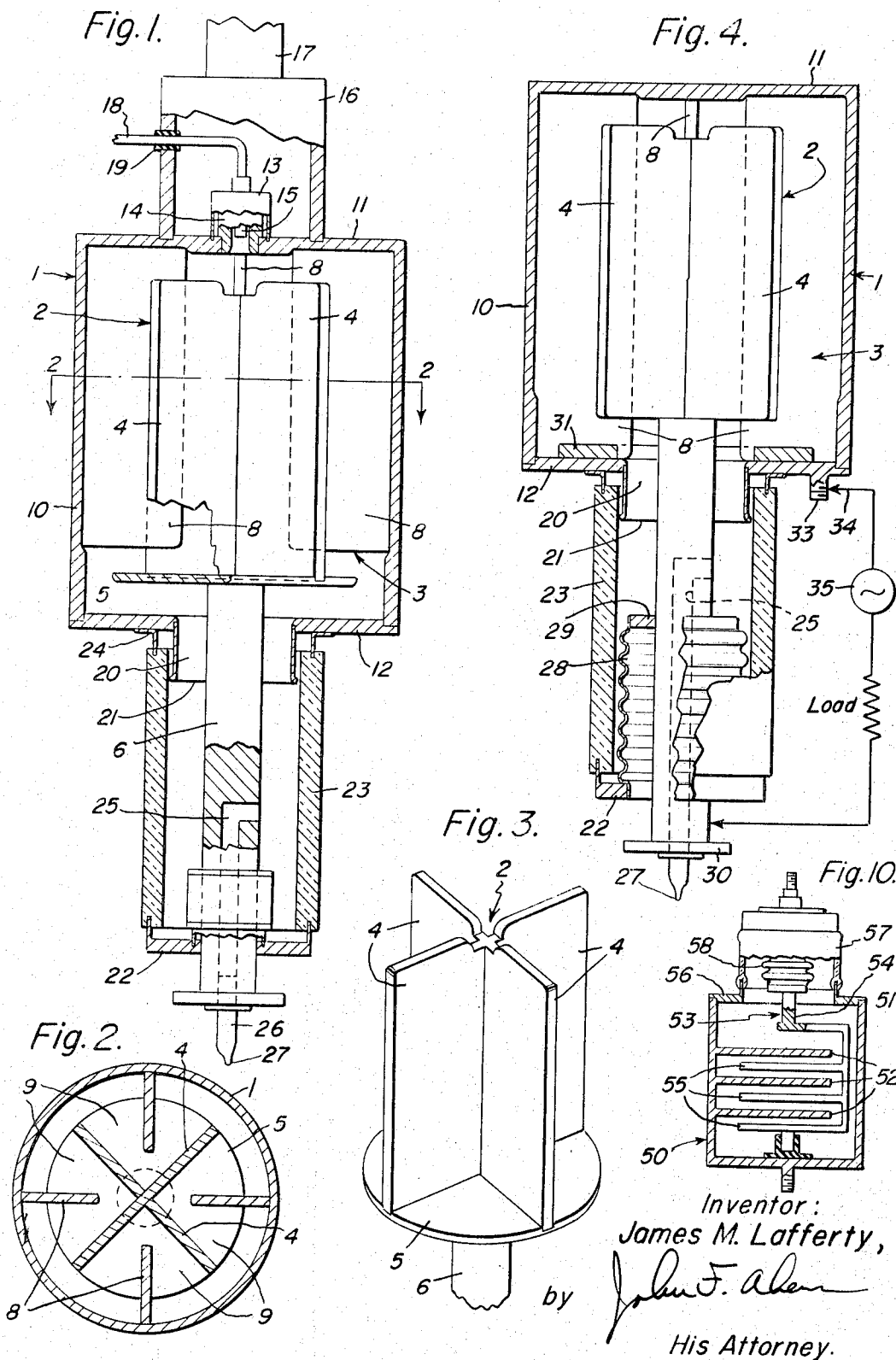
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3,356,893

HIGH POWER VACUUM DISCHARGE DEVICE HAVING A PAIR OF  
INTERLEAVED MULTI-VANED ARCING ELECTRODES

Filed March 21, 1966

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 6.

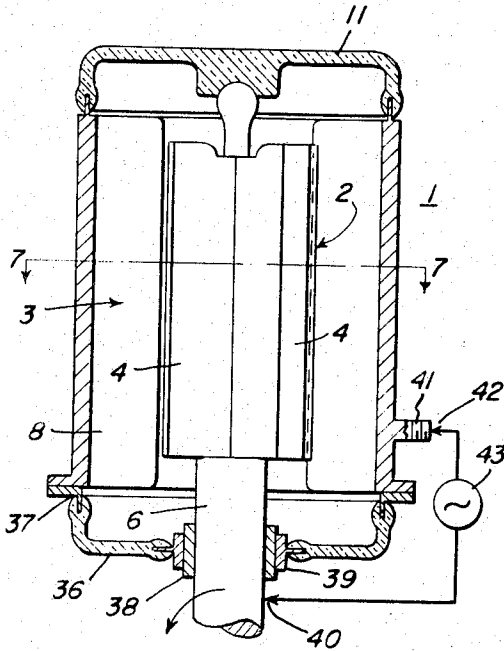


Fig. 5.

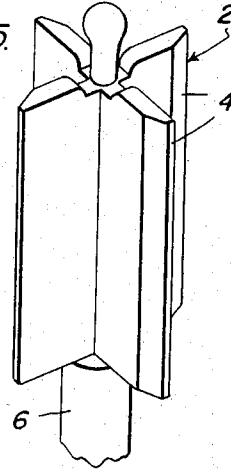


Fig. 7.

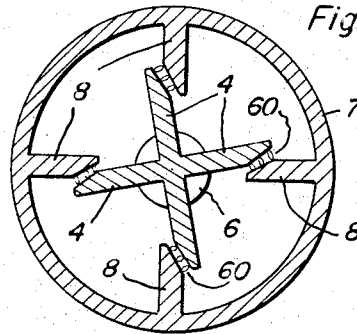


Fig. 9.

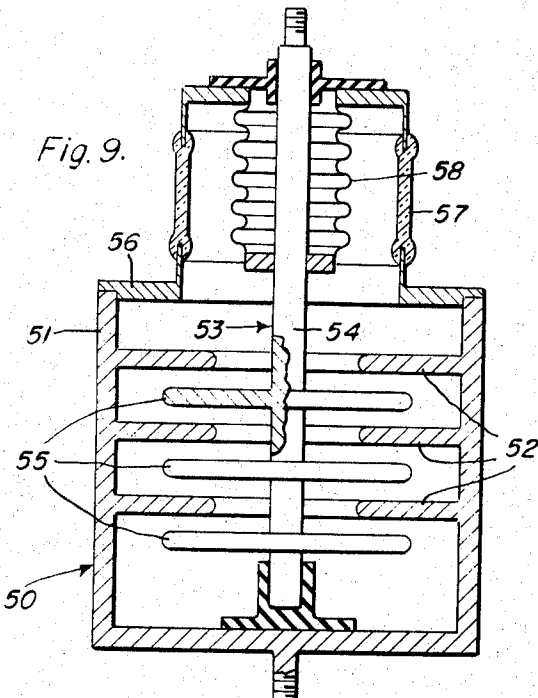
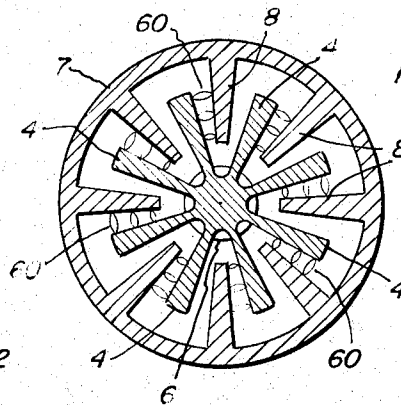


Fig. 8.



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## HIGH POWER VACUUM DISCHARGE DEVICE HAVING A PAIR OF INTERLEAVED MULTI- VANED ARCING ELECTRODES

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Filed Mar. 21, 1966, Ser. No. 535,948  
15 Claims. (Cl. 315-111)

The present invention relates to improved high power, high current vacuum gap devices, particularly those of the triggered vacuum gap and vacuum switch types suitable for the attainment of hitherto unobtainable power and current ratings.

Vacuum gap devices, in particular vacuum switches and fixed vacuum gaps, particularly of the triggered vacuum gap type, have recently been the subject of intense technological and commercial interest. After nearly forty years of developmental evolution commercial vacuum switches at high power ratings are presently being manufactured. Similarly since the advent of the triggered vacuum gap disclosed and claimed in my U.S. Patent No. 3,087,092, issued Apr. 29, 1963, and entitled, "Gas Generating Switching Tube," gaps of this type, which avoid the previously existing problem of instabilities and non-uniform breakdown voltages, have been adapted to a number of commercial applications.

Both vacuum switches and triggered vacuum gaps are often limited in their ability to operate at high power levels, and particularly to carry currents in the hundreds of thousands of ampere range by the inability of conventional anodes to withstand destructive melting caused by the formation of intense anode spots, which are the anode footpoints of individual electric arcs existing between the cathode and anode. In gaps with closely spaced electrodes, destructive melting also occurs at the cathode electrode, although it is not as serious a problem as the destructive melting at the anode electrode.

Accordingly it is an object of the present invention to provide improved vacuum gap devices including unique electrode configurations which facilitate the carrying of hitherto unobtainable high currents in operation at high power and current values without destructive melting of either the cathode or anodes thereof.

A further object of the present invention is to provide vacuum gap devices including vacuum switches and fixed gap devices which are adapted to operate at high current and power levels for long duty cycles and to in general exhibit long lifetime characteristics.

A further object of the present invention is to provide triggered vacuum gap devices suitable for operation at higher current and voltage levels than heretofore obtainable.

Still another object of the present invention is to provide improved high current, high power vacuum switches which may be utilized for a greater number of circuit interruptions than heretofore obtainable from such devices.

Yet another object of the present invention is to provide electrode configurations for vacuum gap devices which facilitate the operation thereof at higher current and power levels and for longer periods of time without destructive melting thereof than devices of the prior art.

In accord with one feature of the present invention I provide vacuum gap devices including as essential elements thereof a pair of primary electrodes which may define therebetween a plurality of parallel vacuum gaps. More specifically, in accord with the present invention the electrodes of the primary gap are interleaved between one another and contained within an evacuable envelope which, during arcing is substantially filled with an electron-ion plasma which provides an infinite number of current-carrying paths, none of which has sufficient current

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density to cause destructive melting of either anode or cathode electrodes and specifically of the anode electrodes. In yet another specific embodiment of the invention, one primary electrode constitutes a plurality of outwardly depending radial fins attached at the center thereof to a center post and the other primary electrode comprises a plurality of inwardly depending radial fins interleaved between the outwardly depending radial fins and connected at the outward edges thereof together so as to form an electrically unitary electrode structure.

In one general class of embodiments of my invention the electrode structure, as described hereinbefore is permanently juxtaposed so as to define a plurality of fixed gaps and current is initiated between the two primary electrode structures by the pulsing of a trigger apparatus associated therewith to cause the injection into the primary gaps of a charged electron-ion plasma to cause the breakdown thereof.

In accord with another general class of devices constructed in accord with my invention the electrode structure, as described hereinbefore, is one moveable with respect to the other so that the central electrode apparatus, for example, may be moved with respect to the outward electrode apparatus, either by a longitudinal motion or by rotation thereof. In either case, plasma to form a conduction path between the primary arc-electrodes is produced by the arc struck upon circuit-breaking and the vaporizing and ionizing of electrode material. The initial arc is struck upon the separation of the two electrode apparatus and the arc rapidly diffuses over the many parallel surfaces of the electrode structures so that the evacuated volume containing the electrodes is rapidly filled with an electron-ion plasma which conducts high currents at high power levels until the occurrence of a current zero at which time the discharge is immediately distinguished.

The novel features believed characteristic of the present invention are set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may be more readily understood by reference to the appended drawings in which:

FIGURE 1 is a vertical cross-sectional view of a fixed gap triggered device constructed in accord with the present invention;

FIGURE 2 is a horizontal cross-sectional view taken along the lines 2-2 of FIGURE 1 illustrating the juxtaposition of the primary electrode structure;

FIGURE 3 is a perspective view of the central electrode structure of FIGURE 1 of the drawings;

FIGURE 4 is an alternative embodiment of the invention illustrating a vacuum switch;

FIGURE 5 is a perspective view of the central electrode structure utilized in the device of FIGURE 4;

FIGURE 6 is a further alternative embodiment of the invention illustrating another form of vacuum switch which may be constructed in accord therewith;

FIGURE 7 is a horizontal cross-sectional view taken along the line 6-6 of FIGURE 6 illustrating the position of the electrodes in a circuit-making position;

FIGURE 8 illustrates an alternative embodiment to electrode structures which may be used in practicing the invention; and

FIGURES 9 and 10 illustrate alternative embodiments of the invention.

A triggered vacuum gap device constructed in accord with one embodiment of the invention and illustrated in FIGURE 1 of the drawing comprises an evacuable envelope represented generally as 1 containing therein a pair of primary electrode assemblies including a central electrode assembly 2 and an outer electrode assembly 3. Central electrode assembly 2, which is illustrated in perspective in greater detail in FIGURE 3 of the drawing, comprises a plurality of outwardly depending radial vanes

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each of which is thin, having a small thickness dimension as compared with its length and width dimensions, and is substantially perpendicular to a transverse plane and which are fastened at their lowermost ends to a plate or disc 5 which is connected to and supported upon an electrode support member 6. Electrode assembly 2 is also illustrated in FIGURE 2 of the drawing in vertical cross-section showing the interrelationship of vanes 4, plate 5 and support member 6. The plane of the cross section is, in this instance, a transverse plane to which vanes 4 and 8 are substantially perpendicular. Outer electrode assembly 3 is also illustrated in greater detail in FIGURE 2 and comprises a hollow cylindrical member 7 and a plurality of inwardly depending radial vanes 8 physically and electrically connected thereto. Vanes 8 are also thin, having a small thickness dimension as compared with their length and width dimensions and substantially perpendicular to the same transverse plane. Electrode assemblies 2 and 3 are juxtaposed so that the individual inwardly depending vanes 8 and the individual outwardly depending vanes 4 define a plurality of electrically parallel breakdown gaps 9 therebetween. Each of gaps 9 is substantially equally dimensional to the others. Vanes 8 of arc-electrode assembly 3 extend for substantially the entire length of the discharge space within envelope 1. The vanes 4 of arc-electrode assembly 2 are somewhat shorter, as is consistent with the necessity of maintaining the space between arc-electrode 2, and end wall members 11 and 12 of such length to prevent spurious arcing, since these members are at the same electrical potential as arc-electrode 3. As a practical matter, however vanes 4 are at least  $\frac{1}{2}$  the length of vanes 8. The thinness of vanes 4 and 8 is such that essentially no appreciable increase in electrical resistivity is incurred, but due to the thinness, a large number of parallel primary breakdown gaps, none of which is overloaded by extreme current densities may be formed in a relatively small volume.

Envelope 1 of the device of FIGURE 1 contains a metallic, substantially cylindrical side wall member 10 closed by an apertured upper end cap 11 and an apertured lower end cap 12. Each of members 10, 11 and 12 are composed of a suitably conductive metal as, for example, copper or the equivalent. The cylindrical sidewall member 10 may be the cylindrical portion 7 of exterior electrode assembly 3, or, alternatively, the electrode assembly may be firmly mechanically and electrically connected to the interior thereof. The aperture in upper end plate 11 is hermetically closed with a suitable trigger electrode assembly 13 having a trigger anode 15, a trigger cathode 14, and a trigger gap therein (not shown) for supplying a pulse of a gaseous ion-electron plasma or vaporized and ionized electrode material to cause breakdown between primary electrodes 2 and 3 upon the initiation of a suitable electrical signal to trigger electrode assembly 13. Electrode assembly 13 is suitably brazed to end plate 11. Such trigger electrode assemblies are illustrated, disclosed and claimed in my aforementioned U.S. patent and in my copending applications, Ser. No. 516,941, now abandoned; Ser. No. 516,942; and Ser. No. 516,943, now Patent No. 3,323,002, issued May 30, 1967, all filed Dec. 28, 1965 and assigned to the assignee of the present invention.

The trigger electrode assembly 13 is surrounded by a conductive cylindrical member 16 which is brazed to end plate 11 and which may be an intermediate electrical connection therebetween and electrical terminal connector 17. An insulated trigger electrode lead 18 passes through cylinder 16 to allow for connection of trigger electrode assembly 13 to a suitable source of pulsed voltage (not shown).

Central electrode support rod 6 passes down through the aperture 20 in end closure 12, through a ferruled breakdown shield 21 and is supported by a closure disc 22 which is hermetically sealed into a ceramic insulator bushing 23 which in turn is hermetically sealed to end

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closure 12 by means of a suitable annular Fernico alloy sealing flange 24. A central tubulation 25 in support rod 6 permits the evacuation of envelope 1 and is sealed into an exterior tubulation 26 which extends through the end of support rod 6 and is pinched off at 27 to complete the evacuation and sealing of envelope 1.

FIGURE 2 illustrates in vertical cross-section, taken across section lines 2—2 of FIGURE 1, the juxtaposition of the inwardly depending vanes 8 of electrode assembly 3 and the outwardly depending vanes 4 of central electrode apparatus 2 as is described hereinbefore.

FIGURE 3 illustrates, in perspective, the central electrode assembly 2 illustrated in and utilized in the embodiment of the invention illustrated in FIGURE 1 of the drawing.

FIGURE 4 of the drawing illustrates, in vertical cross-section with parts broken away, one embodiment of the invention. In FIGURE 4 which has many similar structural features common to the embodiment of FIGURE 1, like numerals are utilized to identify like members. In FIGURE 4 an evacuable envelope comprises a generally cylindrical metallic sidewall member 10, a closed upper end plate 11 and a lower apertured end plate 12. The aperture in end plate 12 is closed by an hermetic seal between an annular sealing flange member 24 of a suitable Fe-Ni-Co alloy and a ceramic insulating bushing 23. Ceramic insulating bushing 23 is closed by an annular apertured end plate 22 which is hermetically sealed by ceramic-to-metal sealing techniques thereto and welded, brazed or otherwise suitably fastened to a longitudinally flexible bellows 28 which is capped by an annular end piece 29 which is sealed around and, by an hermetic seal, sealed to electrode support member 6 to complete a vacuum-tight envelope. Within the envelope of FIGURE 4, a first central primary electrode assembly 2 comprising a plurality of outwardly depending radial vanes 4 is interdigitated between the inwardly depending radial vanes 8 of an outer electrode assembly 3 which is substantially the same as that illustrated in the embodiment of FIGURE 1 of the drawing and which are electrically and mechanically a portion of the outer electrode assembly 3. Vanes 4 and 8 are thin as described hereinbefore, define a plurality of electrically parallel gaps, and are substantially perpendicular to the same transverse plane. A metallic contact ring 31 rests in electrical and mechanical contact with the inner surface of the lower metallic end plate 12, and is also, electrically, a portion of electrode assembly 3.

As in the embodiment of FIGURE 1, the device of FIGURE 4 may be evacuated through a central tubulation 25 in electrode support member 6 which terminates in a tubulation 26, which after evacuation, is sealed, to vacuum, at pinch 27. The device of FIGURE 4 constitutes a vacuum switch or circuit interrupter. In operation the two primary contacts are brought into electrical circuit-making position by a downward thrust upon annular flange 30 surrounding the lower end of electrode support member 6 or an equivalent force. At the end of the downward stroke the lower edges of the outwardly depending radial vanes 4 of central electrode apparatus impinge upon and make electrical contact with annular contact ring 31. While any number of contact vanes may be used, contact at all points between vanes 4 and ring 31 is facilitated if three vanes only extend from the central post. A circuit to be switched is connected through the switch by making one device terminal to the lower end of electrode support member 6 as represented by arrow 32. The other terminal may be made at a suitable annular connecting ring 33 attached to the outward portion of lower end plate 12, contact being represented by arrow 34. Between these two terminals a source of alternating voltage may be connected in series or parallel circuit relationship.

To interrupt the flow of current through the switch the electrode support member 6 is moved longitudinally

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upwardly, as permitted by bellows 28 separating the lower portions of vanes 4 of electrode assembly 2 from the upper surface of contact ring 31. A plurality of arcs are thereby struck between each of the vanes and the contact ring. Since the path of current through support member 6, electrode assembly 2, the arc, contact ring 31, lower end plate 12 and terminal lug 30 constitutes a loop, magnetic forces cause a concentration of flux at the center of the loop, which urges the arc upwardly between the vanes of the inwardly depending outer electrode assembly and the outwardly depending inward electrode assembly, thus rendering the entire surface of the vanes available as contact surfaces on the electric arcs.

The location of electrical terminals for current connection as shown in FIGURE 4 is extremely important. While it has long been recognized that dispersal of high current carrying arcs into a plurality of segments, both in series and parallel, is desirable in arcing devices, the achievement of such dispersal has not heretofore been effectively attained. Any system in which the initial arc is struck between one pair of electrodes and transferred to another pair is difficult to achieve because the arc always seeks the lowest energy position. Herein, magnetic forces generated by the arc itself are utilized in a novel fashion to force the arc into the space between the interleaved radial vanes, which, except for a slight longitudinal displacement remain substantially fixed with respect to one another and with arcing surfaces in substantial parallelism during operation. If, on the other hand, terminals were placed longitudinally along the axis of the device of FIGURE 1, and an attempt made to utilize the vanes, the balanced magnetic fields established by the initial arc struck between vanes 4 and ring 31 would prevent the original arc or arcs from ever being transferred, by magnetic or other propulsion into the gaps between vanes 4 and 8. Once the discharge is dispersed between electrode apparatus 2 and 3, no high current density electrode spots, particularly destructive anode spots, are formed and the entire interior surface of the envelope within the arcing area is filled with a gaseous plasma conducting electricity between the outward and inward electrode assemblies. Current continues to flow until the occurrence of the first current zero, at which time the arc is extinguished and the vaporized metals, which constitute the arc conduction carriers, evaporate to the cold walls where they condense, so that the high dielectric strength of the vacuum is returned, holding off further high but permissible voltages.

In FIGURE 5 of the drawing, a central electrode assembly with outwardly depending radial vanes 4, as is utilized in the device of FIGURE 4, is illustrated in a perspective view. This assembly is essentially the same as that shown in FIGURE 3, without lower disc 5 thereof and serves essentially the same function.

In FIGURE 6 of the drawing, there is illustrated yet another alternative embodiment of the invention in which a vacuum switch embodying the invention operates to move from a circuit-making to a circuit-breaking position in response to a rotational motion of the central electrode assembly. As with the device of FIGURE 3, like numerals are utilized to identify like parts. The envelope of the device of FIGURE 6 is composed of a substantially cylindrical metallic side wall member 1, an upper closed end plate 11 and a lower, disc or upwardly flanged apertured end plate 36. Members 1 and 11 are composed of a highly conductive material, as for example, copper. Member 36 is composed of a suitable gas impervious insulating dielectric material as for example, an alumina ceramic. Apertured end wall member 36 is fastened hermetically to cylindrical side wall member 1 by means of an annular sealing flange 37, preferably of a Fernico alloy. A vacuum-tight sleeve bearing permitting limited rotation of the central electrode assembly is connected and hermetically sealed with central electrode support rod 6 and comprises a sleeve member 38 which is hermetical-

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ly sealed to ceramic end wall member 36 by means of an annular ceramic-to-metal seal flange member 39. Electrical contact is made to the respective primary electrode apparatus by making contacts to electrode support member 6 as represented schematically by arrow 40 and by making contact to cylindrical side wall member 1 at terminal lug 41 as represented schematically by arrow 42. An alternating current source 43 and a suitable load impedance 44 may be disposed in series or parallel circuit relationship between these points as indicated schematically.

In operation, the device, once having been fabricated and evacuated to a pressure of less than  $10^{-5}$  mm. of mercury, is caused to move from a circuit-making condition in which the electrodes are in substantial mating position as illustrated by FIGURE 7 of the drawing, to a circuit-breaking position, by a slight rotation of the central electrode apparatus. From a perusal of FIGURE 7 it may be seen that contact is made between coupled thin contact vanes each of which is substantially perpendicular to the same transverse plane at the abutting edges thereof. To increase the area of contact, both inner and outer vanes are beveled at the ends to meet flushly with the mating vane. It is along these beveled surfaces that a plurality of parallel arcs are struck upon separation of the electrodes. As the arc current increases the discharge spreads out substantially over the entire surface of the vanes constituting the individual portions of the electrode structure. When the device is in a circuit-opening position a cross-sectional view of the electrode position is illustrated substantially as in FIGURE 2 of the drawing. Since the arc is extinguished at the first occurring current zero, which for sixty cycle alternating current occurs at less than 8 milliseconds, the vanes do not have time to separate far enough so that the arc spreads between the back surface of a moveable vane and the back surface of the next adjacent fixed vane. Hence arcs are established in the switch only as shown by the schematic representation of arcs shown at 60 in FIGURE 8. Arcs are not generated at the other gaps due to the simple fact that it is not mechanically feasible to bring the remaining gaps to the gap length required to strike arcs therein in less than 8 milliseconds.

FIGURE 8 of the drawing illustrates an alternative embodiment for the structure of interior and exterior electrode assemblies which permits for a greater area of the electrodes to be in contact when in circuit-making position. In this embodiment, a rotational motion of the central electrode apparatus of the device of FIGURE 6 causes the separation of the respective electrode assemblies to produce an infinite number of parallel paths, not only vertically along a line of contact between a mating pair of electrodes, but also horizontally along the entire face of the electrodes. In FIGURE 8, it will be noticed that the inwardly depending outer electrode vanes are in the shape of thin truncated prisms with the apices thereof pointed toward the longitudinal axis of the assembly. Likewise, the outwardly depending radial electrode vanes are also in the shape of thin inwardly oriented truncated prisms fastened to the central post so that the outwardly and inwardly depending electrode vanes abut flushly against one another when the device is in the circuit-making position. While this structure has been disclosed herein with respect to the embodiment of FIGURE 6 in which a circuit interrupter device is disclosed operating upon a radial motion, the electrode structure illustrated in cross-section in FIGURE 8 may similarly be utilized in the embodiment of FIGURES 1 and 4 since the advantage obtained is equally applicable to all embodiments of the invention.

While one of the greatest advantages of the present invention is that of achievement of balanced magnetic fields once the arc has been diffused among the surfaces of the vanes of the primary arc-electrodes, and this effect is one great advantage of the arrangement of one central

arc-electrode and one concentric peripheral electrode, certain advantages of the invention may be gained with other structures embodying other features of the invention.

Thus, for example, the advantage of a plurality of parallel arcs simultaneously struck between different segments of a pair of primary arc electrodes may be obtained by constructing the primary arc electrodes of either a fixed or moveable gap device which may be achieved with any suitable arrangement of interdigitated vanes wherein alternate vanes are a portion of opposite primary arc electrodes.

One such structure is illustrated in FIGURE 9. In FIGURE 9, which illustrates a vacuum switch, one primary arc electrode 50 includes a metallic cylindrical portion 51 having flat apertured disc-shaped thin vanes 52 arranged at equal distances transverse to the longitudinal axis thereof and substantially perpendicular to a transverse plane. The other primary electrode 53 comprises a central rod 54 with a plurality of transverse, equally spaced thin vanes 55 which are substantially perpendicular to the same transverse plane. The envelope is closed by a suitable apertured end cap 56, an insulated bushing 57, and a flexible bellows 58 which close an hermetically sealed envelope. Conveniently this device would have cylindrical symmetry, although it could be rectangular. If rectangular it could be more convenient to cause the thin vanes to interdigitate from one side to the other. Conveniently the vanes, which would eventually deteriorate, could be removeable for low cost replacement to extend the useful life of the device. Such an embodiment is illustrated in vertical cross-sectional view in FIGURE 10 and uses the same reference numerals as used in FIGURE 9 to identify like parts.

In all embodiments of the invention the materials constituting the electrodes are highly conductive materials having reasonably high vapor pressure so that the arc, once struck is composed of metallic ions which are evolved from the electrode materials. Under this condition of operation rapid deionization and recovery of the device upon the circuit interruption is obtained by virtue of the fact that upon the occurrence of a first current zero the arc is interrupted and the metallic ions immediately migrate to the nearest cold surface, condense and deionize and are removed from the enclosure to restore the high dielectric strength of the vacuum therein. Some such materials are copper, silver and the materials disclosed and claimed in Patent No. 2,975,256 to Lee and Cobine and my Patents Nos. 2,975,255 and 3,016,436. The ceramic materials used for bushing materials are of gas impervious high dielectric strength ceramic as for example Coor's V-200 or American Lava T-164 or a Fosterite ceramic. The metallic electrode materials should be substantially free of all gas and gas forming material to the extent that over repeated arcing, a pressure of  $10^{-5}$  mm. of mercury or less may readily be maintained. This means that the presence of all gas and gas-forming constituents within the material must be reduced to a figure of no higher than  $10^{-7}$ . Such gas free materials may conveniently be attained by a special zone refining process as disclosed in Patent No. 3,234,351, issued Feb. 8, 1966 to M. H. Hebb.

As is discussed hereinbefore, a previous limitation upon currents and power which could be handled by vacuum arc devices of the triggered gap and vacuum switch types, for example, lay in the destructive melting of the electrodes, particularly the anode electrode, by the formation of intense heating by local anode spots at which practically all the current being carried between the two electrodes was concentrated. In accord with the present invention there is provided means for providing a broad area electrode structure over which the arc, be it initiated by the injection of a pulse of ionized plasma, or be it initiated by a circuit-opening motion may readily spread without the formation of localized spots particularly on the anode. Such localized, high current density spots cause

destructive melting and hence limit both the current carrying and power handling capacity of the devices and the duty cycle at which the devices may be operated. This invention, therefore provides higher voltage and current rating devices with substantially longer lifetimes than has heretofore been obtainable with vacuum arc devices.

As an example of the efficacy of the present invention in providing for the interruption of high voltage, high current alternating currents, one embodiment of the device as illustrated in FIGURE 1 of the drawing, wherein each individual vane was of copper and had a dimension of 5.25" long 2" wide and 0.25" thick, operated to carry a peak current of 170,000 amperes at a voltage of approximately 35,000 volts for one half cycle without any evidence of gross melting of either of the electrodes. One contributing factor to this achievement is that with the electrode configuration disclosed herein, all magnetic forces due to current flow through the gap are balanced so that there is no tendency to force the discharge in either a radial or an axial direction, as is often the case in circuit interrupting devices in which it is desired to rapidly extinguish the arc. This difference avoids the concentration of current in a particular area and sets forth a condition inhibiting the establishment of destructive electrode spots, particularly upon the anode.

While the invention has been set forth herein with respect to several embodiments and modifications thereof, numerous modifications and changes may readily be made by those skilled in the art. Accordingly it is intended that the appended claims cover all such modifications and changes as fall within the true spirit and scope of the invention.

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

1. A vacuum gap discharge device comprising:
  - (a) an hermetically sealed envelope evacuated to a pressure of  $10^{-5}$  mm. of Hg or less and including a portion fabricated from a high voltage dielectric;
  - (b) a first primary arc electrode assembly supported within said envelope and including a first plurality of thin substantially planar vanes projecting therefrom and being substantially perpendicular to a transverse plane through said envelope;
  - (c) a second primary arc-electrode assembly supported within said envelope and including a second plurality of thin substantially planar vanes projecting therefrom and being substantially perpendicular to said transverse plane through said envelope;
  - (d) the vanes of said first primary arc-electrode assembly and the vanes of said second primary arc-electrode assembly being interleaved alternately between one another so as to define a plurality of electrically-parallel gaps between said first and second primary arc-electrode assemblies to cause electrical breakdown between said primary arc-electrode assemblies to occur simultaneously at a multiplicity of points whereby the formation of high current density anode spots is avoided;
  - (e) means for connecting said primary arc-electrode assemblies in circuit with a high power electric line; and
  - (f) means for producing at a preselected time a copious quantity of electron-ion plasma within said electrically-parallel gaps to establish a plurality of electrically-parallel current arcs within said envelope whereby said device carries a high power load without destructive melting of said electrodes.
2. The discharge device of claim 1 wherein:
  - (a) the primary arc-electrode assemblies are both fixed so as to define a plurality of fixed electrically-parallel gaps; and
  - (b) the means for supplying plasma within said trigger gaps comprises a trigger assembly including a trigger gap and means for generating and injecting into said electrically-parallel gaps a supply of ion-electron

plasma upon the application of a voltage pulse to said trigger gap.

3. The discharge device of claim 1 wherein:

- (a) one of said primary arc-electrode assemblies is movable with respect to the other so as to define a plurality of variable electrically-parallel gaps; 5
- (b) the means for supplying plasma within said gaps comprises means for moving said movable electrode assembly from a circuit-closed position, in which the vanes of said movable electrode assembly are in flush mating position with respect to the corresponding vanes of said fixed electrode assembly over at least a portion of their surface areas, to a circuit-open position, in which a multiplicity of parallel arcs are struck between mating vanes of said primary arc-electrode assemblies; and 10

- (c) the plasma comprises vaporized and ionized metallic species of the respective electrode assemblies. 15

4. The discharge device of claim 1 wherein:

- (a) one of said primary arc-electrode assemblies comprises a cylindrical outer member and a plurality of thin inwardly-depending radial vanes; and 20
- (b) the other of said primary arc-electrode assemblies comprises a plurality of thin centrally-connected outwardly-depending radial vanes interleaved alternately between said inwardly-depending vanes to define a plurality of electrically-parallel gaps. 25

5. The discharge device of claim 1 wherein:

- (a) one of said primary arc-electrode assemblies comprises substantially a rectangular parallelepiped outer container having a plurality of thin substantially parallel rectangular vanes depending inwardly from one wall thereof, and wherein; 30
- (b) the other of said electrode assemblies comprises a plurality of interconnected thin parallel substantially rectangular vanes interleaved alternately between the vanes of said first arc-electrode assembly; and 35
- (c) said first and said second arc-electrode assemblies are separated electrically from one another by said high voltage dielectric. 40

6. The discharge device of claim 4 wherein:

- (a) the primary arc-electrode assemblies are both fixed so as to define a plurality of fixed electrically-parallel gaps; and 45
- (b) the means for supplying plasma within said gaps comprises a trigger assembly including a trigger gap and means for generating and injecting into said electrically-parallel gaps a supply of ion-electron plasma upon the application of a voltage pulse to said trigger gap. 50

7. The discharge device of claim 4 wherein:

- (a) said one electrode assembly is fixed and includes an annular contact ring in said one transverse plane and at one end of said other electrode assembly to define therewith a plurality of starter gaps; 55
- (b) said other electrode assembly is moveable along the longitudinal axis of said envelope to make and break contact with said contact ring to initiate a plurality of parallel electric arcs; and 60
- (c) line voltage connections to said primary arc-electrodes are both made at the same lateral end of said device so that upon arcing when said one primary arc-electrode assembly is separated from said contact ring, current flow through the device produces a magnetic blow-out effect which propels the parallel arcs into the electrically-parallel gaps between adjacent interleaved vanes of said primary arc-electrode assemblies. 65

8. The discharge device of claim 4 wherein:

- (a) said one arc-electrode assembly is fixed; said other arc-electrode assembly is rotatably moveable about the longitudinal axis of said device to make and break contact between mating vanes of said primary arc-electrode assemblies; and 70

- (b) the mating edges of mating arc-electrode vanes are beveled to provide a flush fit and a broad area of contact between the primary arc-electrode assemblies.

9. The discharge device of claim 4 wherein:

- (a) said one arc-electrode assembly is fixed;
- (b) said other arc electrode assembly is rotatably moveable about the longitudinal axis thereof to make and break contact with said one arc-electrode; and
- (c) the vanes of said arc-electrodes are in the cross sectional shape of truncated cones of such pitch that in contact making position, the entire overlapping surfaces of mating vanes of both primary arc-electrodes are in flush contact with one another.

10. The discharge device of claim 5 wherein:

- (a) the primary electrode assemblies are both fixed so as to define a plurality of fixed, electrically-parallel gaps; and
- (b) the means for supplying plasma within said gaps comprises a trigger assembly including a trigger gap and means for and injecting into said electrically-parallel gaps a supply of ion-electron plasma upon the application of a voltage pulse to said trigger gap.

11. The discharge device of claim 3 wherein:

- (a) said first primary arc-electrode comprises a central member having a plurality of transverse disc shaped vanes depending outwardly therefrom at equal intervals along the length thereof; and
- (b) said second arc-electrode assembly comprises a cylindrical outer member and a plurality of inwardly depending transverse annular vanes which are interleaved between the outwardly depending vanes of said first arc-electrode assembly.

12. The discharge device of claim 3 wherein:

- (a) one primary arc-electrode assembly comprises a substantially rectangular parallelepiped outer container having a plurality of thin substantially parallel rectangular vanes depending inwardly from one wall thereof; and
- (b) the other primary arc-electrode assembly comprises a plurality of interconnected thin parallel substantially rectangular vanes interleaved alternately between the vanes of said one primary arc electrode.

13. A vacuum gap discharge device comprising:

- (a) an hermetically sealed envelope evacuated to a pressure of  $10^{-5}$  mm. of Hg or less and including a portion thereof fabricated from a high voltage dielectric;
- (b) a first primary arc-electrode assembly including a substantially cylindrical outer member and a plurality of radial vanes inwardly depending therefrom along the axial length thereof;
- (c) a second primary arc-electrode assembly including a plurality of outwardly depending radial vanes having a length at least greater than one-half the length of the vanes of said first primary arc-electrode assembly interconnected along the longitudinal axis and interleaved between the vanes of said first primary arc-electrode assembly to form a plurality of broad area electrically-parallel primary breakdown gaps for simultaneous low current density current conduction;
- (d) means for connecting said primary arc-electrode assemblies in circuit with a high power electric line; and
- (e) means for producing at a preselected time a copious quantity of electron-ion plasma within said electrically-parallel breakdown gaps to establish a plurality of electrically parallel current arcs within said envelope whereby said device carries a high power load without destructive melting of said electrodes.

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14. The discharge device of claim 13 wherein:  
 (a) both of said primary arc-electrode assemblies are fixed; and  
 (b) the means for supplying an ion-electron plasma between said arc-electrode assemblies comprises a trigger assembly including a trigger gap and means for generating and injecting a supply of plasma upon the application of a voltage pulse to said trigger gap. 5
15. The discharge device of claim 13 wherein:  
 (a) one of said primary arc-electrode assemblies is fixed; and 10  
 (b) the other of said assemblies is rotatably moveable about the longitudinal axis thereof from a circuit making position in which substantially flush contact 15

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is made between a substantial area of mating arc-electrode vanes to a circuit breaking position to establish a multiplicity of simultaneous low current density arcs for the provision of an ion-electron plasma therein.

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