Aug. 11, 1970 E. W. STETSON 3,524,099

SPARK GAP ASSEMBLY FOR LIGHTNING ARRESTERS

Filed June 13, 1968

Fig. 1.

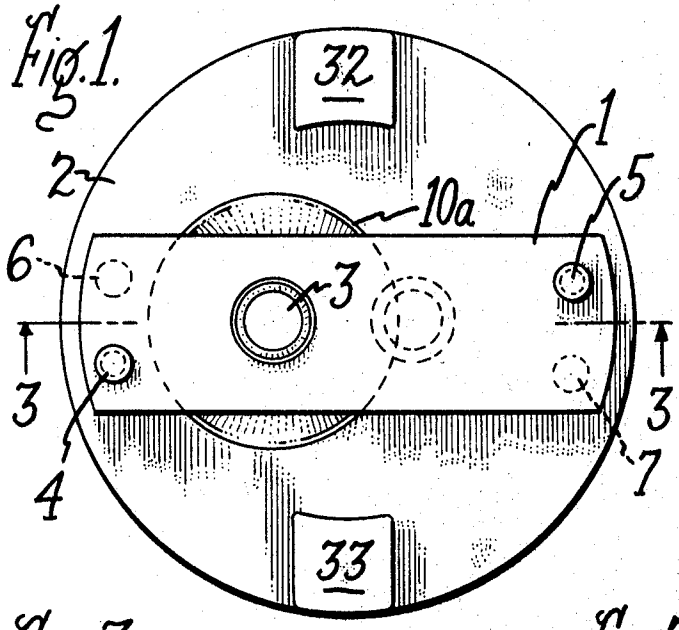


Fig. 2.

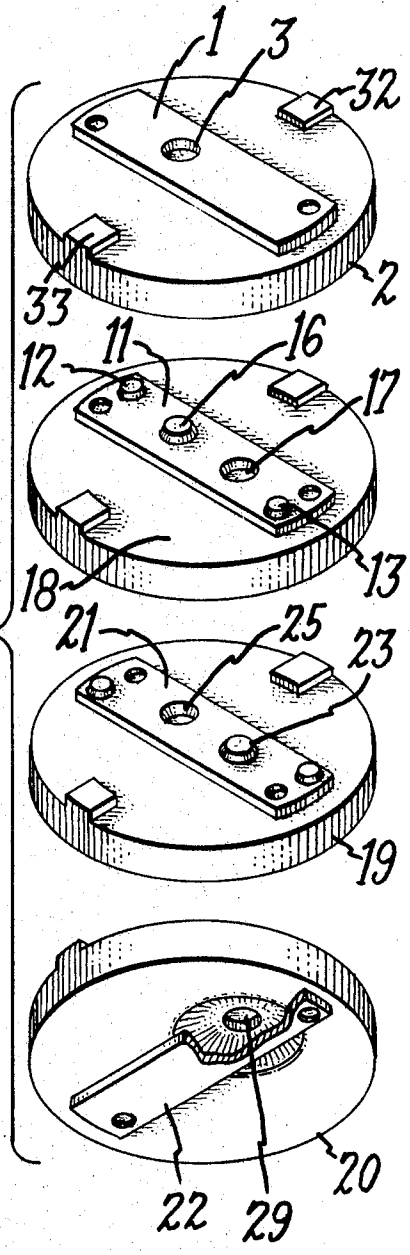


Fig. 3.

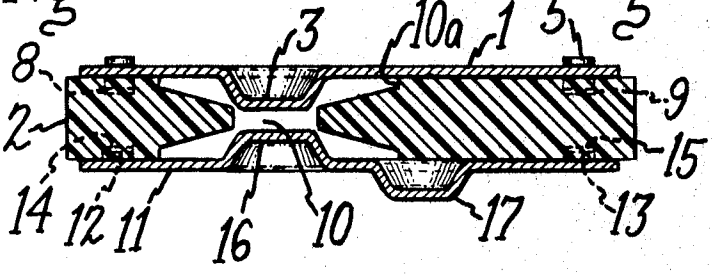
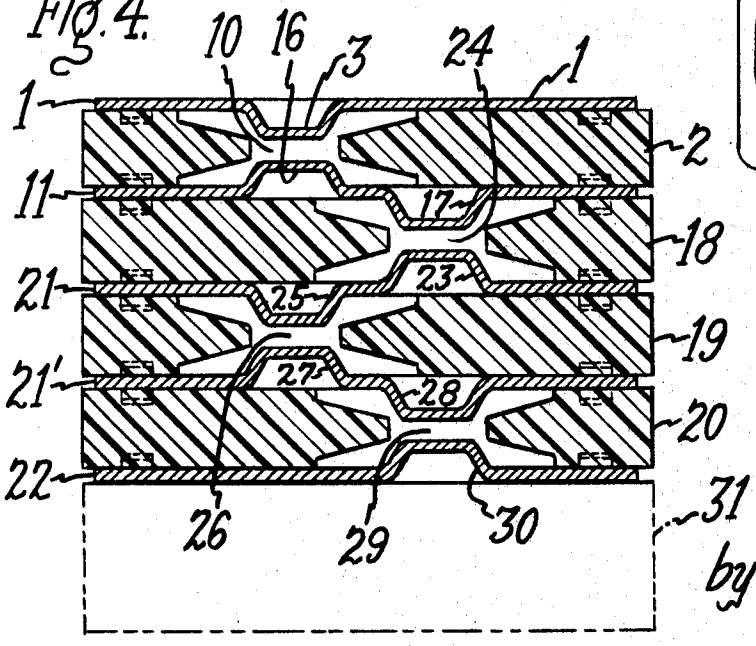


Fig. 4.



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by

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SPARK GAP ASSEMBLY FOR LIGHTNING ARRESTERS

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ABSTRACT OF THE DISCLOSURE

A spark gap assembly having a plurality of stacked, substantially flat, disc-shaped insulating plate members with apertures therethrough, and a plurality of elongated metallic electrodes with raised portions thereon, which project into said apertures to define a spark gap therein between adjacent electrodes. The electrodes and insulating plate members are formed and arranged to afford capacitance grading of the spark gaps, and maximum concentration of arc-moving magnetic flux when the gaps of the assembly are sparked over.

This invention relates to spark gap assemblies and, more particularly to a spark gap assembly of the type adapted for use in distribution lightning arrestors.

It is well known in the lightning arrester art to use spark gap assemblies electrically connected in series with nonlinear resistance valve elements and every effort is made to improve the operating characteristics of such arresters while at the same time reduce the cost of manufacture. Two advantageous features of such spark gap assemblies are; they ability to regulate the sparkover voltage of the arrester within fairly close predetermined tolerances, and their ability to rapidly extinguish power-follow current after an initial overvoltage surge has been discharged through the arrester. Numerous different means have been developed to afford these functions within lightning arrester spark gap assemblies. However, the very competitive economic forces at work in the distribution lightning arrester field require that these arrester operating characteristics be constantly improved and such improvement should, if possible, result in, or incorporate manufacturing cost savings.

In striving to attain these dual goals of improved operating characteristics and reduced manufacturing cost, spark gaps have been developed by inventors in the prior art which embody simplified magnetic means for blowing an arc against a wall of an arcing chamber to cool and extinguish the arc. In addition, voltage grading circuits have been developed for lightning arrester spark gap assemblies to assure a generally uniform distribution of voltage across each of a plurality of spark gaps so that the sparkover voltage of spark gap assemblies can be maintained relatively constant. However, such prior art devices are generally quite complex or expensive to manufacture. Therefore, it is still very desirable to seek more improved relatively low-cost means of attaining these two basic spark gap functions.

Accordingly, an object of my invention is to provide an improved, relatively low cost spark gap assembly for distribution type lightning arresters.

Another object of my invention is to provide an inexpensive and highly efficient electromagnetic arc-moving means for a spark gap assembly.

Still another object of the invention is to provide an inexpensive and accurate capacitance voltage grading circuit for a spark gap assembly.

A further object of the invention is to provide a spark gap assembly that is relatively small in size in relation to its rating.

A still further object of the invention is to provide a spark gap assembly having a plurality of substantially identical component parts that are adapted to be easily assembled into a self-locking stack arrangement that is compact and rugged, as well as highly efficient in operation.

Briefly stated, in one preferred form my invention comprises a spark gap assembly having a plurality of substantially identical insulating plate members with apertures therethrough, and a plurality of elongated electrode members disposed on opposite sides of the plate members and provided with raised terminal portions thereon, which are adapted to extend partially into opposite sides of each insulating plate aperture to define a spark gap therein. The resultant spark gap assembly is characterized by affording low-cost uniform capitance voltage grading for each spark gap, and by providing an unusually strong magnetic field for rapidly moving arc outward from hte respective spark gaps when power-follow current flows through the spark gap assembly following a high voltage discharge. The aperatures through the insulating plate members are uniquely formed to facilitate extinction of an arc moved outwardly therefrom while at the same time making it possible to reduce the over-all size of the spark gap assembly to thus effect a substantial manufacturing cost saving.

Further objects and advantages of the invention will become apparent from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a top plan view of a unique, elongated spark gap terminal member positioned in operating relation on an insulating plate member of the type utilized in a preferred embodiment of the invention.

FIG. 2 is a perspective exploded view illustrating a preferred embodiment of a spark gap assembly embodying my invention.

FIG. 3 is a cross sectional view of a portion of the invention shown in FIG. 1, taken along the plane 3—3 of FIG. 1.

FIG. 4 is a cross sectional view also taken along the plane 3—3 of FIG. 1, showing an entire spark gap assembly of the type illustrated in FIG. 2.

Referring now to FIGS. 1 and 2 of the drawing, there is shown an elongated metallic terminal member **1** positioned on the upper surface of a disc-shaped insulating plate member **2** and provided with a generally dome-shaped terminal portion **3** (also see FIG. 3) protruding from the bottom surface thereof. In the preferred embodiment of my invention, the elongated metallic terminal member **1** is formed of brass; however, it will be understood that other suitable conductive materials may be utilized to form the terminal member **1**. A pair of positioning detents **4** and **5** are formed in the top surface of the terminal member **1** and a second pair of positioning detents **6** and **7** are formed in the bottom surface thereof. In this form of my invention, the detents **4–7** are formed by stamping the brass terminal member **1** while it is positioned over a suitable die that allows the detents **4–7** to be extruded into the circular shape shown. Suitable complementary depressions **8** and **9** (see FIG. 3) are molded in the top surface of the insulating plate member **2** to receive, respectively, the detents **6** and **7**, thereby to position the terminal member **1** in a predetermined fixed relationship with respect to the surface of plate member **2** such that the dome-shaped terminal portion **3** protruding from the bottom surface of member **1** is substantially concentric with the longitudinal axis of an aperture **10** (see FIG. 3) formed through the insulating plate member **2**. The particular unique configuration of the surfaces defining the aperture **10** constitutes an important feature of my invention which will be described in detail below.

An elongated electrode member **11** is positioned in a similar manner between the bottom surface of the plate member **2** and the top surface of plate member **18**. Specifically, a pair of detents **12** and **13** are formed in the top surface of the electrode member **11** in the manner described above and, in assembled position, they nest in complementary depressions **14** and **15**, respectively, in the bottom surface of the insulating plate member **2**. This arrangement serves to position a dome-shaped electrode portion **16** of the electrode member **11** concentrically in the aperture **10** formed in the plate member **2**. Thus it can be seen, referring to FIG. 3, that a spark gap is formed between the dome-shaped terminal portion **3** of terminal member **1** and the dome-shaped electrode portion **16** of the electrode member **11**, each of which protrudes into the aperture **10**.

It will be apparent that the length of the spark gap defined between the dome-shaped terminal portion **3** and the dome-shaped electrode portion **16** is predetermined by the thickness of the insulating plate member **2** and the depth of these respective dome portions, **3** and **16**. Since the shape and structure of these members is simple, the dimensions of the very close tolerances can be maintained during manufacture, thus, a very accurately dimensioned spark gap can be formed at a minimum cost.

The elongated electrode member **11** has a second dome-shaped electrode portion **17** formed in its surface at a predetermined longitudinally spaced distance from the dome-shaped electrode portion **16**. As can best be seen in FIG. 3 of the drawing, the dome-shaped portion **17** protrudes from the surface of the electrode member **11** in a direction opposite the protrusion of the dome-shaped electrode portion **16**.

In the preferred embodiment of the invention depicted in FIG. 2, the spark gap assembly of the invention is shown as including a third and fourth insulating plate member, **19** and **20** respectively. Another elongated electrode member **21** is mounted between the top surface of the insulating plate member **19** and the bottom of plate member **18**, while still another elongated electrode member **21'**, shown in cross section in FIG. 4, is mounted between the bottom of the insulating plate member **19** and plate member **20**. Finally, another elongated terminal member **22** is mounted on the bottom surface of insulating plate member **20**. The elongated electrode members **21** and **21'** are identical in structure to the elongated electrode member **11**, but these members are mounted in alternately reversed positions with respect to the stack of insulating plate members so that their respective protruding dome-shaped electrode portions will extend into the staggered apertures in these insulating plate members. Specifically, the dome-shaped electrode portion **23** protruding upward from the surface of elongated electrode **21** is positioned to extend into the aperture **24** (see FIG. 4) in the insulating plate member **18** to define a spark gap between the respective electrode members **11** and **21**. In like manner, the dome-shaped electrode portion **25** extending from the bottom surface of the elongated electrode member **21** is positioned to extend into the aperture **26** formed in insulating plate member **19** to define a spark gap of predetermined length, with the dome-shaped electrode portion **27** of elongated electrode member **21'**. Finally, the dome-shaped electrode portion **28** of elongated electrode member **21'** is positioned to extend into the aperture **29** formed through the insulating plate member **20** to define a spark gap with the dome-shaped terminal portion **30** of the elongated terminal member **22** mounted on the bottom surface of the insulating plate member **20**.

It will be understood that each of the elongated electrode members **11**, **21** and **21'**, as well as the pair of elongated terminal members **1** and **22** are provided with detent means similar to the detents **4–7**, discussed above with reference to FIG. 1, for positioning these respective members in a predetermined relation to the respective

insulating plate members they come in contact with. These positioning detent means and complementary molded depressions in the respective surfaces of the juxtaposed insulating plate members are adapted to position the elongated electrode members **11**, **21** and **21'**, and the elongated terminal members **1** and **22** so that their dome-shaped portions are positioned in the respective apertures through the insulating plate members **2**, **18**, **19** and **20**, with their longitudinal axes concentric with the respective axes of these apertures, **10**, **24**, **26** and **29**. It should also be understood that while a particular dome-shaped electrode and terminal configuration has been shown for the portions **3**, **16**, **17** etc., other suitable substantially concentric structural forms may be utilized to form these raised portions without departing from the scope of my invention. With regard to this feature of the invention, it is only necessary to provide complementary electrode and terminal portions that form suitable spark gap and complementary horn gap arrangements which serve to facilitate rapid extinction of arcs formed across the respective spark gaps. The dome-shaped configuration shown in the preferred embodiment of the invention described herein is utilized, because it can be accurately and inexpensively formed by a stamping operation at the same time the positioning detents **4–7** are formed.

In addition to the foregoing structural features of my invention, a unique and important feature of the invention resides in the configuration of the respective apertures through the insulating plate members **2**, **18**, **19** and **20**. Referring to FIGS. 3 and 4 of the drawings, it can be seen that these apertures **10**, **24**, **26** and **29**, are defined by a pair of frustoconical surfaces that intersect at their small diameter ends adjacent the respective spark gaps formed in the insulating plate members. The large diameter ends of these frustoconical surfaces are of sufficient diameter to extend beyond the edges of the respective elongated electrode members **11**, **21** and **21'** and the terminal members **1** and **22**, which are disposed over them. For example, referring to FIG. 1, the upper edge **10***a* of the aperture **10** can be seen in respect to the elongated terminal member **1**. This unique configuration of the respective apertures through the insulating plate members **2**, **18**, **19** and **20**, provides an optimum means for rapidly extinguishing arcs formed in the respective spark gaps. This desirable feature will be better understood when explained below with reference to the operation of the invention.

In operation, assuming the spark gap assembly of the invention is mounted in a lightning arrester that is operatively connected to protect a power distribution system, when an overvoltage surge is applied across the spark gap assembly between the pair of elongated terminal members **1** and **22**, the respective spark gaps defined between the juxtaposed dome-shaped electrode and terminal portions **3–16**, **17–23**, etc. sparkover, so that the overvoltage surge is discharged through the spark gap assembly to a nonlinear valve resistor **31** (see FIG. 4), which is mounted in electrical contact with the elongated terminal member **22**. The surge current passes through resistor **31** and thence to ground, in a manner well known in the lightning arrester field. Of course, the spark gap assembly and the nonlinear resistance **31** will be mounted in a conventional manner in a suitable insulating housing to form a complete lightning arrester, as is well known in the art; however, since any suitable conventional insulating housing may be used for this purpose, such a housing has not been illustrated in the drawing. Following the discharge of the overvoltage surge through the spark gap assembly, power-follow current from the protected system will continue to flow across the spark gaps through the serpentine path defined by the respective gaps and the elongated electrode members **11**, **21** and **21'**. Strong arc-moving magnetic fields are developed by this serpentine current path due to the shape of the path that is defined by two closely spaced parallel planes that can be hypothetically drawn

through the edges of the respective dome-shaped electrodes and terminal portions, parallel to the longitudinal axes of the elongated electrode members **11**, **21** and **21'**. These strong magnetic fields exert a powerful arc-moving force that rapidly drives the respective arcs toward the outer periphery of the spark gap assembly where the arc impinges on minimum diameter portions of the respective apertures **10**, **24**, **26** and **29**. Thus, the arcs are quickly cooled by their contact with these inner diameter surfaces, at the same time that they are further lengthened by the continuing electro-dynamic force applied to them by the strong magnetic fields. These two effects act to extinguish the arcs in a minimum interval of time. A further arc-quenching feature of the unique aperture configuration of my invention resides in the fact that gases developed by the respective arcs are quickly vented from the area of the spark gaps through the passageways formed by the overlapping maximum diameter areas of the frustoconical surfaces defining these apertures, see FIG. 4. Such rapid venting of the spark gap areas facilities arc movement, because the gases are not trapped in a manner that could develop movement retarding pressures; moreover, it helps to quickly cool and deionize the area around the spark gaps.

I have found that an optimum diameter for the respective apertures **10**, **24**, **26** and **29** is approximately one and one-half times the diameter of the top of the dome-shaped electrode and terminal portions that define the spark gaps in these respective apertures. Although apertures of smaller diameter tend to better extinguish low current arcs, such apertures do not afford adequate arc-gas dispersion under high-current conditions. On the other hand, I have found that the diameter of these apertures should not exceed two times the top diameter of the dome-shaped electrode portions forming the spark gaps in the apertures, because if an aperture of greater diameter is utilized, the degree of arc-quenching in the spark gap assembly is sharply reduced to an undesirable level.

A further important feature of the invention resides in the fact that the upper and lower surfaces of the respective insulating plate members **2**, **18**, **19** and **20** are substantially flat, except for the respective apertures therein. This configuration allows the insulating plate members **2**, **18**, etc. to be formed of a suitable non-organic type of insulating material that can be easily formed into plate members that have substantially identical dielectric properties. This structural characteristic of the insulating plate members **2**, **18**, etc. is important to the accurate operation of the invention, because with the elongated terminal members **1** and **22** arranged in line with the elongated electrode members **11**, **21** and **21'**, it can be seen that a plurality of capacitances are formed by these respective elongated electrode and terminal members, electrically connected in parallel with the individual spark gaps defined therebetween. By maintaining these respective capacitance values substantially identical, an accurate capacitance voltage-dividing grading means for the spark gap assembly is afforded without requiring the utilization of additional expensive separate capacitors.

Although raised portions are shown on the respective upper surfaces of the insulating plate members, such as the portions **32** and **33** shown on insulating plate member **2**, in FIGS. 1 and 2, to assure the rigidity of the assembly in its assembled form, such raised portions are not an essential part of the invention and may be dispensed with if desired. However, it has been found that they do not result in distortion of the dielectric properties of the respective insulating plate members; therefore, their use is not objectionable from an electrical standpoint.

Finally, in addition to the fact that the elongated electrode and terminal members **1**, **22**, **11**, **21** and **21'** serve to concentrate the magnetic arc-moving flux as noted above, the unique structure of these members allows them to be formed from a continuous strip of metallic stock with a minimum of waste. Thus, the manufacturing cost for these respective components is substantially less than the manufacturing costs incurred in fabricating prior art spark gap electrodes.

In addition to the numerous foregoing desirable features of my invention, I have found that a major cost saving results when the invention is used to provide a given rating of overvoltage protection. This saving is achieved because the unique combination of elongated, relatively thin electrode and terminal members with the particular arc extinguishing apertures inherent in my invention, make it possible to locate adjacent spark gaps in very close proximity to one another, as seen in FIG. 4. Therefore, the overall outside dimensions of the spark gap assembly can be substantially reduced without decreasing the current interrupting ability or in any way reducing the gap performance. Such a reduction in the over-all size of the spark gap assembly makes it possible to substantially reduce the cost of the respective components of the assembly, as well as the significant costs attributable to the insulating housing in which the assembly is mounted.

While a preferred embodiment of the invention has been described herein, it is to be understood that various modifications and improvements may be made therein without departing from the scope of my invention and, therefore, it is intended to cover in the appended claims all such modifications and improvements 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 spark gap assembly comprising a plurality of stacked insulating plate members each having an aperture formed therein, a pair of elongated terminal members each having a dome-shaped terminal portion protruding from one side thereof, each of said terminal members being disposed respectively on opposite ends of the stack of insulating plate members, the dome-shaped terminal portions of said terminal members being disposed to extend respectively into the apertures formed in the endmost plate members, a predetermined number of elongated electrode members each having a pair of generally dome-shaped electrode portions protruding from opposite sides thereof at predetermined longitudinally spaced points, each of said electrode portions being disposed to extend into an aperture formed in one of said insulating plate members in juxtaposition therewith, whereby a plurality of spark gaps are defined in the apertures of said plate members between the respective dome-shaped terminal and electrode portions disposed therein, said spark gaps and said terminal and electrode members being disposed in relation to said stacked insulating plate members to define a current path therethrough that is confined between closely spaced parallel planes, each of said apertures through said plate members having a diameter less than two times the mean diameter of the dome-shaped electrode and terminal portions extending into it.

2. A spark gap assembly comprising a plurality of stacked insulating plate members each having an aperture formed therein, a pair of elongated terminal members each having a generally dome-shaped terminal portion protruding from one side thereof, each of said terminal members being disposed respectively on opposite ends of the stack of insulating plate members, the dome-shaped terminal portions of said terminal members being disposed to extend respectively into the apertures formed in the endmost plate members, a predetermined number of elongated electrode members each having a pair of generally dome-shaped electrode portions protruding from opposite sides thereof at predetermined longitudinally spaced points, each of said electrode portions being disposed to extend into an aperture formed in one of said insulating plate members in juxtaposition therewith, whereby a plurality of spark gaps are defined in the apertures of said plate members between the respective dome-shaped terminal and electrode portions disposed

therein, said spark gaps and said terminal and electrode members being disposed in relation to said stacked insulating plate members to define a current path therethrough that is confined between closely spaced parallel planes, each of said apertures through said plate members being defined by a pair of frustoconical surfaces intersecting at their respective small diameter ends adjacent the spark gap defined in the aperture.

3. A spark gap assembly as defined in claim 2 wherein the minimum diameter of each of said apertures is less than two times the diameter of the top of the dome-shaped electrode and terminal portions extending into it, and the maximum diameters of said apertures are greater than the width of said elongated electrodes.

4. A spark gap assembly comprising a plurality of stacked insulating plate members each having an aperture formed therein, a pair of elongated terminal members each having a generally dome-shaped terminal portion protruding from one side thereof, each of said terminal members being disposed respectively on opposite ends of the stack of insulating plate members, the dome-shaped terminal portions of said terminal members being disposed to extend respectively into the apertures formed in the endmost plate members, a predetermined number of elongated electrode members each having a pair of generally dome-shaped electrode portions protruding from opposite sides thereof at predetermined longitudinally spaced points, each of said electrode portions being disposed to extend into an aperture formed in one of said insulating plate members in juxtaposition therewith, whereby a plurality of spark gaps are defined in the apertures of said plate members between the respective dome-shaped terminal and electrode portions disposed therein, said spark gaps and said terminal and electrode members being disposed in relation to said stacked insulating plate members to define a current path therethrough that is confined between closely spaced parallel planes, each of said insulating plate members and the terminal and electrode members disposed on opposite sides thereof being adapted to form an electrical capacitance of predetermined value such that a plurality of substantially equal capacitances are formed in the spark gap assembly, each of said substantially equal capacitances are respectively electrically connected in parallel with one of said spark gaps and in series with one another thereby to form a capacitance voltage grading means for the spark gaps of the assembly, the dielectric portion of each of said capcitances formed by the respective plate members being coextensive with the electrodes on opposite sides thereof except in the area of said spark gaps whereby the predetermined value of each capacitance is maintained constant.

5. A spark gap assembly as defined in claim 4 wherein each of said insulating plate members is provided with substantially flat upper and lower surfaces, except for the apertures therein, and each of said apertures is defined by a pair of frustoconical surfaces intersecting at their respective small diameter ends adjacent the spark gap defined in the aperture.

6. A spark gap assembly comprising a plurality of stacked insulating plate members each having an aperture formed therein, a pair of elongated terminal members each having a generally dome-shaped terminal portion protruding from one side thereof, each of said terminal members being disposed respectively on opposite ends of the stack of insulating plate members, the dome-shaped terminal portions of said terminal members being disposed to extend respectively into the apertures

formed in the endmost plate members, a predetermined number of elongated electrode members each having a pair of generally dome-shaped electrode portions protruding from opposite sides thereof at predetermined longitudinally spaced points, each of said electrode portions being disposed to extend into an aperture formed in one of said insulating plate members in juxtaposition therewith, whereby a plurality of spark gaps are defined in the apertures of said plate members between the respective dome-shaped terminal and electrode portions disposed therein, said spark gaps and said terminal and electrode members being disposed in relation to said stacked insulating plate members to define a current path therethrough that is confined between closely spaced parallel planes, each of said apertures through said plate members being defined by a pair of frustoconical surfaces the respective small diameter ends of which intersect opposite ends of a cylindrical surface that extends therebetween adjacent the spark gap positioned in the aperture.

7. A spark gap assembly comprising a plurality of stacked insulating plate members each having an aperture formed therein, a pair of elongated terminal members each having a generally dome-shaped terminal portion protruding from one side thereof, each of said terminal members being disposed respectively on opposite ends of the stack of insulating plate members, the dome-shaped terminal portions of said terminal members being disposed to extend respectively into the apertures formed in the endmost plate members, a predetermined number of elongated electrode members each having a pair of generally dome-shaped electrode portions protruding from opposite sides thereof at predetermined longitudinally spaced points, each of said electrode portions being disposed to extend into an aperture formed in one of said insulating plate members in juxtaposition therewith, whereby a plurality of spark gaps are defined in the apertures of said plate members between the respective dome-shaped terminal and electrode portions disposed therein, said spark gaps and said terminal and electrode members being disposed in relation to said stacked insulating plate members to define a current path therethrough that is confined between closely spaced parallel planes, each of said apertures through said plate members being defined by a pair of sloped surfaces extending respectively from opposite sides of their plate member toward one another and toward the spark gap positioned in the plate member, the major axes of the aperture thus defined being greater than the width of said elongated electrodes thereby to afford a gas vent past said electrodes, and the minor axis of the aperture being positioned adjacent said spark gap within a distance less than one-half the distance defined by the mean diameter of the dome-shaped electrode portions extending into it thereby to form an arc stretching and cooling surface that confines the arc to prevent it from arcing-over the spark gap assembly.

References Cited

UNITED STATES PATENTS

3,069,589	12/1962	Cunningham	315—36
3,152,279	10/1964	Misare	315—36 X

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