Nov. 17, 1959 B. BISLIN 2,913,626

MULTIPLE SPARK GAP ARRANGEMENT FOR LIGHTNING ARRESTERS

Filed Sept. 22, 1958 4 Sheets-Sheet 1

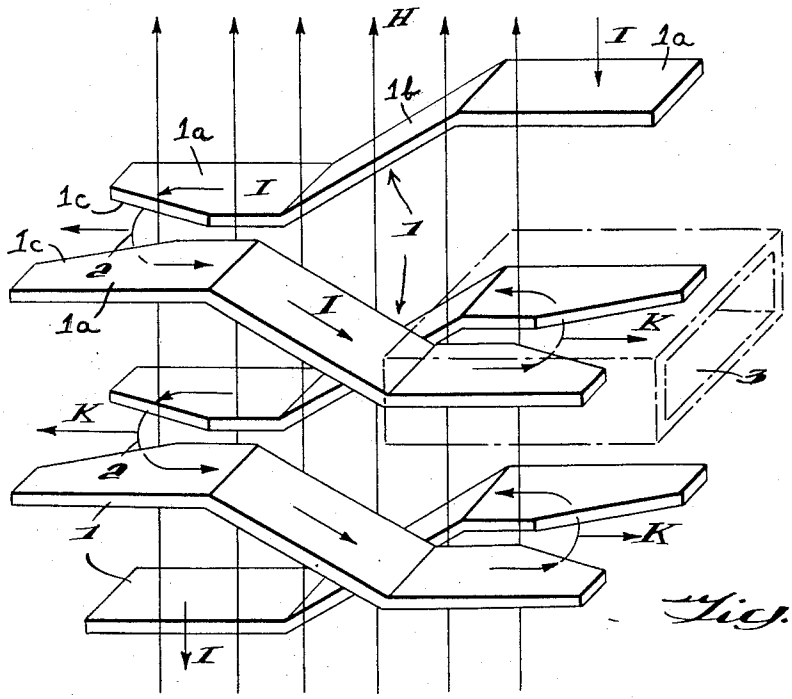


Fig. 1.

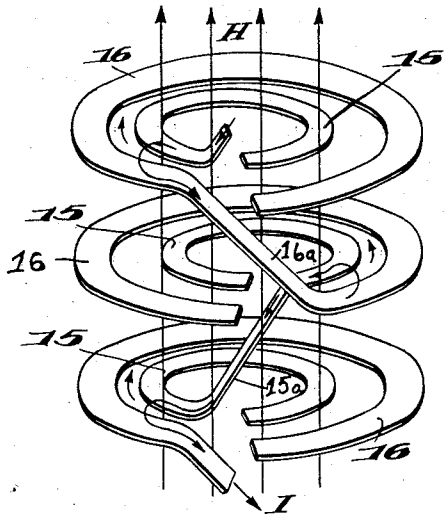


Fig. 7.

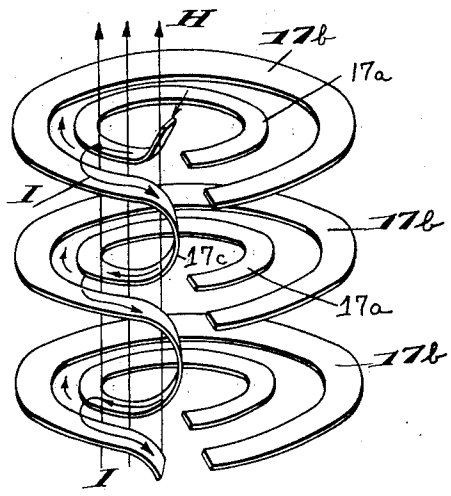


Fig. 8.

INVENTOR

Bernhard Bislin

BY Pierce, Scheffler & Parker

ATTORNEYS

Nov. 17, 1959 B. BISLIN 2,913,626

MULTIPLE SPARK GAP ARRANGEMENT FOR LIGHTNING ARRESTERS

Filed Sept. 22, 1958 4 Sheets-Sheet 2

Fig. 2.

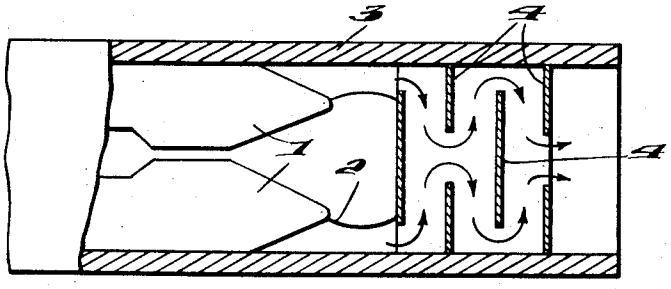


Fig. 3.

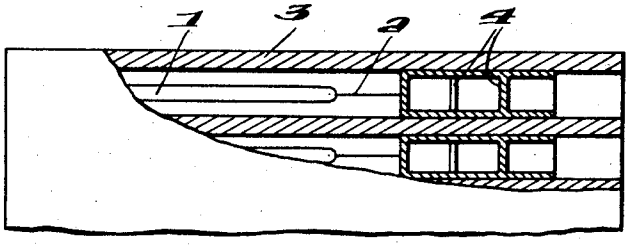
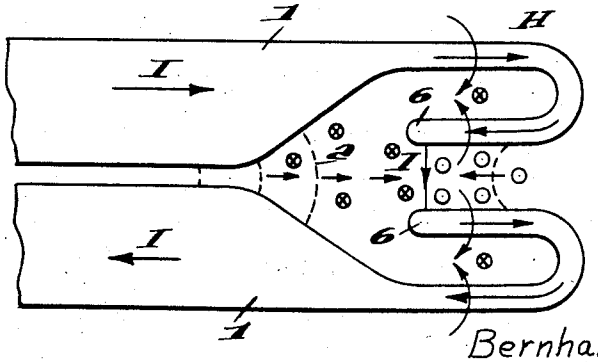


Fig. 4.



INVENTOR

Bernhard Bislin

BY Pierce, Scheffler & Parker

ATTORNEYS

Nov. 17, 1959 B. BISLIN 2,913,626

MULTIPLE SPARK GAP ARRANGEMENT FOR LIGHTNING ARRESTERS

Filed Sept. 22, 1958 4 Sheets-Sheet 3

Fig. 5a.

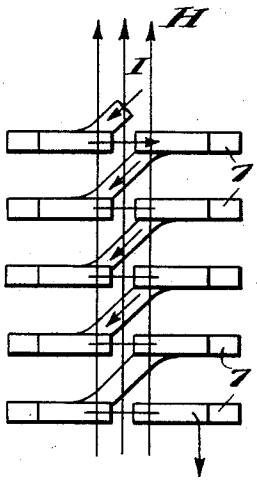


Fig. 6a.

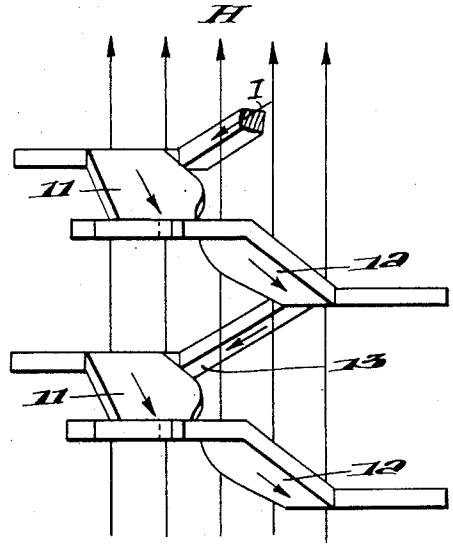


Fig. 5b.

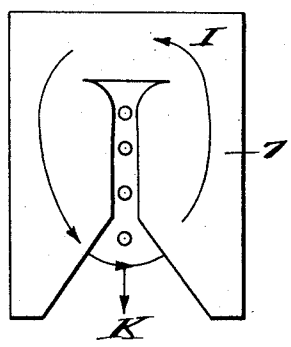
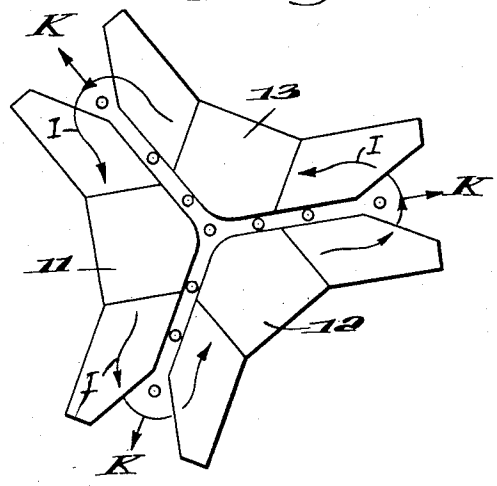


Fig. 6b.



INVENTOR

Bernhard Bislin

BY Pierce, Scheffler & Parker

ATTORNEYS

Nov. 17, 1959 B. BISLIN 2,913,626

MULTIPLE SPARK GAP ARRANGEMENT FOR LIGHTNING ARRESTERS

Filed Sept. 22, 1958 4 Sheets-Sheet 4

Fig. 9.

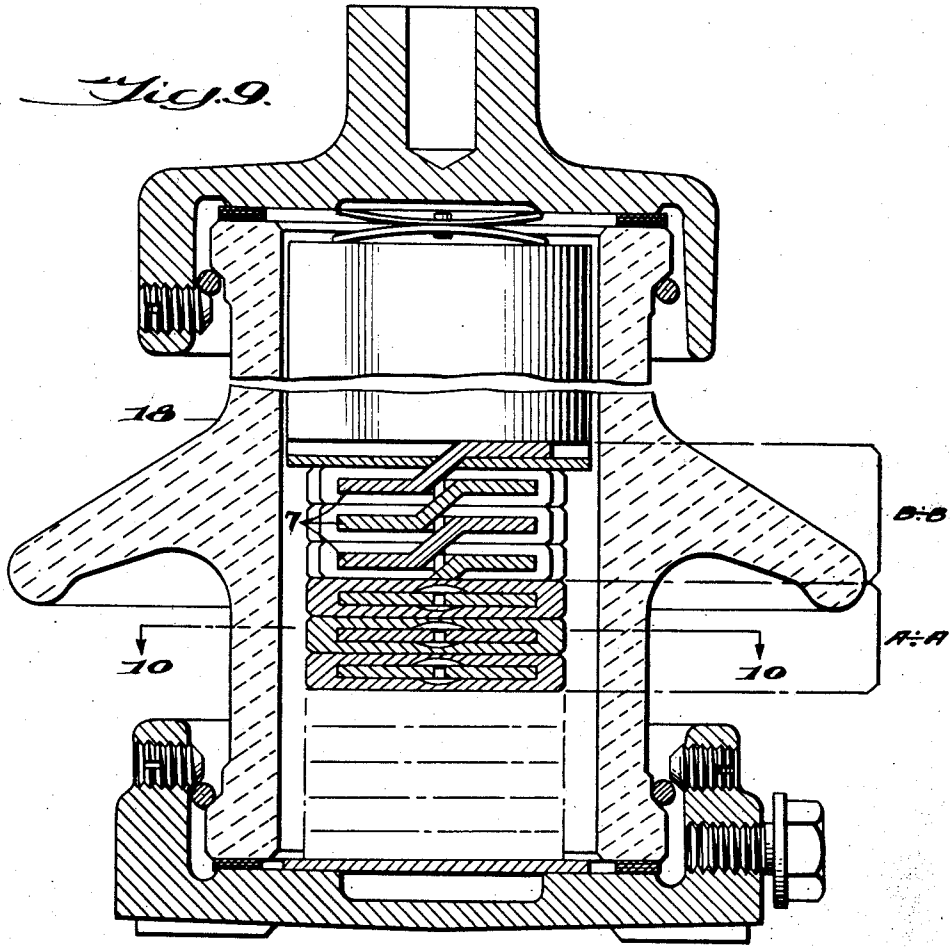
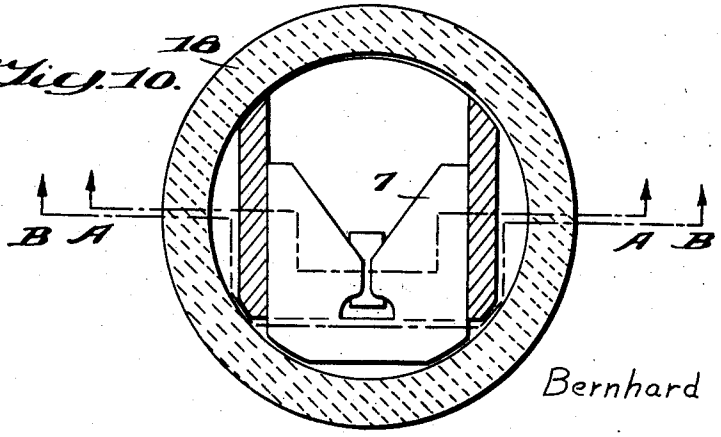


Fig. 10.



INVENTOR

Bernhard Bislin

BY Pierce Scheffler & Parker.

ATTORNEYS

United States Patent Office 2,913,626
Patented Nov. 17, 1959

2,913,626

MULTIPLE SPARK GAP ARRANGEMENT FOR LIGHTNING ARRESTERS

Bernhard Bislin, Wettingen, Switzerland, assignor to Aktiengesellschaft Brown, Boveri & Cie., Baden, Switzerland, a joint-stock company

Application September 22, 1958, Serial No. 762,578

Claims priority, application Switzerland October 4, 1957

16 Claims. (Cl. 315—36)

The present invention relates to lightning, i.e. over-voltage arresters and in particular to those arresters of the type including a plurality of spark gaps connected in series with a plurality of voltage-dependent resistor elements. These arresters are connected to a high-voltage line and function in the event of a sudden high-voltage surge caused by lightning or the like to establish a low impedance path to ground, thus eliminating the surge and protecting the electrical equipment on the line against damage.

In the design of over-voltage arresters having multiple spark gaps and voltage-dependent resistors connected in series, one endeavors in general to maintain the sparkover and residual voltages at a low level. The sparkover voltage at the frequency of the line or network to which the arrester is connected should be such that even overvoltages occurring during switching operations, ground connections and the like are limited by action of the arrester. Lowering the sparkover voltage reduces the ratio of sparkover voltage to recovery voltage. The consequence of this is that the requirements concerning extinguishing ability of the spark gap of the arrester become much higher.

The usual multiple spark gap arrangement, wherein the arc is sub-divided by a plurality of parallel electrodes, have an extinguishing capacity limited by the temperature at the root of the arc. When this limit is exceeded, there occurs, after passage of the current through zero, a restrike, which in the end may lead to destruction of the entire spark gap system.

Methods have previously been devised to increase the extinguishing ability of the spark gaps by causing the arc to shift away from its original point of formation by use of the magnetic blow-out principle. Displacement of the arc cannot cause melt beads on the electrode surface or adversely affect the sparkover voltage. To increase the restrike voltage of the electrode, it is important that the arc does not remain in one place and does cause the same point to be heated excessively. Hot ionized gases can, in fact, reduce the restrike voltage of the arc to such an extent that restrike occurs immediately after the passage of the voltage through zero. To avoid this, the arc must be brought back to a point of increased electrode spacing and, if possible, of intensified ventilation. At this new point, the sparkover voltage must, after the next passage of the voltage through zero, be at least the same as that of the place of arc origin which in the meantime has cooled off and which is swept by de-ionized gases. The magnitude of the currents which can be cut off thus depends upon the intensity of the magnetic blowing and the resulting increase in arcing strength.

Up until now, to generate the magnetic field required for blowing the arc, there have been mainly used permanent magnets or a magnetic field generating coil carrying a portion of the shunt current, but always, however, with the disadvantage of higher cost and great space requirement for the arrester. Also, there are known

lightning arresters with a special design for the arc electrodes, for generating a field which forcibly brings about the desired migration of the arc from place to place on the electrode surfaces. However, the blowing effect in the known arresters of the latter type is relatively weak and by no means sufficient to obtain a substantially high extinguishing capacity, or to keep the sparkover and residual voltage lowered to the desired extent.

It is now the object of the present invention to provide a multiple spark gap for over-voltage arresters having voltage-dependent resistances which does not have the mentioned defects of the previous arresters and which, in particular, provides an intensive magnetic blowing effect by comparatively simple means. According to the invention, this is achieved in that the electrodes of the spark gap are of stepped design and are so arranged in spatial relation to each other that each electrode forms the connection between two current loops present in different planes, adjacent current loops supporting each other upon the generation of the magnetic blow field, and that further the electrodes are so arranged in relation to each other and have a form such that the area enveloped by the current and hence also the inductivity of the spark gap arrangement becomes as small as possible. With such an arrangement and form of the electrodes of the spark gap it is possible to extend the arc during the extinguishing process to at least 10 mm./kv. nominal voltage of the arrester. The relatively high voltage drop over the arc produced in this manner during the flow of the follow current enables the height of the resistance and hence the entire structural height of the arrester to be made smaller. In addition there results the further advantage that by this reduction of the resistances, the residual voltage of the arrester becomes smaller during a surge.

The invention is further explained with reference to the electrode systems shown, by way of example, in Figures 1 to 10. In all of these embodiments the electrodes are of stepped design and are arranged in spatial relation to each in such a way that each electrode forms a connection between two current loops present in different planes.

In Fig. 1, is illustrated a multiple spark gap, which is formed by the electrodes **1**. Each electrode is constituted by an offset electrically conductive metal strip, consisting of parallel, planar straight end portions **1***a* occupying different planes normal to the magnetic field H, and which end portions are interconnected by a middle planar straight portion **1***b* disposed at an angle to the magnetic field. These electrodes are so spaced from each other and arranged in stepped i.e. staircase, form that upon ignition of the arc **2**, the current I passes through the partial spark gaps in downwardly progressing loop-shaped paths through the electrodes. This occurs because the lowermost end portion **1***a* of one electrode lies in the same plane as, but spaced laterally from, the uppermost end portion **1***a* of the next electrode. Thus the arcs are established between co-planar end portions of consecutive electrodes in the staircased arrangement. It will be noted that the inner edge portions **1***c* of the end portions **1***a* are cut off at an angle so as to present a progressively increasing distance between the edges of adjacent coplanar electrode end portions as measured in the direction towards the ends of the electrodes. These current loops are located side-by-side in such a way that their magnetic fields H support one another. On the arc **2**, which stands perpendicular to the resulting magnetic field, there now acts a force K outwardly which tends to drive the arc outwardly into the ever increasing distance between the angled off edges **1***c* of adjacent electrode ends. Depending on the number of adjacent electrodes **1**, at a certain current, a greater or smaller

field strength and hence a corresponding blow effect can be obtained. Due to this special shaping of the electrodes, together with the migration of the arc from the zone of the shortest distance between the electrodes, the arc is thus lengthened, whereby the desired condition of a sufficient high restrike voltage is obtained. In the multiple spark gap according to Fig. 1, there results a subdivision of the partial arcs into two groups with opposite directions of blowing.

The spark gap may be equipped with arc chambers 3, as indicated in broken lines in Fig. 1. These spark chambers 3, may further be provided at the outlet end with built-in plates 4, e.g. of metal. Such a spark chamber 3, is shown on a larger scale in Figures 2 and 3 in elevation and plan, respectively. The electrodes are indicated at 1 and the arc at 2. Within the spark chamber 3 toward the outlet end, the plates 4 are installed, which form subdivided spaces for the cooling of the hot gas, whose direction of flow is indicated by the arrows. By these built-in plates 4, the arc is prevented from leaving the spark chamber and, at the same time, the maximum length of the arc can thus be unambiguously determined.

Another possibility for preventing the arc from leaving the spark chamber is illustrated in Fig. 4. In this case, the ends of the electrodes 1 are designed with horns 6 bent inwardly. Immediately after the arc 2 has flashed, it is driven outwardly by the magnetic field which is concentrated within the current loop. In the figure, the supply of current I occurs from the left up to the moment when the arc reaches the horns 6. Then the arc will shorten to the distance between these horns, so that then the current supply occurs from the right. This produces an inner loop whose magnetic field exerts an inwardly directed force. There is thus formed a practically magnetically neutral zone in which the arc remains standing. At a sufficiently great distance between the horns 6, the desired necessary back-arcing strength is attained.

In Figures 5*a* and 5*b* another embodiment of the invention is represented in elevation and plan. The multiple spark gap is formed by the superposed stepped electrodes 7. This arrangement differs from that of Fig. 1, in that at equal number of break points and equal arrester current I the resulting magnetic field H and hence the force K acting on the arc is approximately doubled. The blowing effect here occurs only in one direction. Figures 9 and 10 illustrate the manner in which the stepped electrodes 7 shown in Figures 5*a* and 5*b* may be assembled within a porcelain insulator casing 18 of conventional construction. The electrodes 7 in the upper portion of the stack are shown in section taken along line B—B of Figure 10 while the electrodes in the lower portion of the stack are shown in section taken along line A—A of Figure 10. The latter view is a section taken along line 10—10 of Fig. 9.

In the embodiment shown in Figures 6*a* and 6*b* in elevation and plan, the multiple spark gap is formed by groups of three stepped electrodes 11, 12 and 13 each, which are so arranged that each partial spark gap is offset relative to the preceding one by 120 deg. In this case there result three different blowing directions for the partial arcs of each electrode group. Also, the structural height of the spark gap system will be somewhat lower, because more space is available for locating the spark chambers.

Finally, Figures 7 and 8 show other multiple spark gap arrangements according to the invention in front elevation. These are particularly advantageous when the spark gap is designed to occupy a cylindrical space. In the model according to Fig. 7, the spark gap is formed by the circularly bent inner and outer annular-like electrodes 15 and 16. The inner and outer electrodes 15, 16 which form each gap are co-planar and several of such gaps are arranged in superposed relation in parallel planes normal to the vertical axis of the arrester. The outer electrode 16 of one gap is interconnected with the outer electrode 16 of the gap next below by means of a downwardly inclined interconnecting portion 16*a*, and the inner electrode 15 of the latter gap is interconnected with the inner electrode 15 of the gap next below by means of a downwardly inclined interconnecting portion 15*a*. Thus, these interconnecting electrode portions 15*a* and 16*a* function in alternation to connect the several gaps in a series arrangement. It will be noted that the inner and outer arcuate electrodes 15 and 16 which form each gap are not placed concentrically such that the radial spacing therebetween would remain equal around the periphery but rather are purposely so configured and spaced that the arc gap distance between the inner periphery of the outer electrode 16 and the outer periphery of the inner electrode 15 progressively increases. Thus the arc will be established between the electrodes of one gap at the point of minimum spacing therebetween and will be driven by the magnetic field H arcuately in the direction indicated by the arrow with ever increasing distance between the inner and outer electrodes. Thus because of the fact that the circular electrodes are bent in the plane of the arc, the arc will continuously rotate and come always to a new de-ionized zone. After the arc passes through the circular path forming one spark gap it returns to the point of origin so that even at extremely intensive blowing, the arc can never be displaced into an uncontrollable area. In the Fig. 7 arrangement, the arc will travel clockwise around and between the electrodes of one gap and then counter-clockwise around and between the electrodes of the next gap in the series. Thus the arc path alternates in direction for successive gaps in the series.

The embodiment shown in Fig. 8 is similar to that illustrated in Fig. 7 in that each spark gap is established by an inner arcuately bent electrode 17*a* and an outer arcuately bent electrode 17*b* which is co-planar with the inner electrode 17*a*, there being provided an ever increasing distance between the inner periphery of the outer electrode 17*b* and the outer periphery of the inner electrode 17*a*. However, it will be seen from the drawing that the outer electrode of one gap is structurally integrated with the inner electrode of the adjacent gap in the series, the two being interconnected by a reversely bent portion 17*c* which establishes one and the same direction of travel for the arc around the electrodes for all gaps in the series.

In all of the foregoing embodiments which have been described, the stepped current conduction in the gaps has the great advantage that the area enveloped by the current is very small. With steep current increases, this property is further supported by the current displacement to the inner edges of the electrodes. As the self-inductance of a coil is known to be directly proportional to the area enveloped by the current, the self-inductivity and hence the inductive voltage drop at steep wave fronts becomes small for the electrode arrangement in accordance with the invention. Also, due to the fact that no unnecessarily large electrode areas are opposite each other, an unambiguous path is prescribed for the arc.

In conclusion, it will be understood that while several embodiments of the invention have been illustrated and described, various other changes and modifications may be made without, however, departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. A multiple spark gap for connection in series with voltage-dependent resistances to establish a lightning arrester for use on high voltage lines, said multiple spark gap comprising a plurality of sets of spaced electrodes, said electrode sets being interconnected in series and disposed each above the other in parallel planes to establish a current flow through the same in series in a looped path, said current establishing a magnetic field extending through the spaces between the electrodes of each set normal to the respective parallel planes in which they

lie thereby serving to blow and hence lengthen the respective arcs established in the spaces between the electrodes of each set.

2. A multiple spark gap as defined in claim 1 and which further includes an arc chamber for the electrodes of each set.

3. A multiple spark gap as defined in claim 2 and wherein said arc chambers are each provided with metallic plates disposed to prevent the arcs from coming out of the chamber and for determining the maximum lengths of said arcs.

4. A multiple spark gap as defined in claim 1 wherein the spaced electrodes of each set include end portions provided with inwardly bent horns which when reached by the current produce an inner current loop counteracting the blowing effect of the magnetic field and thus checking the arc.

5. A multiple spark gap as defined in claim 1 wherein said sets of electrodes are spatially arranged such that the respective arcs established in the spaces between the electrodes of each set blow in the same direction.

6. A multiple spark gap as defined in claim 1 wherein said sets of electrodes are spatially arranged such that the respective arcs established in the spaces between the electrodes of each set blow in different directions.

7. A multiple spark gap as defined in claim 1 wherein said sets of electrodes are spatially arranged in two groups such that the arcs established in the spaces between the electrodes of the sets of one group blow in a direction different to the blowing direction of the arcs established in the spaces between the electrodes of the sets constituting the other group.

8. A multiple spark gap as defined in claim 7 wherein said electrode sets are arranged in three groups and the blowing directions of the respective arcs established in the spaces between the electrodes of the sets of each group are spaced 120° apart about the axis of the magnetic field.

9. A multiple spark gap as defined in claim 7 wherein said electrode sets are arranged in two groups and the blowing directions of the respective arcs established in the spaces between the electrodes of the sets of each group are spaced 180° apart about the axis of the magnetic field.

10. A multiple spark gap as defined in claim 1 wherein the length of the arcs during the extinguishing process amounts to at least 10 mm./kv. nominal voltage of the arrester.

11. A multiple spark gap as defined in claim 1 wherein the electrodes of each set are constituted by spaced co-planar end portions of two electrode strips, the opposite end portions of said strips being located in parallel but different planes and forming the arc gaps of adjacent electrode sets.

12. A multiple spark gap as defined in claim 11 wherein the confronting edges of the co-planar end portions of said electrode strips diverge in the direction in which the arc established therebetween is blown.

13. A multiple spark gap as defined in claim 1 wherein the electrodes of each set are constituted by spaced inner and outer co-planar electrode members having an arcuate configuration.

14. A multiple spark gap as defined in claim 13 wherein the spacing between said inner and outer co-planar arcuate electrode members of each electrode set increases in the arcuate direction in which the arc established therebetween is blown.

15. A multiple spark gap as defined in claim 13 wherein the outer arcuate electrode member of each electrode set is electrically connected to the outer arcuate electrode member of the next adjacent electrode set and the inner arcuate electrode member of each electrode set is electrically connected to the inner arcuate electrode member of the next adjacent electrode set, the respective directions of travel of the arcs for said adjacent electrode sets being opposite to each other.

16. A multiple spark gap as defined in claim 13 wherein the outer arcuate electrode member of each electrode set is electrically connected to the inner arcuate electrode member of the next adjacent electrode set, the respective directions of travel of the arcs for said adjacent electrode sets being the same.

References Cited in the file of this patent

UNITED STATES PATENTS

2,151,559	McEachron	Mar. 21, 1939
2,392,679	MacCarthy	Jan. 8, 1946
2,495,154	Zimmerman	Jan. 17, 1950
2,825,008	Kalb	Feb. 25, 1958