Oct. 14, 1952 J. W. KALB 2,614,232

AIR GAP CONSTRUCTION

Filed Sept. 15, 1950 2 SHEETS--SHEET 1

Fig. 1.

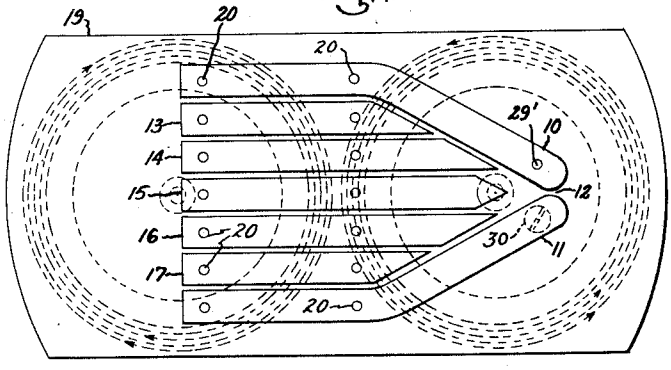


Fig. 2.

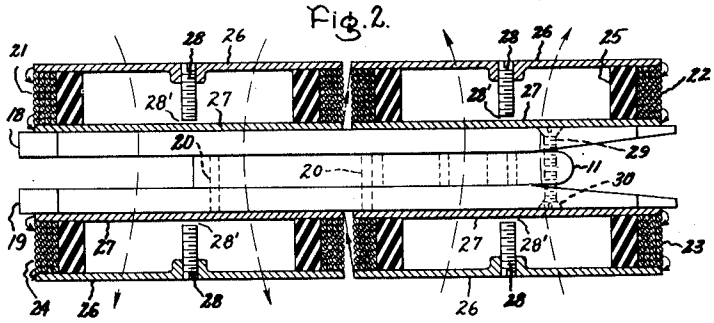


Fig. 3.

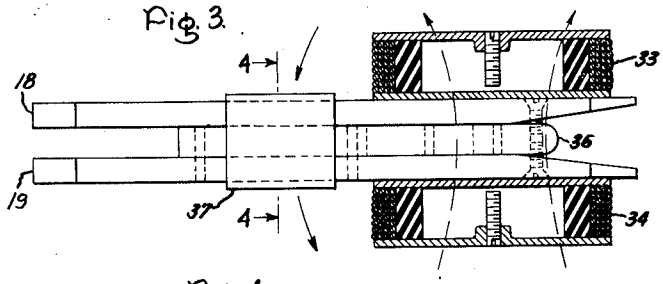


Fig. 4.

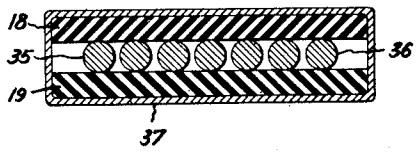


Fig. 5.

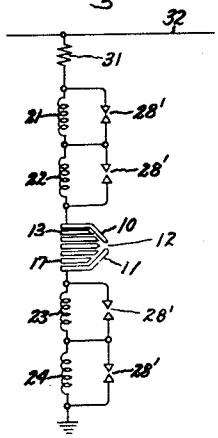


Fig. 6.

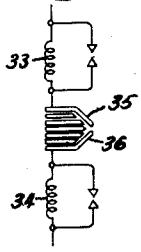
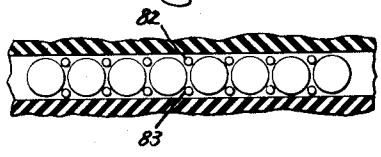


Fig. 15.



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AIR GAP CONSTRUCTION

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Fig. 7.

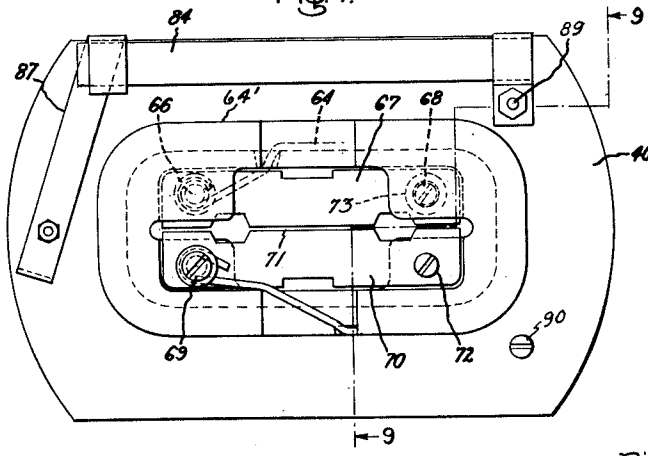


Fig. 9.

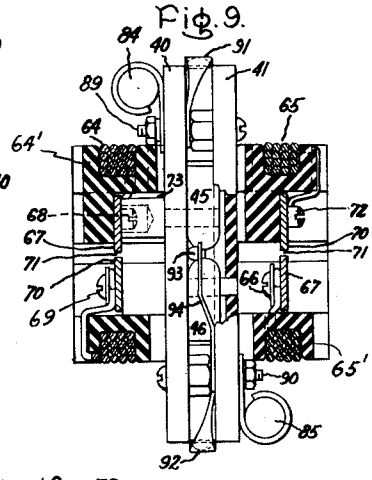


Fig. 8.

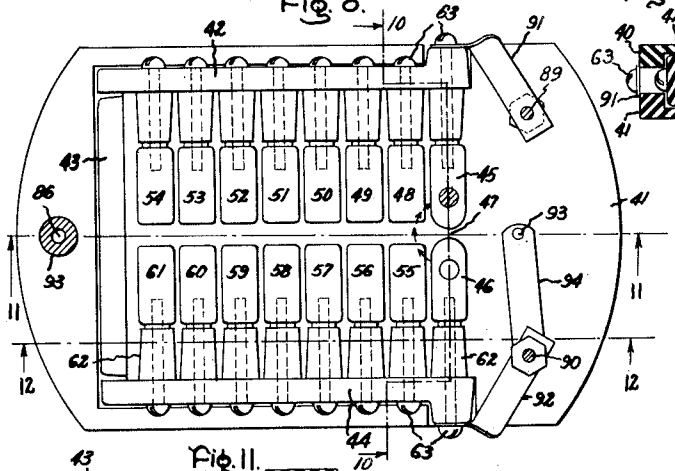


Fig. 10

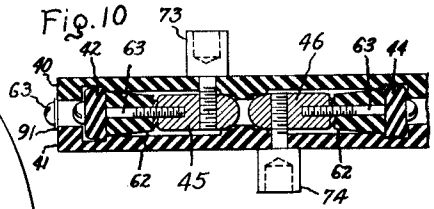


Fig. 14.

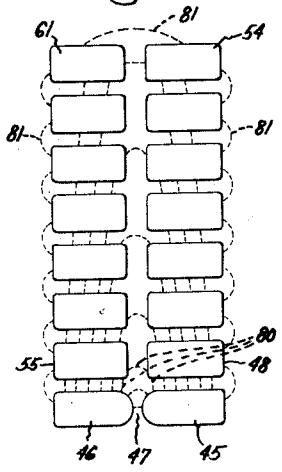


Fig. 11.

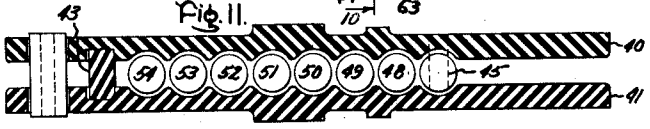
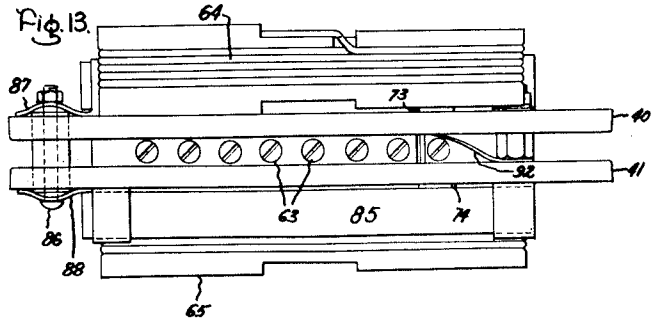


Fig. 12.



Fig. 13.



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Patented Oct. 14, 1952 2,614,232

UNITED STATES PATENT OFFICE

2,614,232

AIR GAP CONSTRUCTION

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Application September 15, 1950, Serial No. 184,925

21 Claims. (Cl. 313—156)

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My invention relates to an air gap construction and more particularly to an improved air gap construction for incorporation in a lightning arrester.

One type of lightning arrester now in general use comprises an air gap and a current limiting resistor in series in an electric circuit connected between the ground and a conductor supplying current at a predetermined voltage to electrical apparatus to be protected. The length of the air gap is such that during normal operating conditions the voltage between the supply conductor and the ground is not sufficient to break down the air gap and allow current to flow through the current limiting resistor. However, when lightning strikes the supply conductor, a large transient high frequency current surge flows in the supply conductor so that the voltage of the supply conductor increases relative to the ground to a sufficiently high value to cause the air gap to arc over and establish through the current limiting resistor a current conducting circuit through which the large transient current surge produced by the lightning can discharge to the ground. However, the breakdown of the air gap also allows the source of current normally supplying current to the apparatus being protected to supply to the ground through the current limiting resistor a large current called a power follow current.

In order that the large transient current surge may not produce an excessive voltage drop across the current limiting resistor and thereby impress a high voltage across the apparatus being protected, it is desirable to use a current limiting resistor having a very low value of resistance. Furthermore, as soon as the high transient current surge has been completely discharged to ground, it is desirable to interrupt the flow of the power follow current through the lightning arrester so as to restore the arrester to its normal nonconducting condition. However, it has been found that a current limiting resistor which has the proper low resistance value to prevent an excessive voltage drop being produced across it by the large transient current surge allows such a large power follow current to flow through it that the air gap is not sufficiently long to interrupt this large power follow current. Furthermore, it is evident that increasing the length of the air gap is not a solution of the problem because that increases the minimum voltage between the ground and the supply conductor required to arc over the air gap to too high a value.

In many cases, satisfactory operation is obtained by using a current limiting resistor which has the unusual characteristic that its resistance decreases as the current flowing through it increases, and vice versa, so that the resistance of the resistor when both the transient current surge and the power follow current are flowing through it is much lower than the resistance when only the power follow current is flowing through it. However, when such an arrangement is used on a very high voltage supply circuit, it has been found that when a current limiting resistor having the proper low resistance value to prevent an excessive voltage from being produced across it by the transient surge current is used, the resistance thereof when only the power follow current is flowing through it still is not high enough to limit this power follow current to a value which can be interrupted by the series connected air gap.

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Therefore, it would be desirable to provide for incorporation in a lightning arrester an air gap construction which has an air gap of a sufficiently small length to break down in response to the occurrence of a predetermined abnormal voltage across the air gap and which also has sufficient interrupting capacity to interrupt a power follow current that is materially greater than can be interrupted by that air gap, and one object of my invention is to provide such an improved air gap construction.

Another object of my invention is to provide an improved air gap construction which permits an arc to be initially established directly between the two electrodes of an air gap having a predetermined length and which automatically causes this arc to be divided immediately into a plurality of arcs in series between said electrodes, said plurality of arcs being respectively established across different air gaps having an aggregate length greater than said predetermined length.

A further object of my invention is to provide an improved air gap construction which causes an arc initially established directly between the two electrodes of an air gap having a predetermined length to be successively replaced by an increasing number of arcs in series between said electrodes, said arcs being respectively established across different air gaps having an aggregate length greater than said predetermined length.

In accordance with my invention, my improved air gap construction comprises a pair of electrodes defining a main air gap and so spaced apart that an arc is established between them

when the voltage impressed across them exceeds a predetermined abnormal value. A plurality of auxiliary electrodes are also so spaced and positioned relative to each other and to the electrodes of the main air gap as to form a progressively increasing number of air gaps in series between the electrodes of the main gap and so related thereto that movement of said arc in a predetermined direction relative to its initial position causes the arc to become a progressively increasing number of arcs in series established across said series connected auxiliary air gaps which have an aggregate length greater than the length of said main gap. Magnetic means, such as one or more coil windings, are connected in series with the pair of electrodes of the main air gap and so positioned relative thereto that said electrodes are located directly opposite the area within the periphery of each coil winding whereby the magnetic field produced by the current in each winding and the magnetic field produced by the arc current react on each other in accordance with the well-known electric motor principle to cause the arc to move in said predetermined direction. Movement of the arc in said predetermined direction may be arrested or restrained by causing the magnetic field produced by the arc current also to react either with the magnetic field produced by the current in each winding or with some other magnetic field in such a manner as to produce at a point remote from the main air gap, but within the path of movement of the arc, a force tending to move the arc in the reverse direction.

The invention will be better understood from the following description when taken in connection with the accompanying drawings and the scope of the invention will be pointed out in the appended claims. In the drawings, Fig. 1 is a plan view of an arc extinguishing device embodying the invention with the upper plate and coils removed to better illustrate the arrangement of gap electrodes therein; Fig. 2 is an elevation or a side view partly in section of the Fig. 1 device; Fig. 3 is a view similar to Fig. 2 illustrating a modification of the invention; Fig. 4 is a sectional view taken on the line 4—4 of Fig. 3; Fig. 5 is a schematic diagram illustrating the circuit arrangement employed in the device shown in Figs. 1 and 2; Fig. 6 is a schematic diagram illustrating the circuit arrangement of the device shown in Figs. 3 and 4; Fig. 7 is a plan view of a further modification of the invention; Fig. 8 is another plan view of the same embodiment with the top plate and upper coil winding removed to better illustrate the internal structure of the device; Fig. 9 is an end view shown partly in section along the line 9—9 of Fig. 7; Fig. 10 is a sectional view of this embodiment along the line 10—10 of Fig. 8 with the top plate in position; Fig. 11 is another sectional view along the line 11—11 of Fig. 8; Fig. 12 is a fragmentary sectional view taken on the line 12—12 of Fig. 8; Fig. 13 is a side elevation of the embodiment of Fig. 7; Fig. 14 is a diagrammatic representation of the electrodes of the device of Fig. 7 illustrating the movement or progression of an arc to be interrupted; and Fig. 15 is a partial sectional view similar to Fig. 11 and illustrating a modification of the structure of Fig. 7 as it would appear if taken on a line corresponding to line 11—11 of Fig. 8.

Referring now to Figs. 1, 2 and 5 of the drawings, I have illustrated an air gap construction or gap unit comprising a pair of spaced members 10 and 11 shaped to provide diverging electrodes defining an arc gap at 12 and having parallel portions extending away from their diverging portions. A plurality of elongated and spaced electrodes 13 to 17, inclusive, are positioned with their longitudinal axes in a common plane between electrodes 10 and 11 and parallel to the parallel portions thereof. Electrodes 13 to 17 define a plurality of quench or auxiliary arc gaps electrically in series between the electrodes 10 and 11 parallel with the gap 12 and disposed in substantially the same plane. In order that the gaps in series will progressively increase as the distance from main gap 12 is increased in a leftward direction, as viewed in Fig. 1, auxiliary electrodes 14 and 16 are provided longer than electrodes 13 and 17 so that the former electrodes extend further toward gap 12 while electrode 15 is still longer than all of the other auxiliary electrodes. Thus, as the distance away from main gap 12 is increased, two gaps in series are first defined between electrodes 10, 15 and 11, then four gaps in series are defined between electrodes 10, 14, 15, 16 and 11, and finally six gaps in series are defined between electrodes 10, 13, 14, 15, 16, 17 and 11. Electrodes 10 and 11 and the auxiliary electrodes are interposed between a pair of parallel disposed plates or slabs of insulating material 18 and 19 which are positioned parallel to the longitudinal axes of the electrodes and the gaps therebetween. The electrodes may be fixed in any suitable manner such as by pins or screws 20 to one or both of the plates 18 and 19. Magnetic means such as a pair of adjacently positioned coil windings 21 and 22 and another pair of oppositely positioned coil windings 24 and 23 respectively are suitably mounted on the outside surfaces of slabs 18 and 19 with the axis of each winding disposed substantially normal to the longitudinal axes of the electrodes, as shown. Each of the windings is mounted on a spool 25 of insulating material upon which are also mounted oppositely disposed plates 26 and 27 of conducting material. Threadedly mounted in each of the plates 26 is an adjustable screw 28 of conducting material, the opposite end of which is properly spaced from the oppositely disposed plate 27 to define an arc gap 28' therewith. Each plate 26 is electrically connected with one end of the adjacent coil winding while the opposite plate 27 is, in each case, electrically connected to the other end of the winding, as indicated in Fig. 2 by the short arrows. A screw 29 through insulating plate 18 is threaded into a threaded opening 29' in main electrode 10 and serves to connect electrically this electrode with conducting plate 27 of coil 22, while a similarly positioned screw 30 threaded into the other main electrode 11 serves to connect electrically this electrode with plate 27 of coil 23 and thereby electrically connect windings 22 and 23 in series with electrodes 10 and 11 and the gap therebetween. Plate 26 of coil 22 is electrically connected in series with one end of the winding, or the conducting plate to which it is electrically fixed, of coil 21 while the other end of the winding of coil 21, or the conducting plate to which it is electrically fixed, may be connected directly or through a current limiting resistor 31 to a source of electrical power to be protected such as a power transmission line 32 indicated schematically in Fig. 5. Coil 24 is similarly connected electrically in series with coil 23 with the free end of the winding of coil 24 electrically connected to ground either directly or through additional gap and coil units. Instead of connecting one end of the winding of coil 21

to a source of electrical power and one end of the winding of coil 24 to ground, it will be apparent that this arrangement may be reversed so that coil 21 is connected to ground while coil 24 is connected to a source of power.

It should be noted that the oppositely disposed windings 22 and 23 are so positioned that the areas within the peripheries thereof are opposite the main electrodes 10 and 11 and also opposite one end or a portion of each of the auxiliary electrodes, while the oppositely disposed windings 21 and 24 are so positioned that the areas within the peripheries thereof are opposite portions of the auxiliary electrodes adjacent the opposite ends thereof. It should furthermore be observed that the windings are so connected electrically in series that when energized, the current flow in oppositely positioned windings 22 and 23 will be in a given direction such as counterclockwise as viewed and illustrated by the arrow heads in Fig. 1, while the current flow in windings 21 and 24 will be in the opposite direction or clockwise. Thus, the magnetic field or flux produced by and within the peripheries of coils 22 and 23 and a portion of the return magnetic field produced by and outside of the peripheries of coils 21 and 24 will traverse the gap spaces between electrodes 10 and 11 and between corresponding ends of the auxiliary electrodes in an upward direction substantially normal to the common plane of the gaps as illustrated by the curved broken lines in Fig. 2, while the magnetic field produced by and within the peripheries of coils 21 and 24 together with a portion produced by and outside the peripheries of coils 22 and 23 will traverse the gap spaces between the balance portion of the auxiliary electrodes in a downward direction and substantially normal to the plane of the gaps. It will be apparent that each of the gaps 28', if broken down, will serve to shunt or by-pass respectively one of the coil windings.

Under normal conditions, there is no current across the gap between electrodes 10 and 11 and the voltage across this gap is that from line to ground. There is no current through the coils nor across the gaps 28' and no voltage drop across them. If a dangerously high transient voltage appears on line 32, it will first spark over the gap 12 between electrodes 10 and 11 and establish a current in the circuit extending from line 32 through the coils 21 and 22, then across the gap 12 from electrode 10 to electrode 11, then through coils 23 and 24 to ground. If, as is usually the case, the transient includes components with rapid rates of change of current, gaps 28' will then spark over, after which the current will flow through gaps 28' rather than through the coils. After the transient has been dissipated, power follow current from line 32 may follow the same path. However, this power current, which would not include components with rapid rates of change, would follow the path of lower impedance through the coils rather than flow through the gaps 28', and the arc across these gaps would be rapidly extinguished.

The magnetic field resulting from the current through the coils 22 and 23 and traversing the gap 12 between electrodes 10 and 11 will react with the magnetic field produced by the current in the arc across gap 12 on a motor principle virtually to push the arc out of gap 12 toward the left, as viewed in Fig. 1, similar to the manner in which the conductors on a motor armature are moved. This leftward movement into the region of the auxiliary electrodes will result in the progressive breaking up of the initial arc into an increasing number of arcs in series until eventually six arcs electrically in series will be established between the electrodes in the region between the diverging portion of electrodes 10 and 11 adjacent the parallel portions thereof. The reaction between the upward moving magnetic fields, as viewed in Fig. 2, of windings 22 and 23 and the magnetic fields of the arcs will tend to cause continued movement of these arcs toward the extreme left-hand ends of the electrodes where the auxiliary arcs would reunite or recombine into an objectionable single long arc if such further movement were permitted. However, since the relative positions of coils and electrodes are such that substantially all of the parallel portions of the electrodes 10 and 11 and substantially all portions of the auxiliary electrodes between such parallel portions of electrodes 10 and 11 are opposite the areas outside the peripheries of coils 22 and 23 but opposite the areas within the peripheries of coils 21 and 24, the downward moving magnetic field in this region, being in a reverse direction, is effective to arrest further leftward movement of the six series arcs short of the extreme left-hand ends of the electrodes. Actually the six arcs are confined to the mid-region of the auxiliary electrodes and their voltage per gap is so low that they are readily extinguished as a result of which large power follow currents can be interrupted. Thus, the favorable condition of a single gap of small spacing for low sparkover and many gaps of larger aggregate spacing for high current interrupting ability is obtained.

The embodiment illustrated by Figs. 3, 4 and 6 is substantially identical to the embodiment hereinbefore described in so far as the electrode arrangement is concerned. Like the magnetic field in the Figs. 1, 2 and 5 embodiment, the field between and directly opposite the oppositely disposed coils 33 and 34, corresponding to coils 22 and 23 respectively, is employed to move an initial arc between a pair of electrodes 35 and 36, corresponding to electrodes 10 and 11 respectively, into the region of a plurality of spaced auxiliary electrodes; but unlike the arrangement in the embodiment of Figs. 1, 2 and 5, only the return flux or field outside the peripheries of coils 33 and 34 and traversing or cutting the electrodes and gaps therebetween in a reverse direction is employed to arrest movement of the auxiliary arcs toward the left-hand end of the electrodes. In order more positively to arrest movement of the arcs, the parallel portions of electrodes 10 and 11 and portions of the auxiliary electrodes therebetween and to the right of the extreme left-hand ends of the electrodes may be encompassed in some cases by a yoke 37 of magnetizable material, as illustrated more clearly by Fig. 4.

Thus, embodiments of this invention have been illustrated and described in which magnetic means is so positioned that the magnetic field in one direction moves an arc spanning a surge gap into an auxiliary gap area to a predetermined point or region therein, after being broken up into a plurality of arcs, beyond which further movement is arrested or restrained by a magnetic field in a reverse direction produced either by the magnetic means or by additional magnetic means.

In Figs. 7 to 14, inclusive, is illustrated an embodiment of this invention in which a larger number of auxiliary gaps is provided in a given

space than can be realized by the arrangements of Figs. 1 to 6; the sudden energy changes occurring during transfer or multiplication of the initial arc to a plurality of auxiliary arcs are further minimized; and the initial arc is moved into the region of auxiliary electrodes with practically no elongation. In addition, and in contrast to the Figs. 1 to 6 embodiments, a restraining magnetic field moving in a direction reverse to the direction of the field traversing the main electrode gap is not utilized. In the embodiment shown in Figs. 7 to 14, strips or barriers of insulating material **42**, **43** and **44** are provided between a pair of slabs or plates **40** and **41** of insulating material and defines a U-shaped arcing chamber with the open end thereof in communication with the atmosphere. A pair of spaced main electrodes **45** and **46** defining a main arc gap **47** are positioned at the open end of the chamber while a plurality of spaced auxiliary electrodes **48** to **54**, inclusive, arranged side by side in line with electrode **45**, and a plurality of auxiliary electrodes **55** to **61**, inclusive, arranged side by side in line with electrode **46** and respectively opposite electrodes **48** to **54**, are positioned within the chamber. The electrodes are respectively supported on electrode supports **62** of insulating material which in turn are supported on the legs or opposing walls of the U-shaped arcing chamber and serve to space the metallic electrodes therefrom for a purpose which will be explained hereinafter. A metallic screw **63** threadedly engaging a threaded opening in each electrode maintains both the electrode and the electrode support rigidly mounted transversely to and on the chamber walls.

As illustrated in Figs. 7 and 9, a pair of coils **64** and **65** wound on spools **64'** and **65'**, respectively, of insulating material are oppositely positioned on the outside surfaces of insulating plates **40** and **41**, respectively, and, as in the embodiments previously described, are so mounted that the axes of the windings are substantially transverse to all of the gaps and the area within the periphery of each coil is opposite the main pair of electrodes **45** and **46** but, in contrast, this area is also opposite all portions of the auxiliary electrodes. One end of each coil winding is electrically connected by a clamping screw **66** to one end of a conducting bar of metal **67** which is mounted on insulating supports comprised of a pair of ledges constituting part of the spool **64'** or **65'**. A pin **68** of conducting material is mounted at the opposite end of bar **67**. The other end of each coil winding is electrically connected by a clamping screw **69** to one end of another bar of metal **70** similarly mounted on ledges of the spool opposite to and spaced from bar **67** so as to define a gap space **71** therebetween. At the opposite ends of bars **70** are also respectively mounted pins of conducting material **72**. Gap electrodes **45** and **46** are respectively electrically connected, as illustrated by Figs. 9 and 10, with terminals **73** and **74** mounted respectively on the outside surfaces of insulating plates **40** and **41**. So that electrodes **45** and **46** may be respectively connected to the windings, terminal **73** is provided with a depressed or hollowed-out portion which will accommodate pin **68** of upper coil **64** while terminal **74** is also hollowed out to accommodate pin **68** of lower coil **65**, as shown. In order to insure engagement of the outer end of terminal **73** with bar **67** of upper coil **64**, as illustrated in Fig. 9, and the outer end of terminal **74** with bar **67** of lower coil **65**, and thereby effect good electrical contact between the terminals and bars, the over-all thickness of the coil spools at the right-hand end, as viewed in Fig. 13, where the pins **68** are located, is less than the thickness at the left-hand end. Such a construction assures the engagement of terminals **73** and **74** respectively with the bars **67** rather than the engagement of the surfaces of the spools adjacent and with the insulating plates **40** and **41**.

Aside from important structural details to be pointed out hereinafter, the device thus far described constitutes a single gap unit and a pair of coil units which may be stacked and connected in series with a plurality of similar units. In such case, a single coil unit or winding would be interposed between each gap unit or each group of electrodes with pins **72** of the upper and lower windings inserted in the hollowed-out portions of bosses corresponding to terminals **73** or **74** of gap units positioned respectively above winding **64** and below winding **65**. In any event, the pin **72** of one of the coils such as the upper one, for example, would be electrically connected directly or through a current limiting resistor to a source of electrical power to be protected such as a power transmission line while the pin **72** of the lower coil would be connected to ground either directly or through additional gap and coil units.

As in the devices illustrated by Figs. 1 to 6, inclusive, it will be apparent that windings **64** and **65** are electrically connected in series with electrodes **45** and **46** and the gap therebetween while the gaps **71** respectively provide by-passes or shunts around the two windings for their protection during the passage of a transient having components with rapid rates of current change. Following sparkover of gap **47** which establishes an arc between the main electrodes **45** and **46** and after dissipation of the transient, the power follow current path to ground will include windings **64** and **65**, the current paths through which are in the same direction, so that the internal magnetic field produced thereby will traverse the gaps between the electrodes in the same direction. This field will move the initial arc between electrodes **45** and **46** to the left, as viewed in Fig. 8. However, because of the adjacent arrangement of the auxiliary electrodes, the arc will first be broken up into an arc substantially transverse to the initial arc between electrodes **46** and **55**, a second arc substantially parallel to the initial arc between opposed auxiliary electrodes **55** and **48** and a third arc also substantially transverse to the initial arc between electrodes **48** anad **45**. The progressive arc formation is more clearly illustrated by the broken lines **80** in Fig. 14. The arcs are moved progressively by the magnetic field in somewhat the manner illustrated by Fig. 14 with the arcs between opposed electrodes and parallel to the initial arc moving away from the main electrodes and the arcs transverse to the initial arc moving to the far or outer ends of the auxiliary electrodes until eventually the initial arc is finally broken up into fifteen short arcs as indicated by the broken lines **81**. Further movement of the arcs is stopped by the insulating barrier **43** and insulating electrode supports **62** which present a relatively large creepage path over insulation from one electrode to an adjoining electrode.

To minimize the tendency of the arcs to follow the surfaces of plates **40** and **41**, it should be observed that both the metallic electrodes and

the insulating support 62 are spaced a predetermined distance from the inner surfaces of these plates as most clearly illustrated by Figs. 11 and 12. To prevent the arcs from by-passing some electrodes, the inner surfaces of plates 40 and 41 are corrugated or the configuration thereof in relation to the configuration of the electrodes is such that opposing baffles of insulating material project respectively from the inner opposing surfaces of the plates a predetermined distance into the gap spaces between the electrodes. Since such structure prevents an arc at a given electrode from "seeing through" to the next electrode, the tendency of such an arc to strike to the next electrode in a straight line in contact with insulation is eliminated and the tendency to by-pass the next electrode is also eliminated.

These objectives may be accomplished in an alternate manner as illustrated by Fig. 15 showing a pair of rod-shaped intermediate electrodes 82 and 83 positioned in the spaces between the auxiliary electrodes and on opposite sides of the common plane in which the central axes of the electrodes and the gaps therebetween are located. It has been found that in this case the arcs apparently cannot by-pass the larger auxiliary electrodes without contacting the small rod-shaped electrodes. It will be apparent that the number of arcs in series is thereby increased whereby the total voltage required to maintain the arc is raised.

When a plurality of gap and coil units are employed in series, the voltage distribution between successive units is controlled by resistors 84 and 85, Figs. 7, 9 and 13, connected in series by conducting bolt 86, Figs. 8 and 13, together with copper strips 87 and 88, Figs. 7 and 13, and in shunt across the main gap 47 by conducting bolts 89 and 90, Figs. 7, 8 and 9, together with copper strips 91 and 92, Figs. 8 and 9, which are respectively connected to the conducting screw 63, Figs. 8 and 9, supporting main electrodes 45 and 46. Nuts respectively engaging with threads on bolts 86, 89 and 90, Figs. 8 and 9, when drawn up serve to maintain the insulating plates 40 and 41 and the gap units therebetween securely fastened together.

A gap illumination button 93, spring biased against the inner surfaces of one of the insulating plates opposite the main gap by a resilient arm 94 upon which it is mounted serves to encourage or facilitate sparkover of the main gap. As illustrated, button 93 and arm 94 are electrically connected through bolt 90 and copper strip 92 to one of the main gap electrodes.

Thus, an embodiment of this invention has been illustrated and described in which auxiliary electrodes are so spaced and arranged to provide a relatively large number of auxiliary gaps considering the space occupied and the magnetic means is arranged to move the auxiliary arcs along the entire length of the auxiliary gaps to the extremities thereof for interruption without utilizing a restraining or counteracting magnetic field.

The unique features of the structure thus described and illustrated by Figs. 7 to 15, inclusive, result in an arc extinguishing device in which an initial arc is not elongated to any extent, but the initial arc naturally tends to be broken up by degrees and not all at one time. This obviously results in easy transfer from the single initial arc to the final plurality of arcs because of the greater voltage required to maintain them, which arcs are readily extinguished, and without the sudden energy changes necessary if the initial arc encountered all auxiliary electrodes at one time.

While I have, in accordance with the patent statutes, shown and described a particular embodiment of my invention and modifications thereof, it will be obvious that changes and modifications can be made without departing from the invention in its broader aspects and, I, therefore, aim in the appended claims to cover all such changes and modifications 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. In an air gap construction, a first pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said gaps being disposed in substantially the same plane, a coil winding positioned adjacent said electrodes with the axis thereof transverse to said plane and with the area within the periphery of said winding being disposed opposite said pair of electrodes, a portion of the area outside of said periphery being disposed opposite a portion of each of said auxiliary electrodes, said winding being connected electrically in series with said first pair of electrodes and the gap therebetween and a second pair of electrodes defining an arc gap in parallel circuit relation with said coil winding.

2. An air gap construction comprising a first pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, a coil winding positioned adjacent said electrodes with the area within the periphery thereof opposite said first pair of electrodes and a portion of the area outside the periphery being opposite a portion of each of said auxiliary electrodes, said coil being otherwise so mounted relative to said electrodes that upon the establishment of an arc between said pair of electrodes the field produced by said coil will be effective to elongate and move said arc between said auxiliary electrodes whereby it is extinguished by being broken up into a plurality of arcs and a second pair of electrodes defining an arc gap in parallel circuit relation with said coil winding.

3. In an air gap construction, a first pair of spaced electrodes defining a main arc gap, a plurality of elongated and spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, the longitudinal axes of said auxiliary electrodes being disposed in a common plane, a coil winding positioned adjacent said electrodes with the axis thereof transverse to said gaps and said common plane and with the area within the periphery of said winding being disposed opposite said pair of electrodes, a portion of the area outside said periphery being disposed opposite a portion of each of said auxiliary electrodes, said winding being connected electrically in series with said first pair of electrodes and the gap therebetween and a second pair of electrodes defining an arc gap in parallel circuit relation with said coil winding.

4. In an air gap construction, a first pair of parallel slabs of insulating material, a pair of spaced electrodes disposed between said slabs and defining an arc gap parallel thereto, a plurality of spaced auxiliary electrodes disposed between said slabs adjacent said pair of electrodes and defining a plurality of arc gaps parallel to said slabs, a coil winding positioned adjacent said elec-

trodes with the axes thereof tranverse to said slabs and with the area within the periphery of said winding being disposed opposite said pair of electrodes, a portion of the area outside said periphery being disposed opposite a portion of each of said auxiliary electrodes, said winding being connected electrically in series with said first pair of electrodes and the gap therebetween and a second pair of electrodes defining an arc gap in parallel circuit relation with said coil winding.

5. In an air gap construction, a coil winding, a first pair of spaced electrodes defining a main arc gap normal to the axis of said winding, a second pair of electrodes defining an arc gap in parallel circuit relation with said coil winding, said winding being connected electrically in series with said first pair of electrodes and the gap therebetween, and a plurality of elongated and spaced auxiliary electrodes defining a plurality of auxiliary arc gaps positioned adjacent said first pair of electrodes with the longitudinal axes of said electrodes being disposed in a common plane normal to the axis of said winding, said electrodes being positioned adjacent said winding with said first pair of electrodes disposed opposite the area within the periphery of said winding and a portion of each of said auxilary electrodes disposed opposite a portion of the area outside the periphery of said winding.

6. An air gap construction comprising a pair of spaced electrodes defining a main arc gap, a plurality of elongated and spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said gaps being substantially disposed in a common plane, and magnetic means positioned adjacent said electrodes and defining a magnetic field portions of which have opposite directions relative to said common plane, said field being substantially normal to said common plane and traversing the gap between said pair of electrodes and each of said auxiliary electrodes adjacent one end thereof in one direction and each of said auxiliary electrodes adjacent the opposite ends thereof in the opposite direction.

7. An air gap construction comprising a pair of electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes disposed side by side on one side of one of said pair of electrodes and defining a plurality of auxiliary arc gaps therebetween normal to said gap between said pair of electrodes, a plurality of spaced auxiliary electrodes respectively disposed opposite and spaced from said first mentioned auxiliary electrodes side by side on one side of the other of said pair of electrodes, said second mentioned auxiliary electrodes defining a plurality of auxiliary arc gaps therebetween normal to and a plurality of arc gaps with said oppositely disposed electrode substantially parallel to said gap between said pair of electrodes, and a coil winding positioned adjacent said electrodes with the axis thereof transverse to all of said gaps and with the area within the periphery of said winding being disposed opposite said electrodes, said winding being connected electrically in series with said pair of electrodes and the gap therebetween.

8. An air gap construction comprising a pair of plates of insulating material, a U-shaped barrier of insulating material interposed between said plates, a pair of electrodes defining a main arc gap, said electrodes respectively mounted on the legs of said U-shaped barrier at the open end thereof, a plurality of spaced auxiliary electrodes mounted on and extending transversely from one of the legs of said U-shaped barrier

and defining a plurality of auxiliary arc gaps therebetween normal to said gap between said pair of electrodes, a plurality of spaced auxiliary electrodes respectively disposed opposite said first mentioned auxiliary electrodes mounted on and extending transversely from the other of the legs of said U-shaped barrier, said second mentioned auxiliary electrodes defining a plurality of auxiliary arc gaps therebetween normal to and a plurality of auxiliary arc gaps with said oppositely disposed first mentioned auxiliary electrodes parallel to said gap between said pair of electrodes, and a coil winding positioned adjacent said electrodes with the axis thereof transverse to said pair of plates, said winding being connected electrically in series with said pair of electrodes and the gap therebetween.

9. An air gap construction comprising a body of insulating material, a substantially U-shaped arcing chamber within said body, the open end of said U-shaped chamber being vented to the atmosphere, a pair of spaced electrodes defining a main arc gap respectively mounted on opposite walls of said chamber at the open end thereof, a plurality of spaced auxiliary electrodes mounted on and extending transversely from one of said opposite walls and defining a plurality of auxiliary arc gaps therebetween normal to said gap between said pair of electrodes, a plurality of spaced auxiliary electrodes respectively disposed opposite said first mentioned auxiliary electrodes mounted on and extending transversely from the other of said opposite walls, said second mentioned auxiliary electrodes defining a plurality of auxiliary arc gaps therebetween normal to and a plurality of auxiliary arc gaps with said oppositely disposed first mentioned auxiliary electrodes parallel to said gap between said pair of electrodes, and a coil winding positioned adjacent said electrodes with the axis thereof transverse to all of said gaps, said winding being electrically connected in series with said pair of electrodes and the gap therebetween.

10. An air gap construction comprising a pair of spaced parallel plates of insulating material, a U-shaped barrier of insulating material interposed between said plates and defining an arcing chamber opposite walls of which are comprised of the legs of said U-shaped barrier and the inner opposing surfaces of said plates, the open end of said U-shaped chamber being vented to the atmosphere, a pair of electrode supports respectively mounted on the legs of said U-shaped barrier adjacent the open end thereof, a pair of spaced electrodes defining a main arc gap respectively mounted on said electrode supports and respectively spaced from the legs of said barrier thereby, a plurality of spaced electrode supports mounted on and extending into said chamber transversely from one of the legs of said U-shaped barrier, a plurality of spaced auxiliary electrodes defining a plurality of auxiliary arc gaps therebetween transverse to said gap between said pair of electrodes, said auxiliary electrodes being mounted respectively on said plurality of electrode supports and spaced thereby from said one leg of said U-shaped barrier, a plurality of spaced electrode supports mounted on and extending into said chamber transversely from the other of the legs of said U-shaped barrier, a plurality of spaced auxiliary electrodes respectively disposed opposite said first mentioned auxiliary electrodes mounted respectively on said second mentioned plurality of electrode supports and spaced thereby from said other leg of said U-shaped barrier, said second mentioned auxiliary electrodes defin-

ing a plurality of auxiliary arc gaps therebetween normal to and a plurality of auxiliary arc gaps with said oppositely disposed first mentioned electrodes parallel to said gap between said pair of electrodes, said electrodes and said electrode supports being spaced a predetermined distance from said inner surfaces of said plates, opposing baffles of insulating material projecting respectively from the inner opposing surfaces of said plates a predetermined distance into the gap spaces between said electrodes and spaced a predetermined distance therefrom and a coil winding positioned adjacent said electrodes with the axis thereof transverse to all of said gaps, said winding being connected electrically in series with said pair of electrodes and the gap therebetween.

11. An air gap construction comprising a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes disposed side by side on one side of said pair of electrodes and defining a plurality of auxiliary arc gaps therebetween normal to said gap between said pair of electrodes, a plurality of spaced auxiliary electrodes respectively disposed opposite and spaced from said first mentioned auxiliary electrodes on one side of the other of said pair of electrodes, said second mentioned auxiliary electrodes defining a plurality of auxiliary arc gaps therebetween normal to and a plurality of arc gaps with said first mentioned oppositely disposed electrodes parallel to said gap between said pair of electrodes, oppositely disposed spaced barriers of insulating material respectively projecting a predetermined distance therefrom, and a coil winding positioned adjacent said electrodes with the axis thereof transverse to all of said gaps, said winding being connected electrically in series with said pair of electrodes and the gap therebetween.

12. In an air gap construction, a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said gaps being disposed in substantially the same plane, oppositely disposed and spaced barriers of insulating material respectively projecting a predetermined distance into said spaces between said electrodes and spaced a predetermined distance therefrom, and a coil winding positioned adjacent said electrodes with the axis thereof transverse to said plane, said winding being connected electrically in series with said pair of electrodes and the gap therebetween.

13. In an air gap construction, a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said gaps being disposed substantially in the same plane, rod-shaped intermediate electrodes positioned on opposite sides of said plane in said spaces between said auxiliary electrodes and spaced therefrom, and a coil winding positioned adjacent said electrodes with the axis thereof transverse to said plane, said winding being connected electrically in series with said pair of electrodes and the gap therebetween.

14. In an air gap construction, a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said gaps being disposed substantially in the same plane, a coil winding positioned adjacent said electrodes with the axis thereof transverse to said plane and with the area within the periphery of said winding being disposed opposite said pair of electrodes, said winding being connected electrically in series with said pair of electrodes and the gap therebetween, and a yoke of magnetizable material positioned outside the periphery of said winding spaced from and encompassing said auxiliary electrodes.

15. An air gap construction comprising a pair of spaced electrodes defining an arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps disposed in substantially the same plane with the gap between said pair of electrodes, a coil winding positioned adjacent said electrodes with the axis thereof transverse to said common plane and with the area within the periphery of said winding being disposed opposite said pair of electrodes and a portion of said auxiliary electrodes, said winding being electrically connected in series with said pair of electrodes and the gap therebetween, a second coil winding positioned closely adjacent to and with the axis thereof parallel to the axis of said first mentioned coil winding, the area within the periphery of said second mentioned winding being disposed opposite the balance of said auxiliary electrodes, said second mentioned winding being connected electrically in series with said first mentioned winding with the current travelling therethrough, when energized, in a direction opposite to the direction of current flow through said first mentioned winding.

16. An air gap construction comprising a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, oppositely disposed spaced barriers of insulating material respectively projecting a predetermined distance into said spaces between said electrodes and spaced a predetermined distance therefrom, and magnetic means positioned adjacent said electrodes defining a magnetic field, said field traversing said gaps between said electrodes in a direction transverse thereto.

17. An air gap construction comprising a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said gaps being disposed substantially in the same plane, rod-shaped intermediate electrodes positioned on opposite sides of said plane in said spaces between said auxiliary electrodes and spaced therefrom, and magnetic means positioned adjacent said electrodes defining a magnetic field, said field traversing said gaps between said electrodes in a direction transverse thereto.

18. An air gap construction comprising a pair of spaced main electrodes defining a main arc gap, a first group of spaced auxiliary electrodes positioned adjacent one of said pair of main electrodes and defining a plurality of auxiliary arc gaps therebetween normal to said gap between said pair of main electrodes, a second group of spaced auxiliary electrodes respectively disposed opposite and spaced from said first group of auxiliary electrodes adjacent the other of said pair of main electrodes, said second group of auxiliary electrodes defining a plurality of auxiliary arc gaps therebetween normal to and a plurality of arc gaps with said oppositely disposed first group

of electrodes parallel to said gap between said pair of main electrodes, and magnetic means positioned adjacent said electrodes defining a magnetic field, said field transversely traversing the gap between said pair of main electrodes and the gaps between said respectively opposed auxiliary electrodes.

19. An air gap construction comprising a body of insulating material, an arcing chamber within said body, a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, said electrodes being disposed within said chamber between opposite walls thereof, a plurality of grooves in one of said walls, a plurality of respectively opposed grooves in the other of said walls, said grooves defining a surface configuration substantially parallel to the surface configuration of said electrodes, each of said electrodes being positioned between and spaced a predetermined distance from oppositely disposed grooves in said walls, and magnetic means positioned adjacent said electrodes defining a magnetic field traversing said gaps between said electrodes in a direction transverse thereto whereby an arc across said main gap will be moved into the region of and broken up into a plurality of arcs by said auxiliary electrodes.

20. In an air gap construction, a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, electromagnetic means positioned adjacent said main arc gap to move an arc established between said pair of electrodes into the region of said auxiliary electrodes whereby said arc is broken up into a plurality of auxiliary arcs, and additional means positioned adjacent said auxiliary electrodes to prevent subsequent recombining of said auxiliary arcs into a single arc.

21. In an air gap construction, a pair of spaced electrodes defining a main arc gap, a plurality of spaced auxiliary electrodes positioned adjacent said pair of electrodes and defining a plurality of auxiliary arc gaps, and means positioned adjacent said electrode assembly for controlling the movement of an arc between said pair of electrodes and a plurality of arcs between said auxiliary electrodes, said means including a magnetic field producing coil winding with the area within the periphery thereof positioned opposite said pair of electrodes and opposite one end only of each of said auxiliary electrodes for moving an arc between said pair of electrodes into the gap spaces between said auxiliary electrodes, said means also including a member positioned adjacent the opposite ends of said auxiliary electrodes to prevent subsequent recombining of auxiliary arcs in the gap spaces between said auxiliary electrodes into a single arc.

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