Aug. 14, 1951 H. M. STROBEL 2,564,178

DEION CIRCUIT BREAKER

Filed June 8, 1945 5 Sheets-Sheet 1

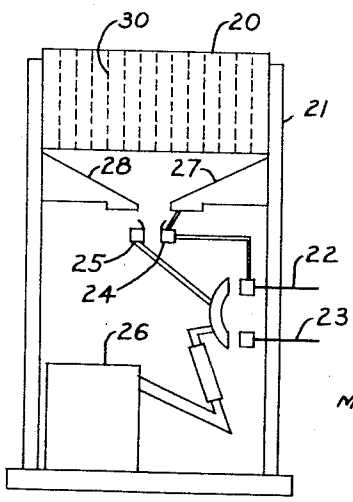

FIG. 2.

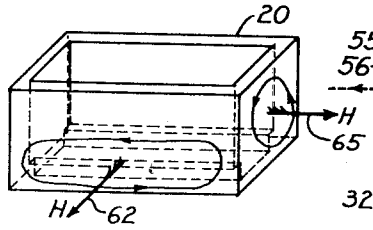

FIG. 4.

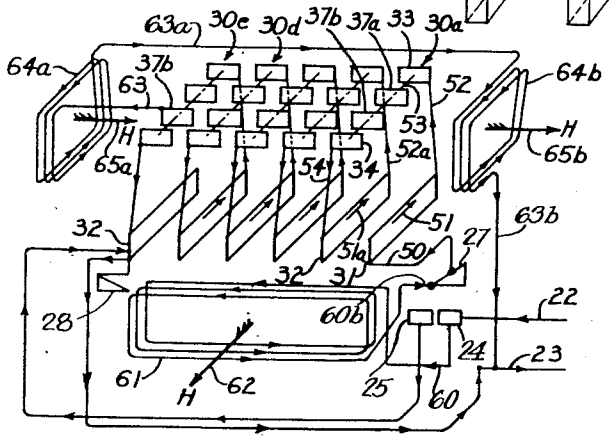

FIG. 5.

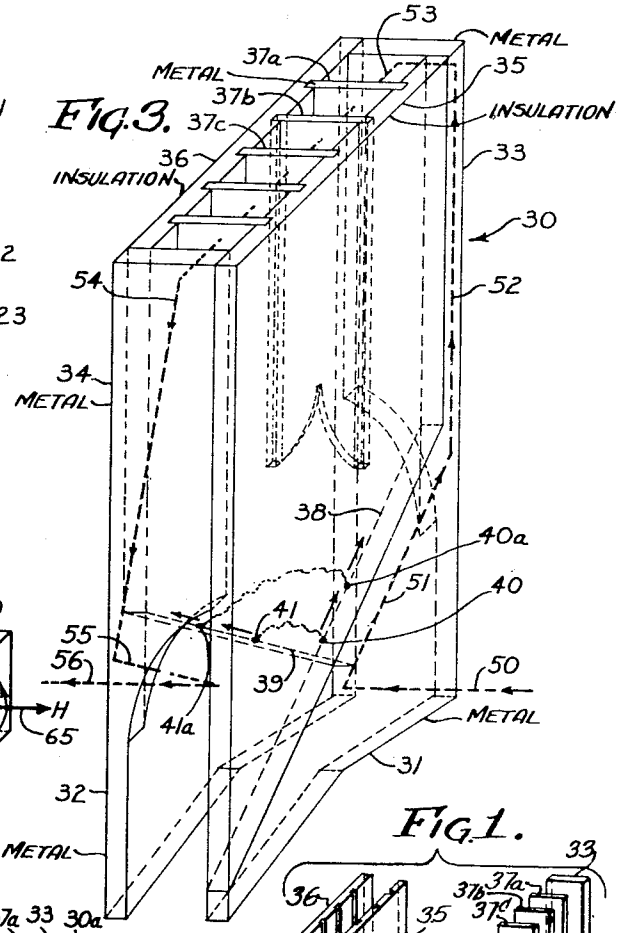

FIG. 3.

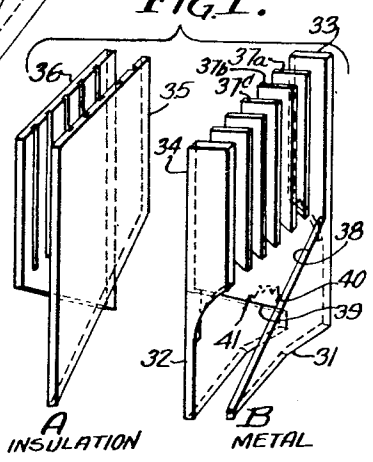

FIG. 1.

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DEION CIRCUIT BREAKER

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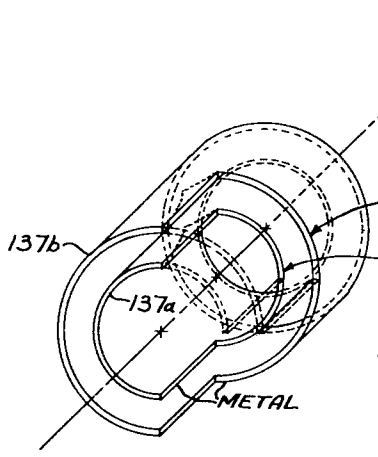

FIG. 7.

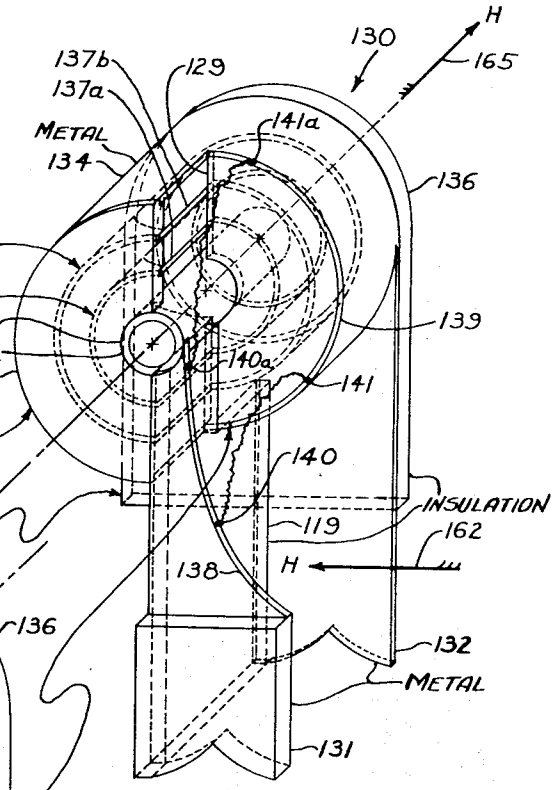

FIG. 6.

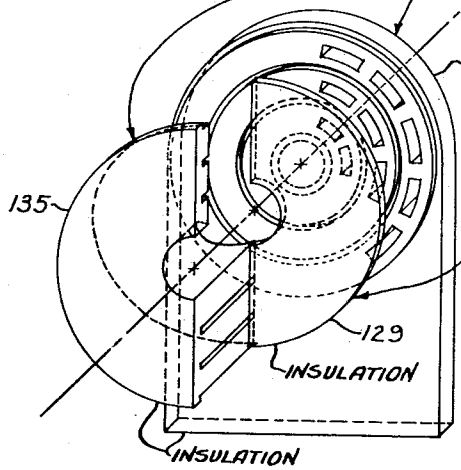

FIG. 8.

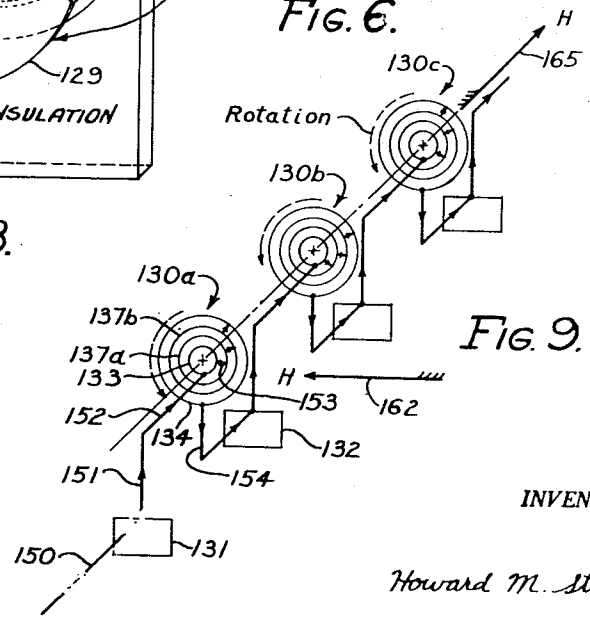

FIG. 9.

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DEION CIRCUIT BREAKER

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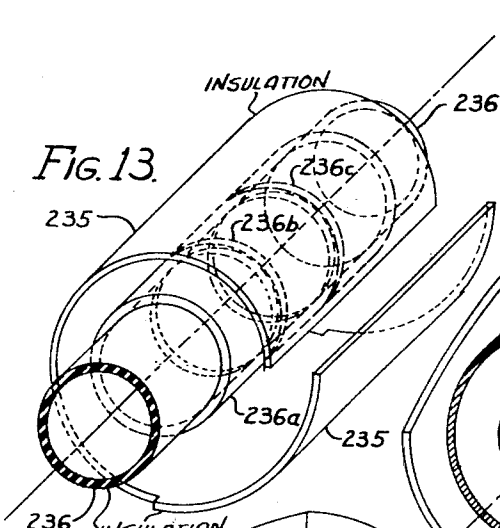

FIG. 13.

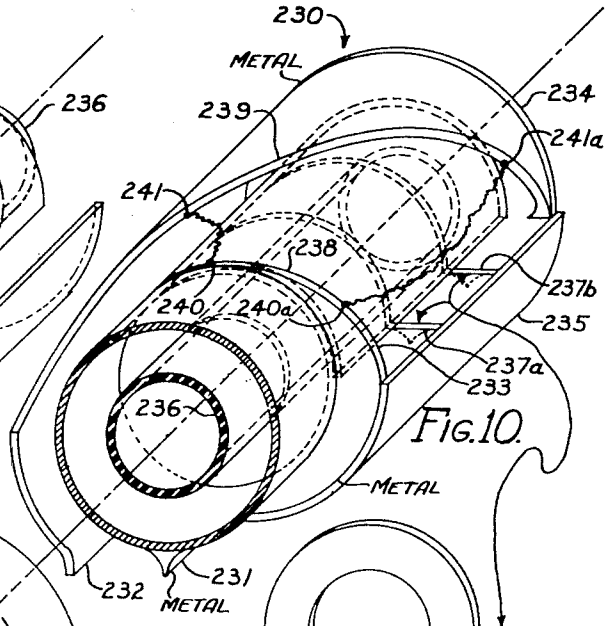

FIG. 10.

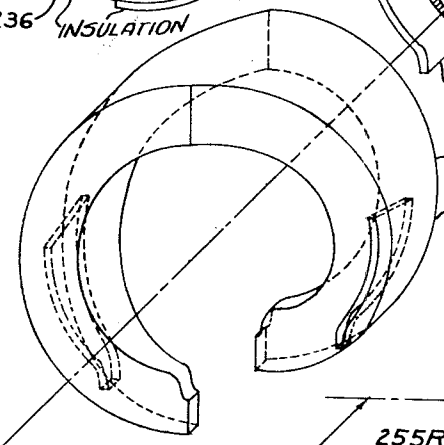

FIG. 12.

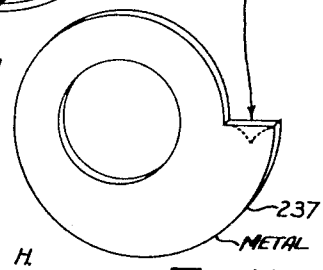

FIG. 11.

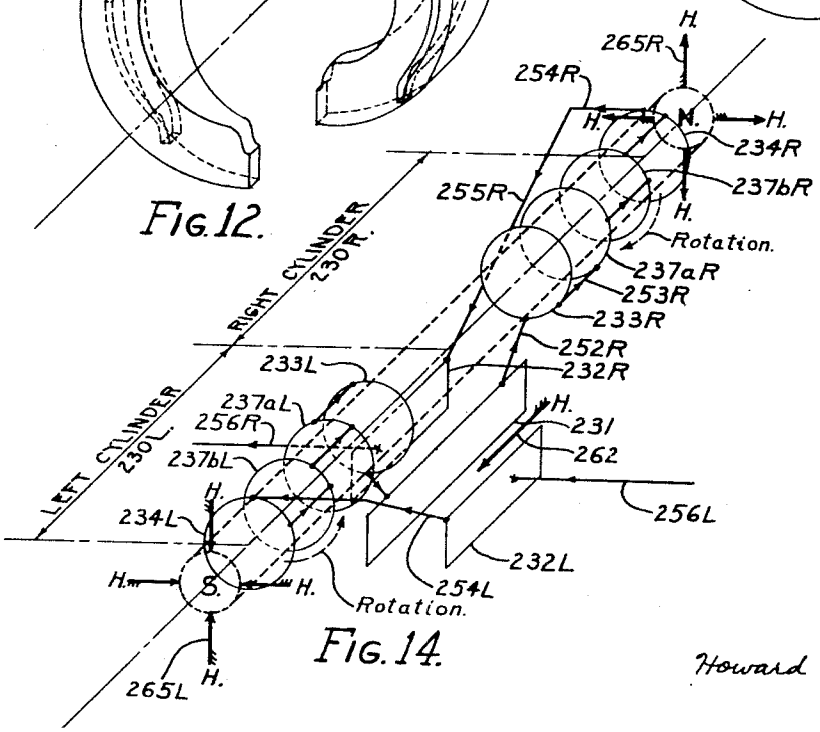

FIG. 14.

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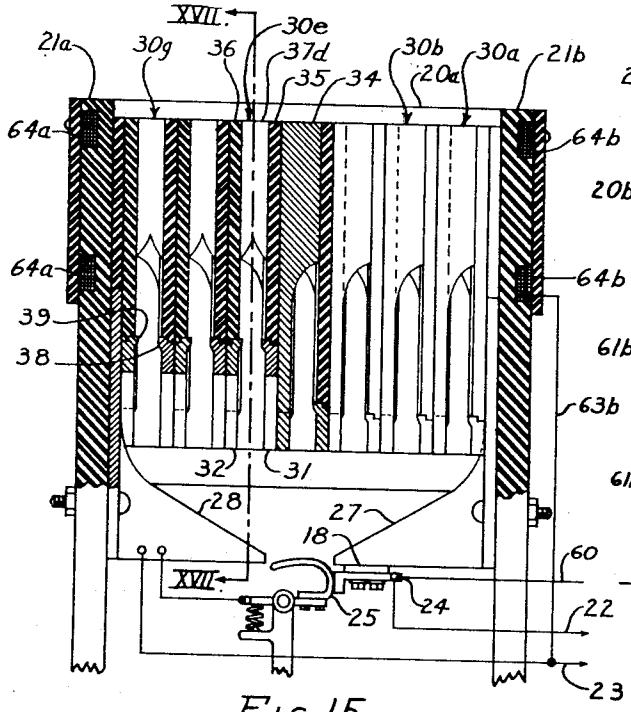

FIG. 15.

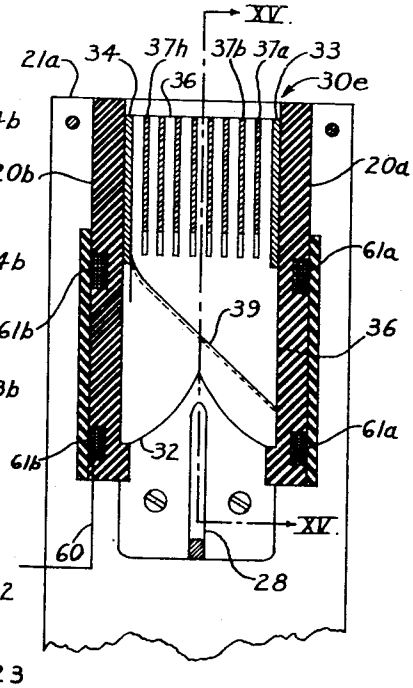

FIG. 17.

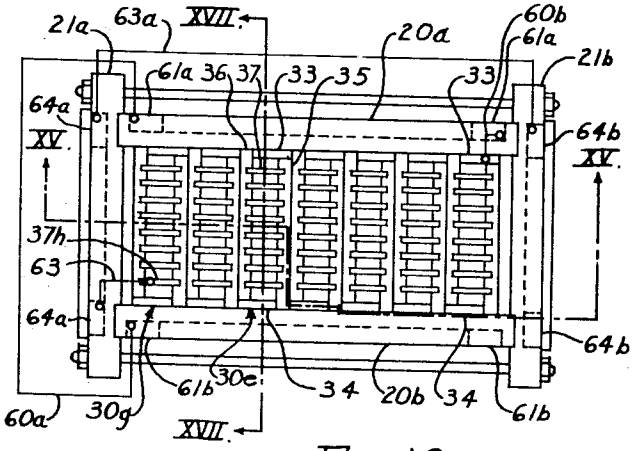

FIG. 16.

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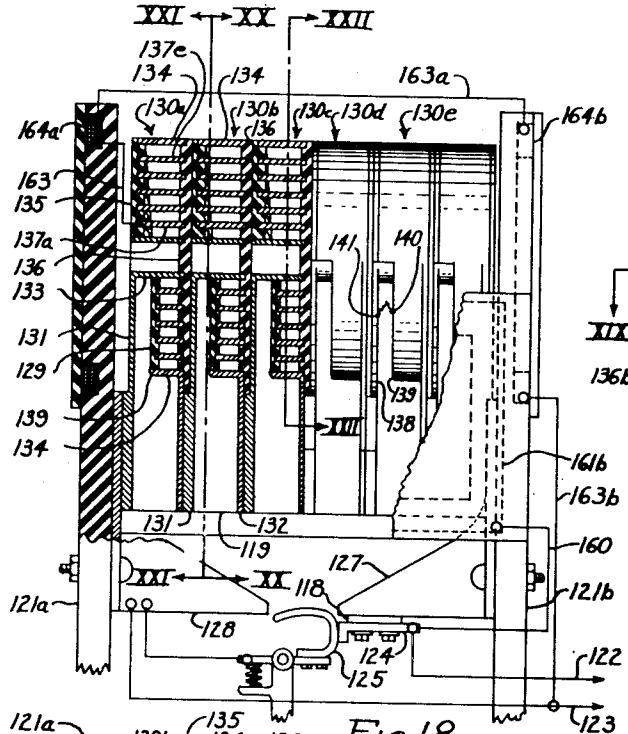

FIG. 18.

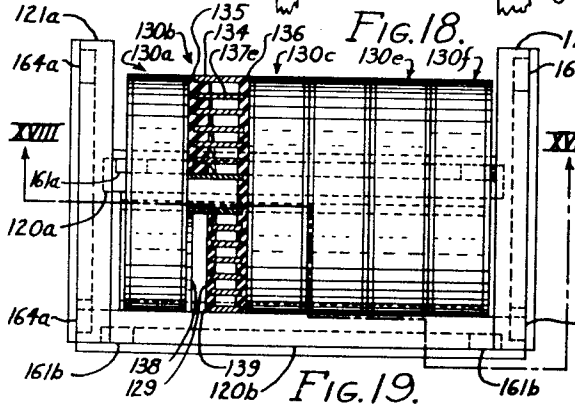

FIG. 19.

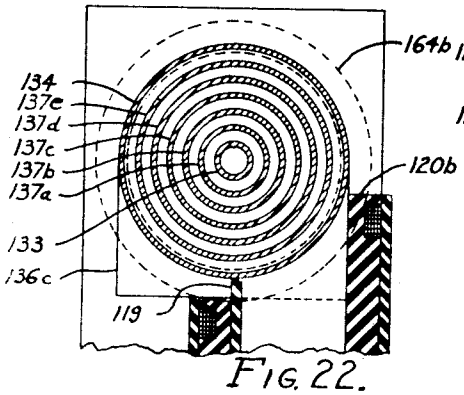

FIG. 22.

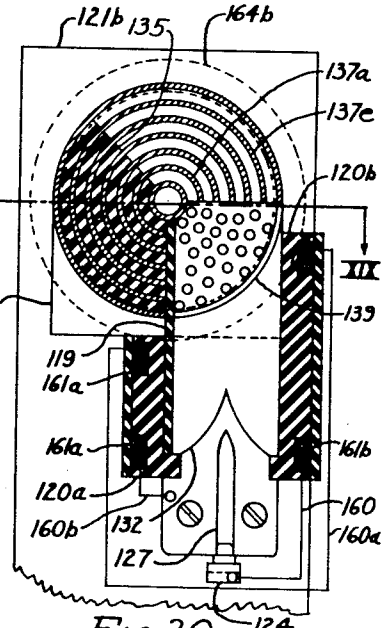

FIG. 20.

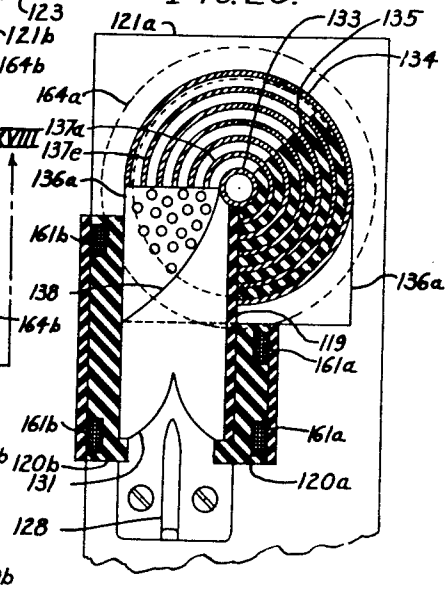

FIG. 21.

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Patented Aug. 14, 1951

2,564,178

UNITED STATES PATENT OFFICE

2,564,178

DEION CIRCUIT BREAKER

Howard M. Strobel, New York, N. Y.

Application June 8, 1945, Serial No. 598,269

9 Claims. (Cl. 200—147)

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This invention relates to de-ion type of electrical circuit breakers in which the extended arc path of relatively low resistance resulting from separating movable contacts is divided into a plurality of smaller arc elements of relatively high resistance.

The primary object of the invention is to provide improved apparatus and method for increasing the number of subdivisional arc elements that may be formed in a de-ion circuit breaker where certain dimensions of size are limited by practical space considerations, and to provide therein improved method and means for magnetically deflecting arc elements along predetermined paths.

Subsidiary objects of the invention relate to the specific adaptation of the primary objects of the invention to particular de-ion structures wherein the magnetically deflected arc elements are moved along different types of predetermined paths.

Attention is directed to the co-pending application Serial No. 236,995 filed July 16, 1951, which is a division of this application, for further descriptions of the application of the de-ion structures disclosed to other circuit breakers.

In the conventional de-ion circuit breaker the main arc, which is drawn out between the separable arcing contacts, is moved into an arc receiving means comprising spaced conducting plates adapted to subdivide the main arc into a plurality of smaller primary arcs. The geometry of the spaced conducting plates defines the form of path that the smaller primary arcs are to be moved along. The path so defined may be open-minded, as when the final primary arc movement is translational, or recurrent, as when each primary arc is finally rotated like a cylindrical element or like a radial element along a substantial circular path.

A more specific object of my invention is the provision of improved apparatus for a circuit interrupter having a plurality of de-ion units racked side by side in series connection, each of said units having two successive arrays each of which includes a plurality of spaced conducting arc splitting members, the first array of each unit being formed preferably of substantially two spaced parallel plane plates with arc receiving means arranged substantially transverse to the main arc path and having a suitable deflective means or magnetic circuit adapted to move the main arc into its arc receiving means, whereby the main arc is moved into the arc receiving means of the first array of each de-ion unit and separated into as many short or primary arcs

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as there are de-ion units in series, and connecting means being provided between the first and second arrays of each de-ion unit so that each of said primary arcs in moving successively from one to the other is extended and oriented to a position substantially askew to and at right angles to the main arc path, the second array of each de-ion unit having arc receiving members arranged substantially transverse to the extended and oriented primary arcs and having provided a suitable deflective means or magnetic circuit adapted to move each of the extended and oriented primary arcs into its respective arc receiving means, whereby each extended and reoriented primary arc is moved into the arc receiving means of the second array of each de-ion unit and further separated into a plurality of shorter or secondary arcs which are then made to move along an open-ended or recurrent path as defined by the arc running members of each de-ion unit of the improved apparatus until extinguished.

More particularly, the invention consists in the system and method hereinafter described, illustrated in the accompanying drawings and defined in the claims hereto appended, it being understood that various changes in form, arrangement and details both of circuits and of method within the scope of the claims may be resorted to without departing from the spirit or sacrificing any of the advantages of the invention.

A clearer understanding of the operation of the invention and its improvement over known methods can be obtained by reference to the following figures and the descriptions relating thereto.

Fig. 1 is a pictorial view of the parts used in the de-ion unit 30 shown in Fig. 3, wherein the pieces made of insulation are shown on the left at A, and the pieces made of metal are shown on the right at B.

Fig. 2 is an elevational view of a conventional mounting arrangement for a de-ion circuit breaker.

Fig. 3 is a pictorial view of one section or unit of the improved de-ion device whose structure is adapted to define the path of the arc elements to give final translational motion in an open-ended path.

Fig. 4 shows a box for holding a plurality of the units shown in Fig. 3.

Fig. 5 shows pictorially the flow of current through a circuit breaker of the form shown in Fig. 15 which uses a plurality of the units shown in Fig. 3.

Fig. 6 is a pictorial view of one section or unit

of the improved de-ion device whose structure is adapted to define the paths of the arc elements to give final radial rotation in a recurrent path.

Fig. 7 shows two of the conductive cylindrical pieces used in the device of Fig. 6.

Fig. 8 shows three of the insulative pieces which are used in supporting the conductive cylindrical pieces of Fig. 6.

Fig. 9 shows pictorially the flow of current through a circuit breaker using a plurality of the units shown in Fig. 6.

Fig. 10 is a pictorial view of one section or unit of the improved de-ion device whose structure is adapted to define the paths of the arc elements to give final cylindrical rotation in a recurrent path.

Fig. 11 shows one of the conductive disc plates or annular ring plates used in the unit shown in Fig. 10.

Fig. 12 shows the insulative piece which fits into the end of the unit in Fig. 10.

Fig. 13 shows insulative pieces which are used in supporting the conductive pieces of Fig. 10.

Fig. 14 shows pictorially the flow of current through a circuit breaker using two units, one right handed and one left handed, similar to the one shown in Fig. 10.

Fig. 15 shows a view partly in section and partly in elevation of the arc extinguisher of my invention which uses seven de-ion units similar to the one in Fig. 3; the section has been taken along the line XV—XV in the plan view of Fig. 16.

Fig. 16 shows a plan view of the arc extinguisher with seven of the improved de-ion units similar to the one in Fig. 3 assembled in series.

Fig. 17 is a cross sectional view through the arc extinguisher of Fig. 15 taken along the line XVII—XVII.

Fig. 18 shows a view partly in section and partly in elevation of the arc extinguisher of my invention which uses six de-ion units substantially similar to the one in Fig. 6; the section has been taken along the line XVIII—XVIII in the plan view of Fig. 19.

Fig. 19 shows a plan view of an arc extinguisher with six of the improved de-ion units substantially similar to the one in Fig. 6 assembled in series.

Fig. 20 is a cross sectional view through the arc extinguisher of Fig. 18 taken along the line XX—XX.

Fig. 21 is a cross sectional view through the arc extinguisher of Fig. 18 taken along the line XXI—XXI.

Fig. 22 is a cross sectional view through the de-ion unit **130***e* of Fig. 18 taken along the line XXII—XXII.

Fig. 1 shows in separated views the various members, which, when assembled together form the de-ion unit **30** shown in Fig. 3. Thus Fig. 1–A shows the insulative pieces alone in their proper space relationship, and Fig. 1–B shows the metallic pieces alone in their proper space relationship. Referring to Fig. 1 and Fig. 3, it will be noted that the resulting structure comprises a pair of spaced parallel primary plates **31**, **32**, having a pair of spaced parallel end plates **33**, **34** joined to their upper ends (the plane of the end plates **33**, **34** being at right angles to the plane of the plates **31**, **32**), with a set of spaced parallel secondary plates **37** placed between and parallel to the end plates **33**, **34**. All of the above three pairs or sets of plates are made of metal, as is indicated in Fig. 1–B. The pair of baffles **35**, **36** (see Fig. 1–A) are of insulating material and support the set of plates **37** between the primary end plates **33**, **34**.

Fig. 2 shows a diagrammatic sketch of a de-ion circuit breaker and Fig. 15 shows in elevation a view of the structure of a circuit breaker using seven of the improved de-ion units **30**. The improved arc splitting devices or de-ion units **30** are racked in a holding box **20** which is supported by the frame **21**. Electrical connection to the circuit breaker are made at **22** and **23**. On interrupting the circuit, the main arc is drawn between the fixed contact **24** and the movable contact **25**, the moving contact **25** being operated by the lever mechanism **26**. The main arc formed between the separable contacts **24** and **25** is moved upwards and transferred to the arcing horns **27** and **28**, where it is extended and directed into the improved arc splitting devices **30**. The improved arc splitting devices or de-ion units **30** may have a structure similar to that shown in the perspective views of Fig. 3 and Fig. 6. Face and sectional views of the structure of a circuit breaker using a series assembly of seven of the improved de-ion units **30** are shown in Figs. 15, 16, and 17, while similar views of the structure of a circuit breaker using a series assembly of six of the improved de-ion units **130** are shown in Figs. 18 to 22.

Fig. 3 shows a structure for defining the paths and motions of the arc elements or sections to give final translational motion in an open-ended path. The primary arc splitting plates are indicated by **31** and **32**. The end plate **33** is joined to the upper end of **31**, and the end plate **34** to the upper end of **32**. These plates **31** to **34** are made of conducting material. The insulating baffles **35** and **36** are adapted to support the conductive secondary arc splitting plates **37***a*, **37***b*, **37***c*, etc., between the primary metal end plates **33** and **34**. The numbers **38** and **39** indicate those edges of the primary arc splitting plates **31** and **32** which serve as arcing guides to extend and orient the primary arc existing between the points **40** and **41**. The arrowed heavy dotted line **50**, **51**, **52**, **53**, **54**, **55**, and **56** indicates the flow of current after the secondary arc elements have been formed.

Figs. 15, 16 and 17 show elevation, plan and cross sectional views of an arc extinguisher using seven de-ion units **30***a* to **30***g*. Each of these de-ion units is similar to the one shown in perspective in Fig. 3, except that eight secondary arc-splitting plates **37***a* to **37***h* are shown in lieu of the five shown for descriptive purposes in Fig. 3. The identifying numbers used to indicate the parts of unit **30** in Fig. 3 are used to indicate the same parts in the Figs. 15, 16 and 17. Referring to Figs. 15 and 16, the uprights **21***a*, **21***b* are made of insulating material and support the cross pieces **20***a* and **20***b*, also made of insulating material, to form a box or rack to hold the seven de-ion units **30***a* to **30***g*. The arcing horns **27** and **28** are bolted to the uprights **21***b* and **21***a* respectively, as shown. The stationary contact **24** is supported from the arc horn **27** but insulated therefrom by the block of insulation **18**. The moving contact **25** may be actuated to open position by any suitable type of operating mechanism which may be provided with main contacts for normally completing the circuit through the circuit breaker. The line terminal **22** of the circuit connects to the stationary contact **24** and the other line terminal **23** to the arc horn **28** and the moving contact **25**. The coils **61***a* and **61***b* of Figs. 16 and 17 are positioned in grooves provid-

ed in the insulating cross pieces 20a and 20b. When energized, the coils 61a and 61b provide a magnetic field transverse to the path of the main arc and thus deflect the main arc into and past the primary arc splitting plates 31 and 32 of each de-ion unit 30. The coils 61a and 61b are connected in series by the jumper 60a (Fig. 16), with one end of the coil 61b connected to the stationary contact 24 through the conductor 60 (Figs. 15 and 17), and the other end of coil 61a returned to arc horn 27 through the conductor 60b (Fig. 16). The coils 64a and 64b of Figs. 15 and 16 are positioned in grooves provided in the insulating uprights 21a and 21b. When energized, the coils 64a and 64b create a magnetic field through the secondary array of such direction as to be transverse to the path of the secondary arc elements formed between the secondary arc-splitting plates 37 in each de-ion unit 30. The coils 64a and 64b are connected in series by the jumper 63a (Fig. 16), with the other end of coils 64a connected through conductor 63 to the end secondary switching plate 37h of de-ion unit 30g (Fig. 16), and the other end of coil 64b returned to line terminal 23 through the conductor 63b (Fig. 15).

Referring to Fig. 15, when the arcing contacts 24, 25 are separated an arc is formed between them and the current flow is, line terminal 22 to stationary contact 24, to movable contact 25, and return to line terminal 23. The arc flame is then moved upward between the arc horns 27 and 28, the transfer of one end of the arc from stationary contact 24 to arc horn 27 automatically switching in coil 61 so that the line current must now flow from line terminal 22, to stationary contact 24, through conductor 60, coil 61 to arc horn 27, and thence through the arc to arc horn 28 and return to the line terminal 23. The connections and current flow through the coil 61 are indicated schematically in Fig. 5, and the arrow 62 indicates the direction of the magnetic field H produced by the coil 61. Referring back to Fig. 15, the magnetic field deflects the arc flame upwards into the primary arc-splitting plates 31, 32 of each of the seven de-ion units 30a to 30g shown. The main arc is thus divided into a plurality of shorter arcs or primary arcs by the seven de-ion units 30a to 30g. It is to be pointed out that the apparatus and method used to create and deflect the main arc into the primary arc-splitting plates. where it is divided into a plurality of primary arcs, follow conventional practice and are well known to the art. According to this modification of the invention (the de-ion unit 30 of Fig. 3), the primary arc existing between each pair of primary arc-splitting plates 31, 32 of each de-ion unit 30 (Fig. 3 or 15) is then moved upwards, extended and oriented to a line of position above and substantially at right angles to the line of position of the original primary arc. Each extended and reoriented primary arc is then moved into the secondary array of its de-ion unit 30 where it is further subdivided into a plurality of secondary arc elements until the arc is extinguished.

By referring to the perspective view of one of the de-ion units 30 shown in Fig. 3 it will become clear how the structure of a de-ion unit 30 extends, orients, and further subdivides each primary arc element. As mentioned above, when the main arc strikes the primary arc-splitting plates 31 and 32, it is subdivided to form a primary arc between the primary plates 31 and 32. The primary arc moves upward between the plates until the hot spot 40 on plate 31 reaches the arcing runner 38, and the hot spot 41 on plate 32 reaches the arcing runner 39. Since the primary arc between 40 and 41 is still being deflected upwards by the magnetic field, the hot spot 40 moves along 38 to point 40a, while the hot spot 41 moves along 39 to point 41a. It will be noted that this movement of the arc hot spots along the arcing runners results in both extending the primary arc and in substantially reorienting it to a position at right angles to the direction of the main arc. Ultimately the hot spot 40 reaches the end plate 33 of plate 31, and hot spot 41 reaches the end plate 34 of plate 32. In this position, it will be noted that the primary arc has been extended so that it exists between end plates 33 and 34, and has thus been oriented to a position at right angles to the original main arc path. As the extended and oriented primary arc is further deflected upwards by magnetic or mechanical means, it will strike the arc receiving means of the secondary arc splitting plates 37a, 37b, 37c, etc., which then divide the primary arc into a plurality of secondary arc elements. The secondary arc elements are deflected vertically upward between the secondary arc splitting plates 37a, 37b, 37c, etc., until the arc is extinguished. The secondary arc splitting plates 37 may all be similar to the plate 37b shown in dotted outline, and may be constructed with a substantially V-shaped notch at the bottom to assist in guiding and extinguishing the deflected arc element.

Fig. 4 shows a box 20 for holding a plurality of the arc splitting units 30. As shown in Fig. 2 or 15, the box 20 holding the racked units 30 is mounted in a frame 21 over the arc forming contacts 24 and 25. Referring to Fig. 4, the H arrow 62 indicates the instantaneous direction of the deflecting magnetic field H required to deflect the main arc upward before it has been oriented, while the arrow 65 indicates the instantaneous direction of the deflecting magnetic field H required to deflect the secondary arcs (having the instantaneous direction of current flow 50 to 56 shown in Fig. 3) upward after they have been oriented to a position substantially at right angles to the original direction of the main arc path. One means of providing for energizing these two magnetic fields 62 and 65 is shown schematically in Fig. 5. In this figure and others, the instantaneous direction of the arrows representing the magnetic field is always with reference to the instantaneous direction of the arrows for representing current flow. When A. C. current is being used, of course, the arrows reverse direction for each half cycle.

Fig. 5 is a schematic view of the flow of current through a de-ion circuit breaker utilizing a plurality of units 30 and having coils 61 and 64 for producing the magnetic fields 62 and 65. The basic numbers identifying the parts of the circuit correspond to those used in Figs. 2, 3, 4, 15, 16 and 17. It will be noted that the H magnetic field 62 is positioned so that when the main arc is drawn between the arcing contacts 24, 25, and 27, it is deflected upwards into the arc receiving means of plates 31, 32, and that the magnetic field 65 is positioned so that after the elements of the subdivided main arc are extended and oriented they will be deflected upwards into the arc receiving means of the secondary arc splitting plates 37a, 37b, etc. As shown in the diagram, conventional means have been provided for the arc path to perform a switching operation which first produces the H magnetic field 62, and then

produces the field 65. When the arcing contacts 24, 25 separate an arc is formed which then moves upwards until it is between the arc horns 27 and 28. It will be observed that when one end of the arc transfers itself from 24 to 27 that the coil 61 is inserted in series therebetween, and consequently the line current then flows through it and creates the magnetic field 62. After the arc has been deflected upwards into the primary arc splitting plates, the current path is 22, 24, 60, 61, 60b, 27 and 50, through the series of primary plates 31, 32 to 23. As each primary arc element is extended and oriented in each of the series of units 30, the current flow in each is as previously described for Fig. 3. However, the end unit (here 30e) has its last secondary plate (here 37b) connected to the coils 64 through lead 63, so that when the arc path reaches this plate it automatically transfers the flow of current to coil 64. The switching secondary plate 37b may be so adapted as to form and position as to produce the magnetic field 65 at the most opportune moment, in order that the oriented secondary arc elements will have a suitable deflecting field 65. It is to be noted that the flow of current through each of the units 30 is in the form of a single loop in each of them (path 31, 51, 52, 33, 53, 34, 54, 32, and 51a), which for certain applications may self-produce the required field 65 without the use of external magnetizing coils 64a and 64b.

Fig. 6 shows a structure for defining the paths and motions of the arc elements to give final radial rotation thereof in a plurality of circular recurrent paths. The primary arc splitting plates are indicated by 131 and 132. The inner cylindrical member 133 is joined to the upper end of plate 131, and the outer cylindrical member 134 is joined to the upper end of plate 132. The insulating members 129, 135 and 136 are adapted to support the cylindrical secondary arc splitting plates 137a, and 137b. For clarity, only two cylindrical plates 137 are shown here, although it is obvious that as many such cylindrical plates 137 can be used as considerations of spacing and size permit. (In Figs. 18 to 22, for example, five concentric cylindrical secondary plates 137a to 137e, have been shown.) Piece 119 is an insulative baffle. The numbers 138 and 139 indicate the edges of the primary arc splitting plates 131 and 132 (or 134) which serve as arcing guides to extend and orient the primary arc existing between the points 140 and 141.

Referring to Fig. 6, it is noted that the cylinders which serve as the secondary arc splitting plates are formed by cutting out a 180° sector from the cylinders as shown. This would require that the extended and oriented primary arc element should be in a vertical radial position as it entered the secondary arc splitting plates. However, as a matter of practical design, it might be more desirable that the said primary arc element should be in a horizontal radial position and be moving upwards as it entered the secondary arc-splitting plates. (The units 130 shown in Figs. 18 to 22 are made in this manner.) The cutting out of the 180° sector from the cylinders as shown here in Fig. 6 served to clarify the drawings and the description of the operation of the device. However, by cutting out a 90° sector from all of the cylinders, as indicated by the dotted line extension of the cylinders 137a and 137b in Fig. 7, and as shown in Figs. 18 to 22, the primary arc element would be in a horizontal position while entering the secondary arc splitting plates. With such a construction, of course, it would be necessary to modify pieces 135 and 136 as to their shape and the locations of the venting holes as is shown in Figs. 20 and 21. These minor mechanical details are more or less obvious. Also, the arc receiving means of 137 may be notched similar to 37b of Fig. 3, or similar to 131 of Fig. 6.

Fig. 7 shows the conductive cylindrical secondary arc splitting plates 137a, 137b. Fig. 8 shows the three insulative members 135, 129 and 136 in the same relative space positions that they occupy in the assembled unit 130 shown in Fig. 6. These members are provided with grooves to retain and support the cylindrical members 133, 134, 137a and 137b.

Figs. 18 to 22 show elevation, plan and cross sectional views of an arc extinguisher using six de-ion units 130a to 130f. Each of these de-ion units is similar to the one shown in perspective in Fig. 6, except that five cylindrical secondary arc-splitting plates 137a to 137e are shown in lieu of the two shown for descriptive purposes in Figs. 6 and 7. The identifying numbers used to indicate the parts of unit 130 in Fig. 6 are used to indicate the same parts in Figs. 18 to 22. Referring to Figs. 18 to 21, the uprights 121a, 121b are made of insulating material and support the cross pieces 120a and 120b, also made of insulating material, to form a box or rack to hold the six de-ion units 130a to 130f. The arcing horns 127 and 128 are bolted to the uprights 121b and 121a respectively, as shown. The stationary contact 124 is supported from the arc horn 127 but insulated therefrom by the block of insulation 118. The moving contact 125 may be actuated to open position by any suitable type of operating mechanism which may be provided with main contacts for normally completing the circuit through the circuit breaker. The line terminal 122 of the circuit connects to the stationary contact 124 and the other line terminal 123 to the arc horn 128 and the moving contact 125. The coils 161a and 161b of Figs. 18, 19, and 20 are positioned in grooves provided in the insulating cross pieces 120a and 120b. When energized, the coils 161a and 161b provide a magnetic field transverse to the path of the main arc and thus deflect the main arc into and past the primary arc-splitting plates 131 and 132 of each de-ion unit 130. The coils 161a and 161b are connected in series by the jumper 160a (Fig. 20), with one end of the coil 161b connected to the stationary contact 124 through the conductor 160 (Figs. 18 and 20), and the other end of coil 161a returned to arc horn 127 through the conductor 160b (Fig. 20). The coils 164a and 164b of Figs. 18 and 19 are positioned in grooves provided in the insulating uprights 121a and 121b. When energized, the coils 164a and 164b create a magnetic field through the secondary array of concentric cylinders of such direction as to be parallel to the common axis of the cylinders and thus transverse to the paths of the secondary arc elements formed between the cylindrical secondary arc-splitting plates 137 in each de-ion unit 130. The coils 164a and 164b are connected in series by the jumper 163a (Fig. 18), with the other end of coil 164a connected through conductor 163 to the end secondary switching plate 137a of de-ion unit 130a (Fig. 18), and the other end of coil 164b returned to line terminal 123 through the conductor 163b (Fig. 18).

Referring to Fig. 18, it will be seen that the circuit breaker apparatus for drawing out the

main arc, and the wiring connections for energizing the magnetic deflecting coils, are the same as for those previously described in connection with Fig. 15. In this regard, it is to be pointed out that the apparatus and method used to create and deflect the main arc into the primary arc splitting plates, where it is divided into a plurality of primary arcs, follow conventional practice and are well known to the art. According to this modification of the invention (the de-ion unit 130 of Fig. 6), the primary arc existing between each pair of primary arc splitting plates 131, 132 of each de-ion unit 130 (Fig. 6 or 18) is then moved upwards, extended and oriented to a line of position above and substantially at right angles to the line of position of the original primary arc. Each extended and reoriented primary arc is then moved into the arc receiving means of the secondary array of its de-ion unit 130 where it is further subdivided into a plurality of secondary arc elements. These secondary arc elements are then rotated radially by magnetic means in a recurrent circular path as defined by the concentric cylinders of the secondary array until the arc is extinguished.

By referring to the perspective view of one of the de-ion units 130 shown in Fig. 6 it will become clear how the structure of a de-ion unit 130 extends, orients, and further subdivides each primary arc element into a plurality of secondary arc elements and then causes them to rotate radially along a circular recurrent path. As mentioned above, when the main arc strikes the primary arc splitting plates 131 and 132 it is subdivided to form a primary arc element between plates 131 and 132. The primary arc element moves upward between these plates until the hot spot 140 on plate 131 reaches the arcing runner 138, and the hot spot 141 on plate 132 reaches the arcing runner 139. Since the primary arc between 140 and 141 is still being deflected upwards by the magnetic field, the hot spot 140 moves along 138 to point 140*a*, while hot spot 141 moves along 139 to point 141*a*. It will be noted that this movement of the arc hot spots along the arcing runners results in both extending the primary arc and in substantially reorienting it to a position substantially at right angles to the direction of the main arc. Ultimately the hot spot 140 reaches the inner cylindrical member 133 of plate 131, and hot spot 141 reaches the outer cylindrical member 134 of plate 132. In this position, it will be noted that the primary arc has been extended between the cylinders 133 and 134, and reoriented to a radial position substantially at right angles to the main arc. As the extended and oriented primary arc is further deflected by magnetic or mechanical means, it will strike the arc receiving edges of the secondary arc splitting plates 137*a* and 137*b*, which then subdivide the primary arc into a plurality of radial secondary arc elements. It is to be noted that the secondary arc elements are radial to the axis of the cylinders, so that when a magnetic field 165 is applied parallel to the axis of the cylinders, the radial secondary arc elements are rotated counter-clockwise between the surfaces of the cylindrical members. The insulative end piece 135 (see Fig. 8) has its inside surface cut as a spiral wedge, which serves to guide the radial secondary arc elements along the axis into the cylindrical region of unit 130 between the disc like insulative members 129 and 136. In this region the secondary arc elements can be radially rotated by the magnetic field 165 around the

circular recurrent path defined by the concentric cylinders until extinguished. As shown in Fig. 8, the end disc 136 can be provided with slots to aid in venting the air heated by the arcs.

A plurality of the units 130 shown in Fig. 6 can be racked side by side in a supporting box like structure 20, Figs. 2 and or a boxlike structure 120—121, Figs. 18 to 20. When properly racked the axis of each unit 130 will line up along a common line, and each insulative end member 136 and metal plate 132 wil be pressed against the plate 131 of the adjacent unit 130. When so racked, if we consider two units 130*a* and 130*b*, with unit 130*a* in front of unit 130*b*, it will be noted that the piece 135*b* of the back unit will be next to the piece 136*a* of the front unit so as to cover up the left hand side of piece 136*a*. For this reason, no vent holes are shown in the left hand side of the insulative piece 136. However, it will be observed that the insulative piece 135 can be cut thinner at its lower half so as to provide space for additional venting holes in piece 136 if required.

It is to be noted that the cylindrical plates 137 and the end plates 133, 134 which make up the secondary array of arc splitting plates in Figs. 6 and 18 to 22 constitute a closed loop. Furthermore, if the de-ion units 130 are used to interrupt alternating currents the coils which supply the magnetic deflecting fields must also be energized with alternating currents. As a result, the varying magnetic fields will induce eddy currents in the closed loops of the cylindrical plates 133, 134 and 137 by transformer action. These eddy currents may be prevented by the conventional method of cutting a longitudinal slot in each cylindrical member which forms a closed loop, taking care to stagger the position of each slot with respect to the position of the slots in adjacent cylinders. It will be obvious, of course, that when the de-ion units 130 are used to interrupt direct current circuits this problem will not arise, and the slots may be omitted.

Fig. 9 is a schematic sketch of the flow of current through a de-ion circuit breaker utilizing a plurality of units 130 (130*a*, 130*b*, 130*c*, etc.). The coils for producing the indicated magnetic fields H, arrows 162 and 165, are not shown, since they can be similar to those already described for Fig. 5. The numbering of the parts in Fig. 9 corresponds substantially to those used in Figs. 6, 7, and 18 to 22. The diagram shows the flow of current through the units 130 after the main arc has been finally subdivided into secondary arc elements which are being radially rotated in a circular path defined by the concentric cylindrical surfaces of the device. At this time, the current (instantaneous) flow is, as indicated by the current arrows, along 150, 151, 152 to 133, 153 to 137*a*, 137*b*, 134, along 154 to 132, and so on through the succeding units 130.

Fig. 10 shows a structure for defining paths and motions of the arc elements to give a final cylindrical rotation thereof in a plurality of circular paths. The concentric cylinders which are adapted to form the primary arc splitting plates are indicated by 231 and 232. The disc-like end plate 233 is joined to the end of cylinder 231, and the disc-like end plate 234 to the end of cylinder 232. The cylindrical insulating baffles 236 (inner cylinder) and 235 (outer split cylinder) are adapted to support between them the disc-like secondary arc splitting plates 237*a*, 237*b*, etc., said plates being arranged parallel to one another and spaced along a common axis. The numbers 238

and 238 indicate the edges of the cylinders forming the primary arc splitting plates 231 and 232 which serve as arcing guides to extend and orient the primary arc existing between the points 240 and 241.

Fig. 11 shows the disc-like annular ring conductive plate 237, a plurality of which are used as secondary arc splitting plates in unit 230 of Fig. 10. Fig. 12 shows the cylindrical insulative piece 229, which is part of the unit 230 shown in Fig. 10. The piece 229 can be so formed as to fit between the two concentric cylinders 231 and 232 of unit 230, or as shown it may have a diameter slightly greater than that of the outer cylinder 232, in which case a slot for engaging the end of 232 must be cut into the left side arm of piece 229. The slot in the right side arm of 229 is for engaging the end 232L of a left cylinder unit 230L, which is substantially the reverse, as regards the construction and the motion of the arc elements shown for the right cylinder unit 230R actually illustrated in Fig. 10. The difference between the right cylinder 230R and the left cylinder 230L construction can be more clearly described later when reference is made to Fig. 14 which shows a diagrammatic line sketch of instantaneous current flow in both 230R and 230L.

Fig. 13 shows the cylindrical insulative members 235, 236, 236*a* to 236*c* in the same relative space positions that they occupy in the assembled unit 230 shown in Fig. 10. In the assembly, the secondary arc splitting plates 237 fit over the center cylinder 236, and are spaced from one another by the cylindrical collars 236*a*, 236*b*, etc., which fit over the center tube 236.

Referring to Fig. 10, in the operation of the de-ion unit 230 the main arc is deflected upwards into the primary arc splitting plates 231 and 232 which are arranged transverse to the main arc path. When the main arc strikes the primary arc splitting plates 231 and 232 it is subdivided to form a primary arc element between the two cylindrical surfaces or plates 231 and 232. The primary arc moves upwards between these plates until the hot spot 240 on plate 231 reaches the arcing runner 238, and the hot spot 241 on plate 232 reaches the arcing runner 239. With means being provided for creating a radial magnetic field in 230, as will be explained later with reference to Fig. 14, the primary arc between 240 and 241 will be deflected by this radial magnetic field so that hot spot 240 moves along the arc runner 238 to point 240*a*, while hot spot 241 moves along arc runner 239 to point 241*a*. It will be noted that this movement of the arc hot spots along the arcing runners results in both extending the spots along the arcing runners results in both extending the primary arc and in reorienting it to a position substantially at right angles to the direction of the main arc. Ultimately the hot spot 240 reaches the disc member 233 which is joined to the cylindrical plate 231, and hot spot 241 reaches the disc member 234 which is joined to the cylindrical plate 232. In this position, it will be noted that the primary arc has been extended between the end discs 233 and 234, and reoriented to a position substantially at right angles to the main arc. As the extended and oriented primary arc is further deflected by magnetic means, it will strike the edges of the secondary arc splitting plates 237*a* and 237*b*, which will divide the primary arc into a plurality of cylindrical secondary arc elements. It is to be noted that the secondary arc elements are then parallel to the common axis of the cylinders, so that when a magnetic field is applied radial to the axis of the cylinders, the cylindrical secondary arc elements are rotated clockwise between the surfaces of the disc plates 237*a*, 237*b* etc. The insulative split cylinder 235 is coiled spiral like, which serves to guide the cylindrical secondary arc elements in a spiral path around the axis into the circular inner cylindrical region of unit 230 between the cylinders 235 and 236. In this region the secondary arc elements can be cylindrically rotated by the radial magnetic field around the circular recurrent path defined by the annular ring portion of the secondary arc splitting plates 237 until extinguished. For venting purposes it is obvious that slots or openings can be cut in the insulative piece 235 without adversely affecting the basic operation of the device.

Referring to Fig. 10, it is to be noted that a primary arc element formed between 231 and 232 is rotated through an arc of substantially 270° while being extended and oriented before it strikes the arc receiving edges of the secondary arc splitting plates. This 270° path of travel for the primary arc elements is purposely shown here for the sake of clarifying the drawing and to facilitate giving a clear description of the operation of the device. However, as a matter of practical design, it might be more desirable that the primary arc element should be in a horizontal position and be moving substantially upwards as it enters the secondary arc splitting plates. This requirement can be easily met structurally by rotating the plates forming the secondary arc receiving means substantially 180° from the position shown. This would place said arc receiving means on the left side of unit 230, with the opening facing downward. With the arc receiving means of the secondary arc splitting plates 237 in this position, the primary arc element formed between primary arc splitting plates 231 and 232 will move through substantially 90° of the circumference of 230 while being extended and oriented, and will be moving substantially upwards as it enters the secondary arc splitting plates.

Fig. 14 is a schematic sketch of the flow of current through a de-ion circuit breaker utilizing two units constructed similar to 230. In this connection, it is to be noted that the units are assembled on a common axis, the unit on the right side being designated by the name "right cylinder" unit 230R and the one on the left by the name "left cylinder" unit 230L. The structure shown in Fig. 10 is for a "right cylinder" unit 230R. The functional operation of the units 230R and 230L are similar, but it will be observed that the direction of rotational movement and of the flow of current of the arc elements in unit 230L is the reverse or opposite of that in unit 230R. In keeping with the above, the radial magnetic field 265R for 230R is directed outwards, while the radial magnetic field 265L for 230L is directed inwards. In the Fig. 14 these magnetic fields are indicated as arrows H extending radially from the dotted line cylinder which is shown extending through both units 230L and 230R, one end being instantaneously designated "N" and the other "S." The means for obtaining a magnetomotive force could be a permanent magnet substantially as indicated by the dotted cylinder where the device was used to interrupt a direct current source. For interrupting alternating currents, the magnetizing force can best be obtained by using coils energized by the current being interrupted. Obviously, in an A. C. circuit breaker, the direction of current flow and of magnetic fields are only

instantaneously true, as is well known in the art. The numbering of the parts in Fig. 14 corresponds to those used in Figs. 10, 11, and 13. The diagram shows the flow of current through the units 230R and 230L after the main arc has been finally subdivided into secondary arc elements which are being cylindrically rotated in a circular path defined by the parallel coaxial annular ring surfaces 237 of the device. With respect to the right cylinder unit 230R, the current flow at this time is, as indicated by the current arrows, from 231 along 252R, 233R, 253R, 237aR, 237bR, 234R, 254R and 255R to 232R, and thence along 256R to the next unit or to the return circuit. For the left cylinder 230L, a similar numerical sequence exists, if one follows a path from 231 against the current arrows to primary plate 232L. It will be noted that the cylindrical secondary arc elements are rotated clockwise in 230R, and counterclockwise in 230L, as is indicated by the dotted arrows. Only one pair of right and left units 230R and 230L is shown in Fig. 14, but it is obvious that a plurality of the units 230 can be racked so that their primary arc splitting plates 232L, 231, 232R are in series with each other, in a manner substantially similar to that previously shown for units 30 and 130.

The above describes the basic operation of my improved de-ion circuit breaker as applied to the three variations in structure shown. In the interest of clarity the drawings showing the members of the various structures in their basic operative positions have been depicted as simply as possible, in order to better illustrate the essential character of the invention. As a matter of practical construction, it is obvious that the insulative members supporting arc splitting members can be slotted and grooved to receive the edges of the arc splitting members, and thus assist in preventing the arc flame from flashing around the arc splitting members. In order to assist in guiding the moving arc elements along the arc running paths in the various structures as are defined by the conducting arc splitting members and the sides of their insulative supporting members, the surface of the conducting members can be given a central raised contour along the line of the defined arc running path. In the drawings the conducting members are shown with square edges, but it is obvious that these could be formed with their edges rounded in such a manner as to reduce the concentration of voltage stresses. Similarly, mechanical changes can be made in notching the arc receiving means of the plates, in making provisions for venting, and for preventing creepage and voltage breakdown in accordance with principles commonly employed in the art, without departing from the spirit of the invention as shown and described.

In the drawings shown the various structures have been adapted to extend and orient the primary arc element to a line of position substantially at right angles to the line of the main arc before dividing each primary arc into secondary arc elements. It is obvious that the 90° angle of orientation of the primary arc element as shown is not a necessary restriction. For example, in Fig. 3 the secondary array is shown oriented at a 90° angle with the line of the primary array, but as far as electrical considerations are concerned, could just as well be at some other angle, such as 45°, for example. As a matter of practical construction, however, the structure of Fig. 3 with the 90° angle of orientation is simpler than that which would be required for some other angle of orientation. A similar line of reasoning can be followed with regard to the other structures shown.

In the illustrations given the arc is deflected into arc splitting members arranged in two successive arrays, which are designated as a primary array and a secondary array. Two arrays substantially as described give a relatively simple physical construction of the device, and permit ready extension and orientation of the arc to a line of position in space where an array comprising a plurality of secondary arc splitting members can be conveniently formed. However, it is readily apparent that arc splitting members could be introduced at intermediate positions between the original position of the primary arc and the final position of the successively extended and oriented arc. Such an increase in the degree of arrays would follow readily from the ideas disclosed in this invention, but from a practical viewpoint it is apparent that such an operational cascading of arrays would result in a more complex physical structure.

The use of this invention, in which a portion or element of the arc is extended and oriented to a position which permits the use of an increased number of arc splitting members, gives rise to many advantages. The arc splitting members can be constructed from sheets of conducting material formed into flat or cylindrical shapes. The use of an increased number of arc splitting members for given considerations of size and space enables the device to interrupt greater voltages and currents than would otherwise be possible. The device as illustrated in Fig. 3 is, for example, relatively simple mechanically, so that problems of construction and repair or maintenance are reduced to a minimum. Also, the open-ended path of deflection of the arc permits the use of a simple magnetic circuit. The device of Fig. 6 provides for a recurrent circular arc running path, in which the secondary arc elements are rotated radially. In this case also, it will be observed that a simple transverse magnetic circuit is all that is required to give the desired recurrent radial rotation of the final secondary arc elements.

I claim:

1. In a circuit interrupter, means for drawing the main arc between a pair of separable contact members, means for dividing said main arc into a plurality of series related primary arc elements, means for extending and orienting at least one of said primary arc elements to a position substantially askew to and at right angles to the main arc path, means for dividing at least one of said extended and oriented primary arc elements into a plurality of series related secondary arc elements, and means for moving at least one of said secondary arc elements along an open-ended arc running path between spaced conducting members in a direction substantially perpendicular to the main arc path until extinguished.

2. In a circuit interrupter, a primary series array of parallel spaced conducting members, a secondary series array of parallel spaced conducting members for substantially each pair of members in the primary series array, said primary series array being positioned along a line substantially parallel to that of the main arc path and having the arc splitting means of its members in a plane substantially transverse to the main arc, each of said secondary series arrays having the arc splitting means of its mem-

bers in a plane substantially parallel to the main arc, substantially each pair of spaced conducting members of said secondary series array defining an arc running path, means for drawing a main arc between a pair of separable contact members, means for causing said main arc to pass into the arc splitting means of the primary series array where it is divided into a plurality of series related primary arc elements, means for causing substantially each primary arc element to pass into the arc splitting means of a secondary series array where it is subdivided into a plurality of series related secondary arc elements, and means for causing substantially each secondary arc element to move along an arc running path as defined by its pair of spaced conducting members in its secondary array until extinguished.

3. In a circuit interrupter, a primary series array of parallel spaced conducting members, a secondary series array of parallel spaced conducting members for substantially each pair of members in the primary series array, said primary series array being positioned along a line substantially parallel to and above that of the main arc path and having the plane of the arc receiving means of its members substantially transverse to the main arc path, each of said secondary series arrays being positioned along a line substantially transverse to and above the primary series array and having the plane of the arc receiving means of its conducting members in a plane substantially transverse to those of the primary series array, means for drawing a main arc between a pair of separable contact members, means for deflecting said main arc into the arc receiving means of the primary series array where it is subdivided into a plurality of series related primary arc elements, means for deflecting substantially each primary arc element into the arc receiving means of a secondary series array where it is subdivided into a plurality of series related secondary arc elements, and means for causing substantially each secondary arc element to move along an arc running path as defined by its pair of spaced conducting plates in the secondary array until extinguished.

4. In a circuit interrupter, a primary series array of parallel spaced conducting primary arc splitting members, a secondary series array of parallel spaced conducting secondary arc splitting members, said members having substantially developable surfaces, the plane of the arc receiving portion of the primary members being arranged substantially transverse to the main arc path, substantially each pair of primary members having an extension for each primary member adapted to form an end plate secondary member in said secondary array, the plane of the arc receiving portion of said end plate members being arranged at an angle to the plane of the arc receiving portion of its primary member, said end plates being spaced substantially parallel to each other, a plurality of spaced conducting secondary members arranged between each pair of said end plate members and having their active surfaces substantially parallel to those of said end plate members, means for causing said main arc to pass into the arc receiving means of the primary series array where it is subdivided into a plurality of series related primary arc elements, means for causing substantially each primary arc element to pass into the arc receiving means of a secondary array where it is subdivided into a plurality of series related secondary arc elements, and means for causing substantially each secondary arc element to move along an arc running path as defined by the active surfaces of its pair of spaced conducting secondary members in the secondary series array until extinguished.

5. In a circuit interrupter, a primary series array of parallel spaced conducting primary members, a secondary series array of spaced conducting secondary members, said members having substantially developable surfaces, said primary members comprising substantially plane flat plates with a lower portion thereof adapted to receive an arc, the plane of the arc receiving portion of said primary members being arranged substantially transverse to and above the main arc path, substantially each pair of primary members having an extension for each primary member adapted to form an end plate member in said secondary array, each of said end plates comprising substantially a plane flat plate with a portion thereof adapted to receive the end termination of an arc, the plane of the arc receiving portion of said end plate members being arranged at an angle to the plane of the arc receiving portion of its primary member, the active surfaces of said end plates being spaced substantially parallel to each other, the spacing between said end plates being greater than the spacing between their respective primary plates, a plurality of spaced conducting secondary members arranged between substantially each pair of said end plate members and having their active surfaces substantially parallel to those of said end plate members, said secondary members comprising substantially plane flat plates with a lower portion thereof adapted to receive and divide an arc, means for drawing an main arc between a pair of contact members, means for causing said main arc to pass into the arc receiving means of the primary series array where it is subdivided into a plurality of series related primary arc elements, means for causing substantially each primary arc element to pass into the arc receiving means of a secondary series array where it is subdivided into a plurality of series related secondary arc elements, and means for causing substantially each secondary arc element to move translationally along an open-ended arc running path as defined by the active surfaces of its pair of spaced conducting secondary members in the secondary array until extinguished.

6. In a circuit interrupter, a primary array of spaced conducting primary members, a secondary array of spaced conducting secondary members, said members having substantially developable surfaces, said primary members comprising substantially plane flat plates with a portion thereof adapted to receive an arc, the plane of the arc receiving portion of said primary members being arranged substantially transverse to the main arc path, substantially each pair of primary members having an extension for each primary member adapted to form an end plate secondary member in said secondary array, each of said end plates comprising substantially a plane flat plate with a portion thereof adapted to receive an arc, the plane of the arc receiving portion of said end plate members being arranged substantially at right angles to the plane of the arc receiving portion of its primary member, the active surfaces of said end plates being spaced substantially parallel to each other, the spacing between said end plates being greater than the spacing between their respective primary plates, a plurality of spaced conducting secondary members arranged between each pair

of said end plate members and having their active surfaces substantially parallel to those of said end plate members, said secondary members comprising substantially plane flat plates with a portion thereof adapted to receive an arc, means for drawing a main arc between a pair of contact members, means for causing said main arc to pass into the arc receiving means of the primary array where it is subdivided into a plurality of series related primary arc elements, means for causing substantially each primary arc element to pass into the arc receiving means of a secondary array where it is subdivided into a plurality of series related secondary arc elements, and means for causing substantially each secondary arc element to move translationally along an open-ended arc running path as defined by the active surfaces of its pair of spaced conducting secondary members in the secondary array until extinguished.

7. In an arc extinguisher, a pair of parallel substantially plane primary arc splitting members and a plurality of parallel plane secondary arc splitting members, said members being formed of conducting sheet material, said conducting members being spaced and supported by insulative members with the plane of the primary members being substantially transverse to the plane of the secondary members, each of said primary members having a connection of conductive material to an end secondary member, said insulative members defining an open-ended path between substantially each pair of secondary members and defining a path extending from adjacent the point where the arc is established between the primary members to the arc receiving means of the secondary members, and means for setting up a magnetic field for moving the arc along said path between said primary members and then along said path between said secondary members.

8. In a circuit interrupter, means for drawing a main arc between a pair of separable contact members, a plurality of spaced conducting primary arc splitting members adapted to divide said main arc into a plurality of series related

primary arc elements, spaced conducting members adapted to extend and orient at least one of said primary arc elements to a line of position substantially askew to and at right angles to the main arc path, at least one conducting secondary arc splitting member adapted to series divide at least one of said extended and oriented primary arc elements into a plurality of series related secondary arc elements, and means for moving at least one of said secondary arc elements along an arc running path between spaced conducting members until extinguished.

9. In a circuit interrupter, at least one deionization unit, said unit including a pair of spaced conducting primary arc splitting vertical plates having their lower ends adapted to split and receive a transverse arc, each of said primary plates having a vertical end-plate extension of conducting material joined to its upper end, said vertical end-plates being substantially at right angles to said vertical primary plates and spaced substantially parallel to one another, a plurality of spaced substantially parallel secondary arc splitting plates between said primary end-plates, insulative means for positioning said secondary arc splitting plates, and means for causing an arc to pass into said unit.

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