

Oct. 24, 1933.

B. P. BAKER

1,932,061

CIRCUIT BREAKER

Filed April 30, 1927

5 Sheets-Sheet 1

Fig. 1.

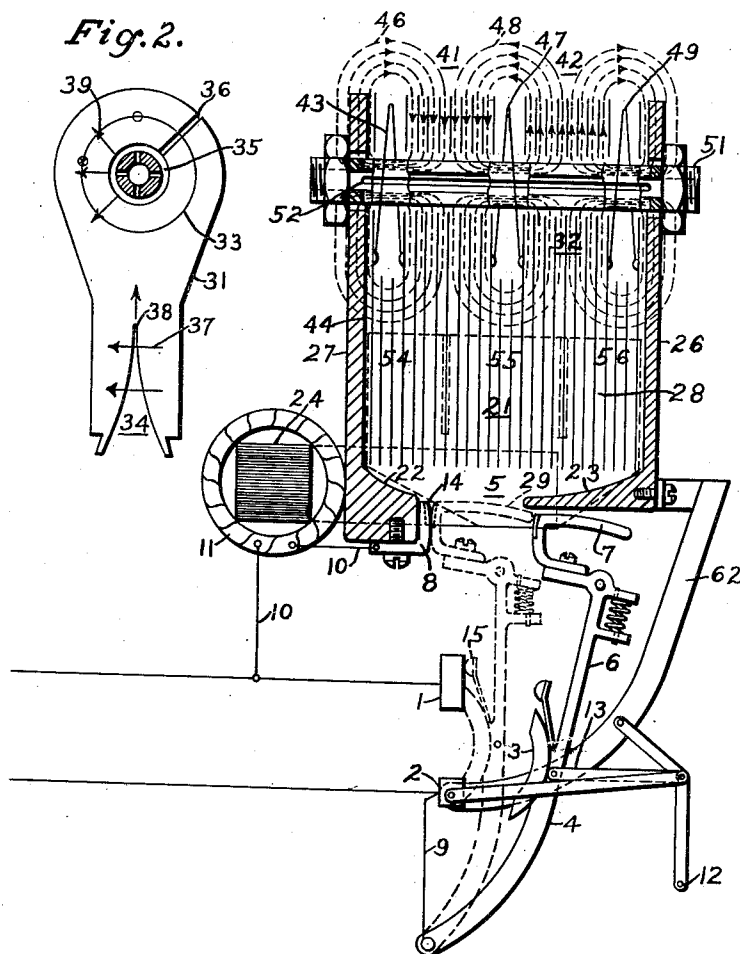


Fig. 2.

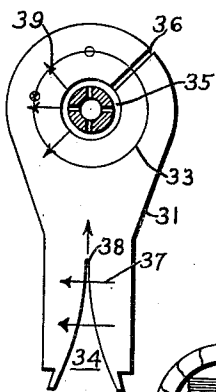


Fig. 3.

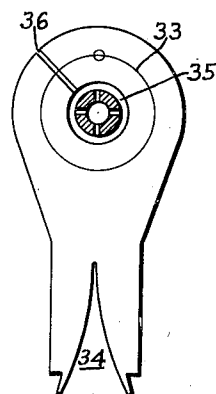


Fig. 4.

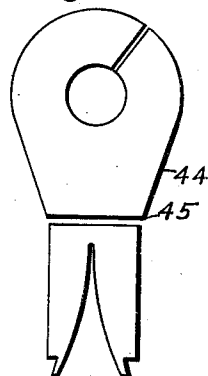
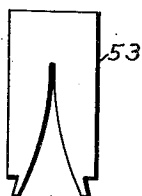


Fig. 5.



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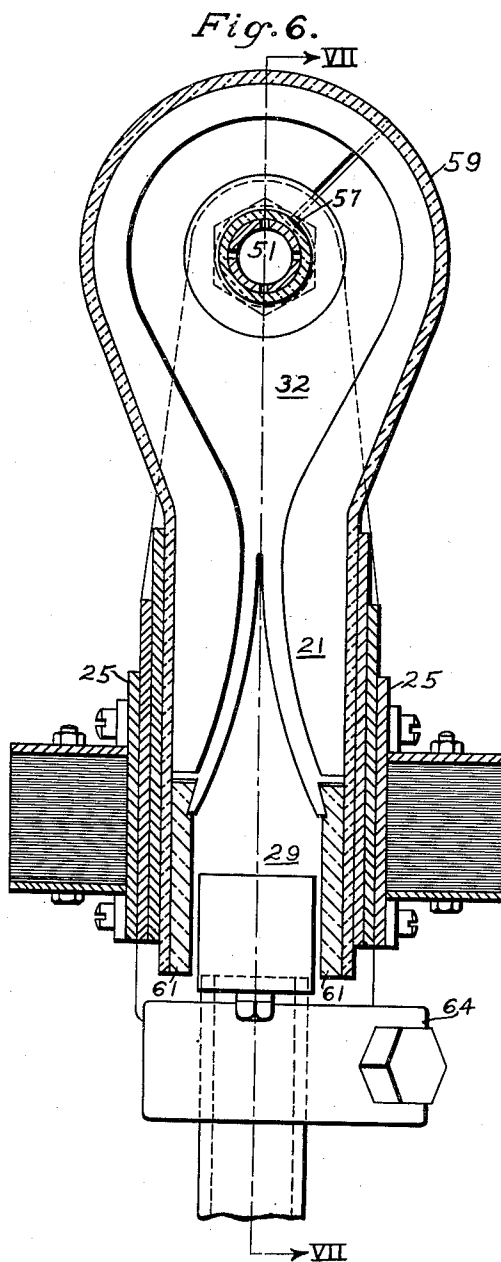
Oct. 24, 1933.

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CIRCUIT BREAKER

1,932,061

Filed April 30, 1927

5 Sheets-Sheet 2



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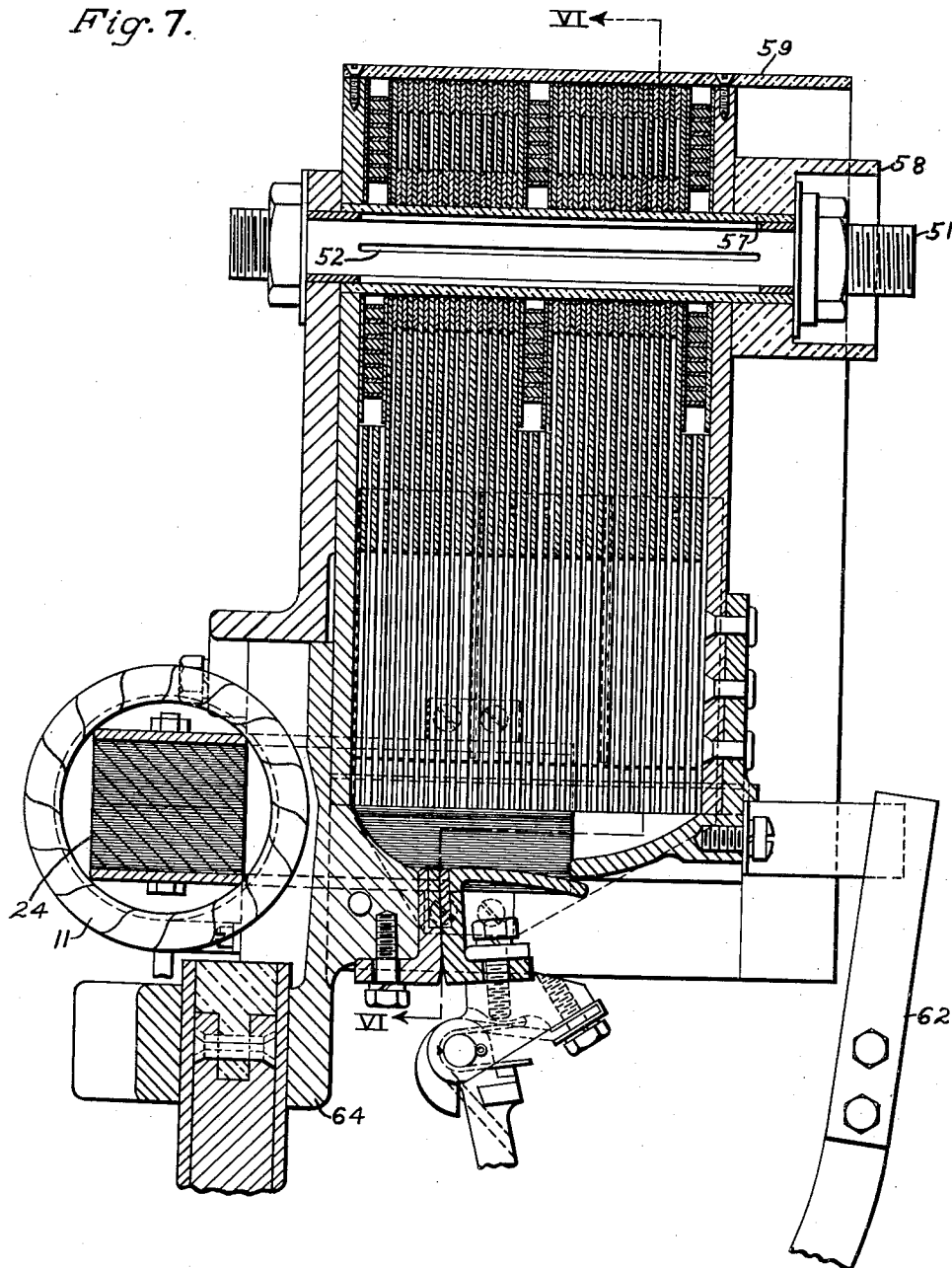
1,932,061

CIRCUIT BREAKER

Filed April 30, 1927

5 Sheets-Sheet 3

Fig. 7.



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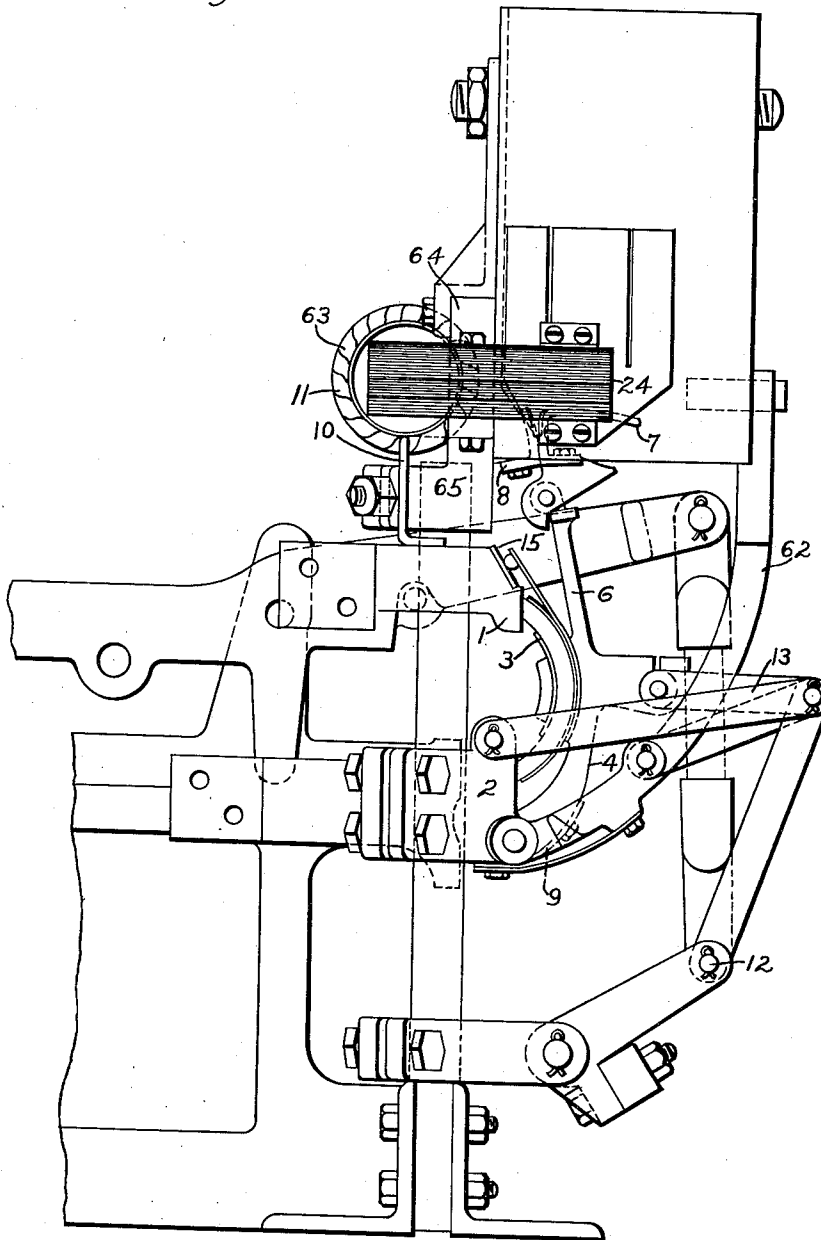
1,932,061

CIRCUIT BREAKER

Filed April 30, 1927

5 Sheets-Sheet 4

Fig. 8.



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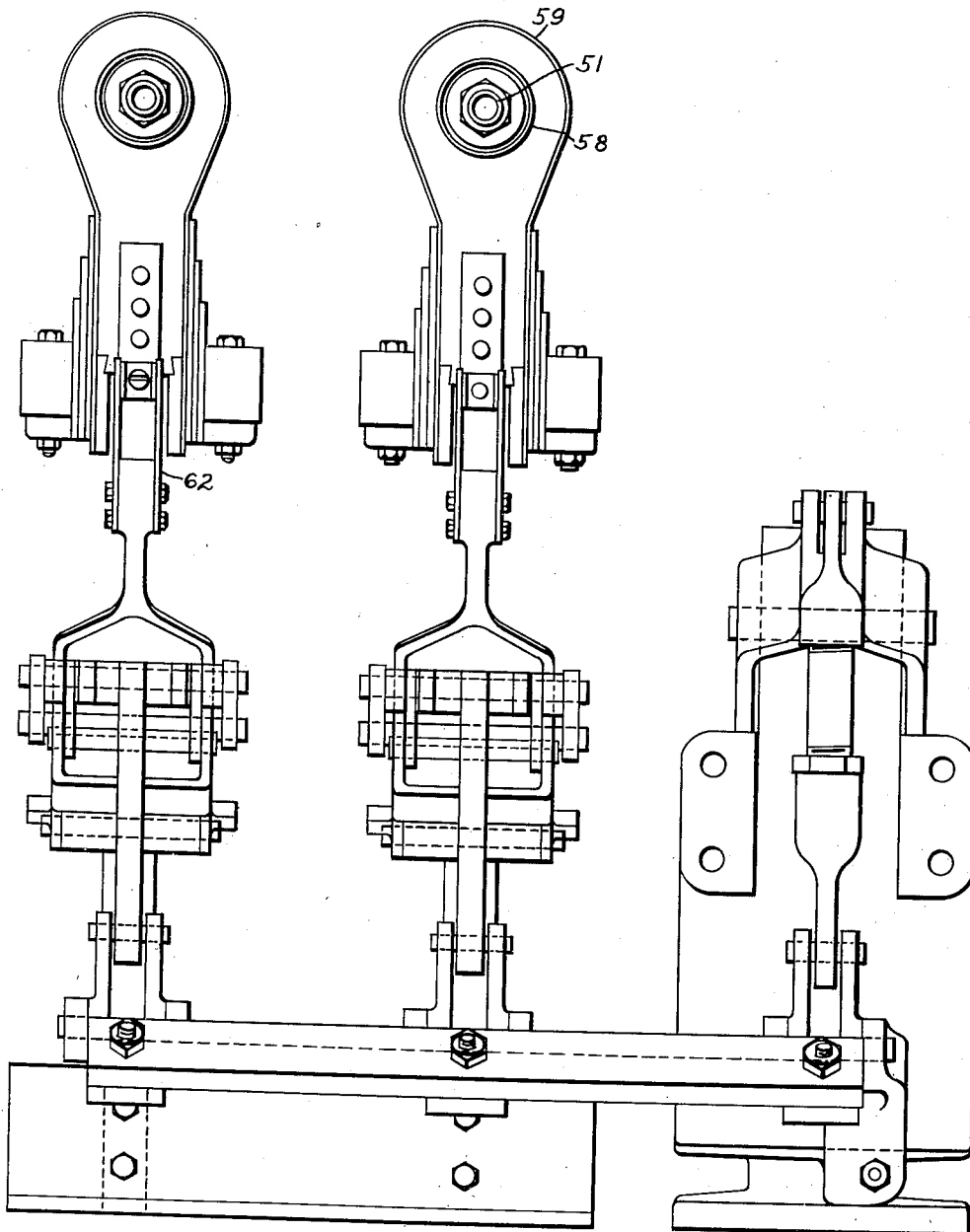
1,932,061

CIRCUIT BREAKER

Filed April 30, 1927

5 Sheets-Sheet 5

Fig. 9.



WITNESSES:
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UNITED STATES PATENT OFFICE

1,932,061

CIRCUIT BREAKER

Benjamin P. Baker, Wilkinsburg, Pa., assignor
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Company, a corporation of Pennsylvania

Application April 30, 1927. Serial No. 187,987

45 Claims. (Cl. 200-144)

My invention relates to interrupting means for electric circuits and particularly to such means for interrupting circuits of high voltages while supplying heavy loads. The general principles of my invention, however, are applicable in connection with devices for interrupting circuits where the voltage and current are of relatively low value; and, in fact, to the interruption of electrical discharges through gases generally.

Among the objects of my invention is the provision of means for interrupting electrical discharges through gases generally.

Another object of my invention is the provision of means for interrupting electrical circuits by means of a pair of separable contacts opening in air or other gaseous media without the need of resorting to the use of oil or similar quenching means.

It is a feature of circuit breakers embodying my invention that the arc incident to the opening of a circuit is driven into an endless arc track and maintained in continuous movement thereon until the arc has been rendered electrically unstable and thereby extinguished. Circuit interrupting means of this general type is disclosed, and the principles of operation thereof thoroughly explained, in Patent No. 1,784,760 of Joseph Slepian, issued December 9, 1930 and assigned to the Westinghouse Electric & Manufacturing Company. In order to bring about the electrical instability of the arc as above mentioned, the arc track is located in a chamber provided with a deionizing structure comprising closely spaced conducting plates, into which the arc is driven and thereby divided into numerous serially related arc-sections. By continuously rotating the arc along these surfaces, they are maintained relatively cool and protected from injury notwithstanding the high arc temperature.

A further object of my invention is to provide an electrical and magnetic structure adapted to produce a magnetic flux distribution suitable for deflecting the arc and rotating it in its retracing track and to devise a magnetizing structure symmetrical and economical of copper, and one which shall be substantially free from effects due to magnetic saturation.

The features of the invention which I believe to be new are particularly pointed out in the appended claims. For a full understanding of the principles of the invention, and the best mode of applying the same, reference may be had to the accompanying drawings, in which

Figure 1 is a diagrammatic view of a circuit

breaker embodying the principal elements of my invention;

Fig. 2 is a detail view of one type of plate as positioned in one section of the de-ionizing structure. These plates may conveniently be referred to as "key grids", or "eye-bolt grids".

Fig. 3 is a detail view of a plate of the same type, as positioned in another section of the de-ionizing structure;

Figs. 4 and 5 are detail views of other plates used in the de-ionizing structure;

Fig. 6 is a sectional view along the line VI—VI of Fig. 7;

Fig. 7 is a sectional view along the line VII—VII of Fig. 6;

Fig. 8 is a side elevation of a circuit-breaker embodying my invention in a commercial unit, and

Fig. 9 is a front elevation and shows two phases of a three-phase circuit breaker embodying my invention.

The present invention is, in some aspects, a further development of the circuit breaker described in the Patent 1,784,760 of Joseph Slepian, issued December 9, 1930 and assigned to the Westinghouse Electric & Manufacturing Company.

According to the present invention, the fact that an arc can be maintained without producing hot cathode spots on the arc electrode is made use of in order to provide a de-ionizing structure in which the arc incident to the opening of a circuit is driven between solid metallic sheets, and split up into small arc sections with distinct cathode and anode terminals, the arcs between the individual sheets being maintained in the form which I may designate as "cold-cathode arc discharges". Arc extinguishing by means of the "cold-cathode discharge" principle is described in the aforesaid Slepian patent.

The de-ionizing structure used in circuit breakers of the type here described makes full use of the very large de-ionizing effect obtained from metal plates closely spaced transversely to the arc, and maintains short arc discharges, between said sheets in the form of "cold arc discharges". That is to say I provide a structure in which I sub-divide the arc incident to the opening of the circuit into a large number of small serially-connected arc sections playing in thin spaces between solid metal or conducting sheets without any considerable heating of said sheets and positively preventing any perceptible

melting or other injury to the sheets by reason of hot cathode spots, or the like.

I have found that if the arcs between the individual sheets are moved with sufficient rapidity over the sheets, there is no melting at the arc terminals and presumably the arc current carriers are supplied entirely by thermal ionization of the air next to the cathode and between the sheets. On arc blow-out structures as used heretofore the speed with which the arc could be moved between the arc electrodes was limited by the fact that during the time of the arc's existence, that is 1/120 of a second in case of 60-cycle alternating current, the arc had to remain confined between the de-ionizing sheets. If the arc was to be given a speed at which it could be maintained without heating the cathode, the prior arc blow-out structures would require a length considerably beyond what was practically possible.

In an effort to obtain an arc blow-out structure in which the speed of the arc movement would be free from limitation with regard to the length of the arc chute, and thus to make possible arc speeds at which the formation of hot cathode spots on the electrodes is avoided, a new type of arc-driving, or arc-blowing, arrangement has been devised which causes the arc to repeatedly move over a limited area at such high speeds as are required to give the arc the necessary characteristics.

The new arc-driving arrangement is based on the idea of producing a peculiarly shaped magnetic field which causes the arc to keep on moving at very high velocity over and over again in a limited space to which the arc is intended to be confined, the high arc velocity preventing excessive heating of the arc-terminal surfaces and the adjacent bodies so that the arc takes the form which I have termed "cold-cathode arc".

The novel arc-driving arrangement is not limited in its utility to de-ionizing structures of the type using closely-spaced de-ionizing sheets disposed transversely to the arc, but it has opened a large number of possibilities in improving other types of electrical apparatus. Some of the claims appended hereto are accordingly directed to the features of the new arc drive structure irrespective of the type of apparatus in which it is utilized.

The diagrammatic illustration of the principal elements of a circuit breaker embodying my invention, as shown in Figs. 1 to 9, will make the novel features explained hereinabove readily understood. The circuit breaker shown in the drawings has the usual main contact members 1 and 2 arranged to be bridged over by a main contact brush 3 that is held on a main contact arm 4. The arm 4 is pivoted to swing the brush 3 between the position in which it closes the circuit between the main contact members 1 and 2, and a position away from said contact members in which the circuit breaker is open.

The circuit breaker is further provided with an arc-drawing structure 5 comprising an arcing contact arm 6 having at its upper end an arcing contact shoe 7 adapted to engage a stationary arcing contact member 8 for finally interrupting the circuit, the arcing shoe 7 and the stationary arcing contact member 8 being suitably connected, as by means of conductors 9 and 10 that include main blow-out windings 11, in parallel to the main contact members 1 and 2.

To open the circuit, the main contact arm 4 and the arcing contact arm 6 are swung to the

right by means of a suitable toggle mechanism comprising a bell crank lever, that is pivoted at 12, and links 13 so arranged that in opening the circuit breaker the brush 3 is first lifted from the contact members 1 and 2, diverting the current from the brush into the shunting circuit through the arcing contact arm 6, arcing contact shoe 7, stationary contact member 8, conductors 9 and 10, and blow-out winding 11. Further movement of the bell crank lever fully opens the circuit by bringing about disengagement of the arcing contact shoe 7 and the stationary arcing contact member 8 at their arcing tips 14.

A pair of auxiliary contact members 15, that are arranged to be opened somewhat later than the main contact members 1, 2 and 3, but somewhat earlier than the arcing-contact tips 14, are usually also provided to relieve the main contact members of arcing incident to the transfer of the current from the main brush 3 to the inductive shunt circuit including the blow-out coil 11 and the arcing contact members 7 and 8. Contact arm 4 is connected near its hinge with contact member 2 through the previously mentioned flexible connector 9 to complete a path through contacts 14 from contact member 1 to contact member 2.

The arc extinguishing structure, to which my invention is principally directed comprises an arc-chute 21 which extends above the space where the arc between tips 14 of the arcing contact members 7 and 8 is drawn. The arc-chute comprises a pair of horn-like inclined arcing plates 22 and 23, to which the arc drawn between the arcing tips 14 of the arcing contact members, is transferred by means of a main blow-out magnet. The blow-out magnet comprises a laminated core 24, that is excited by the previously-mentioned blow-out winding 11, and a pair of pole shoes 25, positioned on opposite sides of the arcing horn plates 22 and 23. The upper ends of the inclined arcing horn plates 22 and 23 merge into vertical arcing plates 26 and 27 integral therewith. The pole shoe 25 and the vertical arcing plates 26 and 27 thus define a straight rectangular chamber 28 having at its lower end the downwardly tapered arc-entrance chamber 29 extending between the inclined arc-horn plates 22 and 23 and the lower portions of the pole shoes 25. The magnetic flux induced between the pole shoes 25 has a direction transverse to the plane of the drawings so that when the circuit breaker is opened and an arc is drawn between the arcing tips 14, the arc is blown toward the inclined arcing horn plates 22, 23, and then upwardly along the latter through the entrance chamber until it reaches the straight portion of the arcing chamber 28.

The straight portion of the arcing chamber between the arcing plates 26 and 27 is filled with a plurality of solid metallic sheets or plates 31, of the form shown in Figs. 2 and 3, which I have before designated as the de-ionizing sheets or grids of the arc interrupting structure. The individual sheets are insulated from each other, as by means of paper strips at the edges of the sheets, I have, however, omitted these from Fig. 1 of the drawings which indicates only the air spaces between the sheets.

Extending directly above the straight portion 21 of the de-ionizing structure, and as a direct continuation thereof there is provided a circular extension 32 into which the arc from the straight portion 21 of the de-ionizing structure

is driven and wherein it is then caused to travel along a closed path 33 about the center of the circular extension. When viewed from the side of Figure 1, the resulting de-ionizing structure appears as shown in the views of Fig. 8.

The individual de-ionizing sheets 31 which are disposed within the space between the end plates 26 and 27 have a lower straight portion with an upper circular extension as shown in Figs. 2 and 3. While the straight portions of the end plates 26 and 27 are solid throughout their entire breadth the straight portions of the intermediate de-ionizing sheets 31 have a tapered slot 34 which is wide at the bottom and narrows down toward the top. I shall later explain the reasons for providing the tapered slot in the individual de-ionizing sheets. The circular portions of the end plates 26 and 27 and of the individual sheets 31 of the de-ionizing chamber have central holes or openings 35, together with a narrow radial slot 36.

Assuming that the arc current, in the structure of Fig. 1 of the drawing flows in the direction from the left to the right, as indicated by the circle with a cross in Fig. 2, then the field in the lower straight portion of the de-ionizing chamber must have a direction as indicated by arrows 37 in Fig. 2, in order to drive the arc upwardly along the straight portion 38 of the arc path. After the arc reaches the circular part of the de-ionizing structure, I cause it to travel along the closed circular path 33 by providing a radial magnetic field indicated by the arrows 39. Since a magnetic field transverse to an electric arc always moves the arc in a path normal to the lines of force composing that field this radial field causes the arcs between the plates of the de-ionizing structure to travel around it continuously in a circular path as long as such arcs remain in existence. The radial field 39 is obtained by means of suitable exciting coils arranged at intervals between the sheets to give a field of required shape and strength in a manner now to be explained.

In the arrangement shown in Fig. 1 there are two main groups of de-ionizing sheets 41 and 42, each group consisting of (approximately nine) sheets 31. On each group of grids, alternate grids are slotted as indicated in Figs. 2 and 3. These slots function to prevent eddy-currents. They are furthermore staggered to prevent a continuous path for the series arcs to combine and form a single arc. Between the left hand sheet of group 41 and the left hand arc terminal plate 27 there is provided a radial field coil 43 which is connected to a special plate 44 adjacent the end plate 27 and to a similar plate 44 adjacent the nearest de-ionizing sheet of the group 41. Member 44 is of the form shown in Fig. 4. As will be seen this member consists essentially of a plate 31 with a gap 45 interposed at the middle thereof. As will be explained in more detail later this arrangement of plates 44 together with cooperating plates 53 causes the arc current to flow through coil 43. With the current in the coil 43 flowing in the direction indicated by the arrow, a radial magnetic field will be produced in the narrow spaces between the de-ionizing sheets of the group 41 the dotted lines 46 indicating the direction and distribution in space of this flux.

In order to provide the radial field for the five right-hand sheets of the de-ionizing group 41 and the five left-hand sheets of group 42, I connect between a member 44 adjacent the right hand sheet of the first group and a similar mem-

ber 44 adjacent the left hand sheet of the second de-ionizing group coils 47 inducing in the spaces between the respective sheets the radial fluxes as indicated by the dotted flux lines 48. A coil 49 disposed to the right of the de-ionizing group which is connected in the same manner as the left hand coil 43 of the de-ionizing group 44. The iron end plates 26 and 27 provide return paths for the magnetic flux set up by coils 43 and 49.

An iron through bolt 51, hollow and with longitudinal slots 52 in its walls to minimize eddy currents, provides an axial path of low reluctances for these fluxes.

Since the radial magnetic field in group 41 is opposite in direction to that in group 42, the arcs in these two members rotate in opposite directions about the central axis.

It is obvious that the de-ionizing structure may comprise as many grid sections as may be appropriate to the circuit being broken.

In these portions of the de-ionizing chamber where the circular portion of the structure is occupied by the exciting coils 43, 47 and 49, the de-ionizing sheets consist of only the straight lower extensions as 53 shown in Fig. 5 of the drawings. Three sections 54, 55 and 56 of such short grids, are provided in the structure below the three sets of circular field exciting coils 43, 47 and 49 respectively.

Enough of the structure of my circuit interrupter has now been described so that the way in which it operates in extinguishing the arc may be understood. The description of certain structural details of practical importance, but the consideration of which would only complicate the exposition of the arc interrupting process, may with advantage be deferred until this has been done.

It will be clear upon a moment's consideration that the tapered slots in the grids 31, 44 and 53 aline, when these are assembled into a de-ionizing unit as above described, to form a groove in the resulting structure which may be roughly described as V-shaped. The reason for providing this V-shaped groove will now be explained.

The production of cold cathode arcs as the means of transferring the current path to the de-ionizing structure requires, as a principal condition, that the arc current should be concentrated in an extremely small cross-sectional area. One object of this V-shaped groove is to bring about this condition. As the arc is driven upwards from the end members 22 and 23 above-described by the field of magnet 24 its current flows through a relatively large cross-section at comparatively low current density therein. The wide mouth at the base of the V-shaped groove permits this arc to enter without difficulty. As the magnetic field forces the arc upward the V-shaped groove gradually contracts the cross-sectional area of the conductive path of the arc this effect being due, probably to the de-ionizing effect of the metal strips constituting the side walls of the groove. As the cross-sectional area of the arc is thus gradually constricted while it is being blown upward the current density therein becomes greater and greater, and the local temperature in the core of the arc correspondingly increases. The potential gradient of the arc rises at the same time. In consequence of this by the time the arc has been forced to the apex of the V-shaped groove the current flow therein is highly concentrated and the voltage gradient available to force it to transfer to the narrow gaps between the de-ionizing plates has simultaneously risen.

It has been found that by properly proportioning the taper of the groove and the number of plates relative to the line voltage and current to be interrupted the arc may be made to transfer readily to the space between the plates and there to operate as a series of cool cathode arcs when kept in motion by means such as the magnetic field herein described.

This increase of current density and of voltage gradient has obviously been gradual throughout the movement of the arc, up the tapering groove and the arc is therefore caused to break up into a series of short arcs running between the de-ionizing plates smoothly and without any abrupt transition in its electrical condition. Not only does this avoidance of an abrupt transition facilitate the transfer of the arc to the cool-cathode mode of operation, but it is of great value in virtue of the fact that it also minimizes electrical disturbances and the production of transients on the circuits on which current flow is being interrupted.

Tracing in detail the steps in the process of arc interruption in my circuit breaker, the movement of the brush member 3 to the right interrupts the direct contact between members 1 and 2 and causes current to flow through winding 11 of the blowout magnet 24 to end plate 27, thence through arcing contacts 7 and 8 to contact arm 6 and conductor 9. As the contact arm 6 moves further to the right an arc is drawn between contacts 7 and 8 until the left hand end of the member 7 passes the lower end of plate 23. The right hand end of the arc then transfers to end plate 23 and the arc is driven upward by the influence of the magnetic field between pole faces 25 until it reaches the mouth of the V-shaped groove in the de-ionizing structure 21. It continues to rise under the application of this magnetic field, and the tapering groove gradually constricts the cross section of the arc, simultaneously increasing its voltage gradient, as has already been described.

By the time the arc has reached the apex of the V-shaped groove the temperature of the arc core and with it the density of ionization has been raised by this current concentration to such a degree that the currents which flow to the metal plates are great enough to cause thermal ionization of the gas adjacent to the cold metal plates. Under these conditions the cold cathode discharge to which I have previously alluded becomes possible between the plates 31 of the de-ionizing structure 21, and the arc readily transfers under the influence of the magnetic field to the space between the plates above the apex of the V-shaped groove.

As soon as the arc has risen under the impulse of the magnet 24, along the straight portion of the chute to a point above gap 45 in members 44, the arc sections in the plate groups 54, 55 and 56, are shunted by the low resistance coils 43, 47 and 49, so that the current diverts from these arc sections into these coils. The gaps 45 obviously assist such a transfer. By the time the arc has reached the top of the straight portion of the chute, the current in the arc sections 54, 55 and 56 has reduced to zero, the coils 43, 47 and 49 carrying all the current and producing the radial magnetic field which drives the remaining arc sections round and round the circular portion of the chute.

During all the time that it is in contact with the metal plates of the de-ionizing structure, energy in the form of heat is being rapidly abstracted from the arc. Due to the rapidity with which it traverses the metal plates no one spot on these

ever becomes heated to a sufficiently high degree to emit an appreciable number of electrons or to melt.

It is readily seen from what has been said above that in a de-ionizing structure comprising merely a series of metal plates, without the tapered slots which have been provided, theory and experiment indicate that the transition of the arc from its initial continuous condition into a series of cold-cathode arcs between metal plates would be difficult, and in many cases practically impossible. Such has in fact been found to be the case and for many purposes de-ionizing structures without such a V-shaped groove as I have described are so ineffective as to be wholly inoperative for the purposes they are required to serve. The presence of this groove is therefore a material addition to my invention. The explanation of its function given above is believed to be correct, but independent of its correctness experience has proved beyond question the much greater effectiveness in practice of de-ionizing structures provided with such grooves.

As to the proportioning of my de-ionizing structure, I have found that there should be such a number of gaps between the de-ionizing plates that not more than 300 volts instantaneous should be impressed across each gap when the full line potential appears across the terminals of the open breaker.

The choice of this 300 volt limit is based upon the well-known experimental fact that in the absence of a hot cathode, or a hot layer of gas next to the cathode, an electrical discharge takes the form of a glow, which requires at least 300 volts to be maintained for the case of copper electrodes in air.

In actual practice, to allow a factor of safety and provide for possible effects of line surges, I provide one gap for each 100 to 200 r. m. s. volts of line potential.

With regard to the design of the de-ionizing structure it may be said that the de-ionizing effect is in general greater the greater the number of plates per unit of length of the structure. Economy of space therefore, calls for as close a spacing of plates as possible. On the other hand, considerations of mechanical rigidity, difficulties of manufacture and the danger of foreign substances finding lodgement between the plates and bridging the gaps, set a limitation on the closeness with which the plates may be spaced. One sixteenth of an inch has been chosen as a compromise between these conflicting requirements.

As to the thickness of plates, it should be so chosen that the heat stored in the plates in an operation of the switch will not raise their temperature unduly. Calculations show that it is only a thin skin of metal on the surface of each plate that can be effective in absorbing heat each time the arc passes a given point, so that thickness of plate has little influence on the speed with which it is necessary to give the arc to prevent melting of the plates. Here again mechanical and manufacturing considerations are really the controlling factor in determining the selection of a thickness of one sixteenth of an inch for the plates 31. Good heat conductivity and a high specific heat, are important in fixing the permissible smallest speed of the arc, and so lead to the use of copper as material for the plates.

The contour to be given to the tapering slots above described in the de-ionizing plates depends upon many factors, such as the amount of cur-

rent to be interrupted, the strength of the blow-out magnet and the dynamics of air flow in the structure. In general we may say that the taper must be sufficiently gradual. For a large
 5 current a gradual taper is necessary, although for small currents a more blunt taper is permissible. At each state in the motion of the arc in the slot, the alternative is presented to it of standing still and being subjected to the blast of
 10 air due to the action of the magnetic field, or of moving with the air and being subjected to the increased constriction of the slot. Either alternative causes its voltage to be raised and evidently it will follow that alternative which will
 15 give the least rise in voltage. The slot should therefore be so designed that the rise in voltage in the arc due to the increasing taper, is less than the rise in voltage which would be produced if the arc stood still and was subjected to the air blast produced by the magnetic field. On
 20 a circuit breaker rated to interrupt 10,000 amperes at 2500 volts on a 60 cycle circuit, for example, a slot which doubles in width for every one half an inch of length has been found to be
 25 effective.

The general mode of operation of my circuit breaker having now been described, certain practical details of construction shown in Figs. 6 and 7 of the drawings will be described. As previously stated, the de-ionizing plates 31 are assembled in units of 9 plates, each pair of plates being separated by annular washers of fish paper, one washer separating the outer edge of the plates and the other washer separating the plates
 30 at their inner edge. At each side of each unit of 9 plates are assembled the magnetizing coils 43, 47 and 49 already described. As many sets of these units as are necessary, in consideration of the line voltage, are assembled on a cylindrical core 57 of some suitable insulating material, such as fiber impregnated with a phenolic condensation resin. This whole assembly of plates, coils
 40 and washers is pressed firmly together into a rigid unit between end members 26 and 27 by means of through bolt 51 and insulating collar 58. This construction is clearly shown in Fig. 7. A shell 59 of insulating material is arranged so as to enclose the sides of the entire unit and may extend beyond the end plate 26 for protective purposes.
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The lower portions of the shell 59 fit closely between pole shoes 25 and form the side-walls of the chute or chamber in which the arc is drawn between arcing contacts 7 and 8 as previously
 55 described. To protect them from the heat of the arc, the side walls are lined with plates 61 of soap-stone. The arc causes a slight vaporization of the metal of arc-shoe 7 and, to prevent the condensation of this metal from forming a continuous conducting coating across the face of the soapstone between arc horns 22 and 23, narrow deep grooves may be provided in the plates 61. Plates 61 are bolted to members 22 and 23 and fit snugly between the sides of shell 59. An arm 62 electrically connects arc horn 23 with main contact member 2.
 60

The de-ionizing structure proper thus constituted is provided on each side of the arcing chamber with iron pole shoes 25 which fit tightly
 70 against the core of the blowout magnet 24. This magnet is energized by the windings 11 which are insulated from core 24 by micarta collars 63.

The entire de-ionizing structure thus constructed is supported, on the framework which supports the main contacts 1, 2 and the operating
 75

levers, a bracket 64, bolted to end plate 27, provided with an insulator at 65.

The structure and details of the mechanism operating the main contacts may be in accordance with standard practice in circuit-breaker
 80 design and require no detailed description.

While in accordance with the patent statutes I have given the foregoing details of a practical embodiment of my invention, it is to be understood that many of these are merely illustrative and that variations of their precise form will be desirable in designing circuit breakers for other voltages and currents than those which I have specified above.
 85

It will also be understood that many features which I have above described are adjunctive to each other, and that it is possible to obtain circuit interrupting means satisfactory for many purposes by the employment of only one of these various devices. Thus, while I provide the above-described V-shaped groove in the de-ionizing structure which facilitates the transfer of the arc to the retracing path in the upper part of the de-ionizing chamber it will be clear that the use of such an annular path to de-ionize the arc is not dependent upon the presence of a V-shaped groove. In many instances it will be possible to cause the arc to transfer to operation between the de-ionizing plates, and to thus utilize the expedient of driving the arc about an annular path, even although no such V-shaped groove is part of the device.
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 95
 100

Also, the provision of the slots in the soap-stone walls of the chute is a valuable feature which co-operates with, but is not limited to, use in connection with the V-shaped groove or the de-ionizing structure generally.
 110

Where a claim states that a plate is symmetrical, it means that it is possible to draw a line on the face of the plate dividing it into two halves which are substantially alike in external contour.
 115

The principles which have been embodied in my circuit breaker are applicable to many other purposes than those of circuit interruption. I, therefore, desire that the language of the accompanying claims shall be accorded the broadest reasonable construction and that my invention be limited solely by what is explicitly stated in the claims and by the prior art.
 120

I claim as my invention:

1. Arc-extinguishing means comprising a plurality of spaced conducting plates providing an arc path having a looped portion and said plates having tapered notches, the lower portion of said notches having central axes substantially radial relative to said looped portions, and means to produce a radial magnetic field near said plates concentric with said looped portion of the arc path.
 125
 130

2. Arc-extinguishing means comprising a plurality of spaced conducting plates providing a circular arc path and a portion projecting from said circular arc path and having a tapered groove, the lower portion of which is radial to said arc path, and means to produce a radial magnetic field between said plates concentric with said circular arc path.
 135
 140

3. Arc-extinguishing means comprising a plurality of spaced conducting plates having a circular portion and a straight portion projecting radially from said circular portion, means to produce a radial magnetic field concentric with said circular portion and a magnetic field transverse to said straight portion between said plates.
 145
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4. Arc-extinguishing means comprising a plurality of spaced grids, each comprising a straight portion and a looped portion symmetrically related thereto and means to produce a radial magnetic field between said grids concentric with the looped portion thereof.
5. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, means to abstract energy through the sides of said arc comprising a series of spaced plates having tapered slots aligned to produce a V-shaped groove and de-ionizing means comprising a series of spaced symmetrical plates each having a looped portion positioned with their axes of symmetry aligned with the axis of symmetry of said groove.
6. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, de-ionizing means comprising a series of spaced metallic grids, each comprising a straight portion and a looped portion symmetrically related to said straight portion, and means for compelling said arc to break up into a plurality of shorter arcs between said plates, and means for compelling some of said arcs to travel clockwise and others to travel counter-clockwise about said looped portions.
7. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, de-ionizing means comprising a series of spaced metallic grids each comprising a looped portion and a radially extending portion at least one of said grids being provided for each 300 volts of line voltage, and means for compelling said arc to break up into a plurality of shorter arcs between said plates, and means for compelling some of said arcs to travel clockwise and others to travel counter-clockwise about said looped portions.
8. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, de-ionizing means comprising a series of metallic grids each comprising a looped portion and a radially extending portion spaced not over $\frac{1}{8}$ of an inch apart, and means for compelling said arc to break up into a plurality of shorter arcs between said plates, and means for compelling some of said arcs to travel clockwise and others to travel counter-clockwise about said looped portions.
9. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, de-ionizing means comprising a series of grids of sheet metal not over $\frac{1}{8}$ of an inch thick and spaced not over $\frac{1}{8}$ of an inch apart and each comprising a looped portion and a radially extending portion, and means for compelling said arc to break up into a plurality of shorter arcs between said plates, and means for compelling some of said arcs to travel clockwise and others to travel counter-clockwise about said looped portions.
10. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, a de-ionizing structure comprising a plurality of groups of symmetrical plates positioned in the path of the arc drawn between said pair of members and a magnetizing coil between each pair of said groups.
11. A structure adapted to interrupt an electric discharge through a gaseous medium comprising a magnetizing coil and a group of spaced metallic plates adjacent each face thereof, each of said groups being in the path of said electric discharge.
12. A structure adapted to interrupt an electric discharge through a gaseous medium comprising a plurality of groups of spaced conducting plates, a single magnetizing coil between each of said groups, alternate coils being disposed so that their adjacent ends are of like polarity.
13. A structure adapted to interrupt an electric discharge through a gaseous medium comprising three or more groups of spaced grids each comprising a looped portion, a single magnetizing coil between each pair of said groups, alternate coils being disposed so that their adjacent faces are of like polarity.
14. A structure adapted to interrupt an arc through a gaseous medium comprising a plurality of groups of spaced conducting plates adapted to provide reentrant paths for said arc to travel and means to produce a magnetic field substantially normal to the arc path which shall have opposite polarities in alternate groups of said plates.
15. A structure adapted to interrupt an arc through a gaseous medium comprising a plurality of groups of symmetrical conducting plates spaced not over $\frac{1}{8}$ of an inch apart adapted to provide annular paths for said arc to travel and means to produce radial magnetic fields of opposite polarities in alternate groups of said plates.
16. A structure adapted to interrupt an arc through a gaseous medium comprising a plurality of groups of conducting plates not over $\frac{1}{8}$ of an inch thick and spaced not over $\frac{1}{8}$ of an inch apart adapted to provide reentrant paths for said arc to travel and means to produce a magnetic field substantially normal to the arc path which shall have opposite polarities in alternate groups of said plates.
17. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, means to abstract energy through the sides of said arc comprising a series of spaced plates having tapered slots aligned to form a V-shaped groove, de-ionizing means comprising a plurality of groups of spaced symmetrical plates positioned with their axes of symmetry aligned with the axis of symmetry of said groove and means to produce radial magnetic fields of opposite polarities in alternate groups of said plates.
18. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, means to abstract energy through the sides of said arc comprising a series of spaced plates having tapered slots aligned to form a V-shaped groove, de-ionizing means comprising a plurality of groups of spaced symmetrical plates positioned with their axes of symmetry aligned with the axis of symmetry of said groove and a magnetizing coil between each of said groups.
19. Circuit-interrupting means comprising a pair of members adapted to draw an arc, means to abstract energy from the sides of said arc comprising a series of spaced metallic plates having tapered slots aligned to form a V-shaped groove, and a de-ionizing structure comprising three or more groups of spaced conducting plates adapted to provide a retracting path to be traversed by said arc, alternate groups being spaced apart by a single magnetizing coil so disposed that their adjacent faces are of like magnetic polarity.
20. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, means to abstract energy through the sides of said arc comprising a series of spaced plates having tapered slots aligned to form a tapered groove, de-ionizing means comprising a plurality of groups of spaced plates and means

to produce magnetic lines of flux between said plates of opposite sense in alternate groups.

21. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, means to abstract energy through the sides of said arc comprising a series of spaced plates having tapered slots alined to form a V-shaped groove, means to drive said arc into said groove, de-ionizing means comprising a plurality of groups of spaced symmetrical plates positioned with their axes of symmetry alined with the axis of symmetry of said groove, and means to produce radial magnetic fields of opposite polarities in alternate groups of said plates.

22. Circuit-interrupting means comprising a pair of members between which an arc may be drawn, means to abstract energy through the sides of said arc comprising a series of spaced plates having tapered slots alined to form a V-shaped groove, means to drive said arc into said groove, de-ionizing means comprising a plurality of groups of spaced plates having a portion providing an annular arc path positioned with the axis of the lower portion of said groove radial to said annular arc path and means to produce radial magnetic fields of opposite polarities in alternate groups of said plates.

23. In arc-extinguishing means a plurality of spaced conducting plates having a looped portion and a straight portion symmetrically placed relative to said loop, and means for compelling said arc to break up into a plurality of shorter arcs between said plates, and means for compelling some of said arcs to travel clockwise and others to travel counter-clockwise about said looped portions.

24. An arc-extinguishing device having a plurality of walls forming looped chambers and a magnetic field so disposed as to have radial lines of flux in said chambers and that the arcs in adjacent chambers are caused to rotate in opposite directions.

25. An arc-extinguishing structure comprising means to produce a plurality of arcs in series and a magnetic system of such form that one closed line of flux produces a force on two series arcs.

26. Circuit-interrupting means comprising means to establish an arc, a de-ionizing structure comprising a plurality of groups of looped plates in the path of said arc and a single magnetizing coil between each pair of said groups.

27. An arc-extinguishing device comprising a plurality of spaced members into which an arc may be moved and means for establishing a magnetic field having radial lines of flux between said members, the sense of the lines of flux between some of said members being opposite to that between other of said members.

28. An arc-extinguishing device comprising a magnetizing coil and a plurality of spaced members into which an arc may be moved, a group of said members being adjacent each face of said coil, the magnetic field set up by said coil having radial lines of flux between said members, said lines of flux being of opposite sense in each group.

29. The method of extinguishing an arc which comprises separating the arc into a number of arcs and in moving one of said arcs in a direction different from another of said arcs.

30. The method of extinguishing an arc which comprises drawing said arc between a pair of members, moving said arc through a fluid medium, separating said arc into a plurality of arcs and moving said plurality of arcs in a curved

path, the direction of movement of one of said arcs being opposite to that of another of said arcs.

31. The method of extinguishing an arc which comprises separating the arc into a plurality of shorter arcs, and moving said shorter arcs over a recurrent path, the direction of rotation of some of said arcs being opposite to that of other of said arcs.

32. The method of extinguishing an arc which comprises drawing said arc between a pair of members, moving said arc through a fluid medium, extracting energy from the sides of said arc as it is being moved, separating said arc into a plurality of shorter arcs and moving said shorter of arcs in a curved path, the direction of movement of some of said shorter arcs being opposite to that of other of said arcs.

33. The method of extinguishing an arc which comprises concentrating said arc to a small cross-section of high current density, separating said concentrated arc into a plurality of shorter arcs and rotating said shorter arcs over a recurrent path, the direction of rotation of some of said arcs being opposite to that of other of said arcs.

34. The method of extinguishing an arc which comprises concentrating the arc to a small cross-section, extracting energy from the sides thereof, separating said concentrated arc into a plurality of short arcs and moving some of said short arcs in a different direction from other of said short arcs.

35. The method of extinguishing an arc which comprises separating the arc into a plurality of cold-cathode arcs and moving said cold-cathode arcs over a recurrent path, the direction of motion of some of said arcs being opposite to that of other of said arcs.

36. The method of extinguishing an arc which comprises concentrating the arc to a small cross-section, separating the concentrated arc into a plurality of cold-cathode arcs and rotating said cold-cathode arcs, the direction of rotation of some of said arcs being opposite to that of other of said arcs.

37. The method of extinguishing an arc which comprises drawing said arc between a pair of members, moving said arc through a fluid medium, concentrating said arc to a small cross-section of high current density and extracting energy therefrom as it is being moved, separating said arc into a plurality of short cold-cathode arcs, and de-ionizing said cold-cathode arcs by rotation thereof, the direction of rotation of some of said arcs being opposite to that of other of said arcs.

38. An arc-extinguishing device comprising a plurality of spaced members, means for establishing a magnetic field about said members, and means for securing said spaced members together comprising a hollow member of magnetic material having slots therein.

39. An arc-extinguishing device comprising a plurality of spaced members, a magnetizing coil, and a hollow member of magnetic material having slots therein and extending through said coil and said spaced members in the path of the flux set up by said coil.

40. An arc-extinguishing device comprising a plurality of groups of spaced members, a magnetizing coil between each of said groups with adjacent coils of opposite polarity, and a bolt of magnetic material extending through said coils and spaced members, said bolt being hollow and having longitudinal slots therein.

41. An arc-extinguishing device comprising a plurality of spaced members, and means for establishing a magnetic field about said members, said magnetizing means being connected between two members in the path of the arc so that said magnetizing member will be energized by the arc current to set up a field about some of said members of opposite sense to that about other of said members.
42. An arc-extinguishing device comprising a plurality of groups of spaced conducting plates, and a magnetizing coil connected between two of said plates so that there is set up a magnetic field of opposite sense about alternate groups.
43. An arc-extinguishing device comprising a plurality of spaced conducting plates having a looped portion and a straight portion, a magnetizing coil connected between two of said plates so that the magnetic field set up between some of said plates will be of opposite sense to that between other of said plates, each of the plates to which the coil is connected having its straight portion spaced from its looped portion.
44. An arc-extinguishing device comprising a plurality of groups of spaced conducting plates having a looped portion and a straight portion, a magnetizing coil between each of said groups and connected to the plates adjacent thereto so that the adjacent faces of the coils are of opposite polarity, each of the plates to which said coils are connected having its straight portion insulated from its looped portion.
45. In an arc extinguishing structure, a plurality of conducting plates having tapered grooves therein, a magnetizing coil for moving the arc among said plates, said coil having its terminals connected to a spaced pair of said plates, one of said plates to which the coil is connected having a gap therein between the top of its slot and the point of connection of the coil.
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