PERFORATED ARC CHUTE BARRIER PLATES
FOR CIRCUIT INTERRUPTER

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This invention relates to circuit interrupting devices and more particularly to arc extinguishing means for use in connection therewith.

In construction and operation of alternating current circuit interrupters, it is frequently necessary to provide means for extinguishing quickly the arc which is drawn between separable arcing contacts. This arc is usually blown by blowout means, such as a magnetic blowout coil or an air blast into an arc chute which is arranged to quench the arc by lengthening it, cooling it, or a combination of both.

Arc chutes having spaced insulting plates to lengthen the arc or squeeze the arc into narrow slots have been used to rapidly increase the arc voltage, decrease the arc current and greatly improve the power factor, thereby facilitating interruption of the arc at a current zero. However, it has been found in many cases that the arc voltage developed by the arc chute was not the most favorable for interrupting the power circuit.

The geometry of the arc chute determines the arc voltage which will be developed for circuit interrupting purposes. This arc voltage can be expressed as a percentage of the line voltage and therefore is not limited to any particular voltage class of breaker.

Therefore, in accordance with the invention claimed an arc chute having a predetermined geometrical configuration is provided adjacent a pair of arcing contacts for receiving the arc at one end thereof and exhausting the deionized arcing products at the other end thereof. The arc chute employs an arc extinguishing device comprising a plurality of spaced insulting plates arranged to extend longitudinally of the axis of the arc chute and providing a slot adjacent the arcing contacts to form an arc passage. The slot may be arranged to gradually restrict the arc until it is reduced to a predetermined cross sectional area at the closed end of the slot to convert the arc from a relatively high current arc having a relatively low current arc having a relatively high arc voltage, and a high arc voltage. Thus the arc current is limited until the next passage of the current through the zero point of its cycle, at which point it should become extinguished by failure to reignite.

A number of the plates are provided with a plurality of spaced apertures, all having a predetermined cross sectional area substantially equal to, or smaller than, the cross sectional area of the arc at the closed end of the slot, for providing a plurality of secondary arc passages for the constricted arc. The particular cross sectional area of the apertures is directly related to the thickness of the barrier plates, plate spacing and voltage gradient to be interrupted. The apertures may be arranged in a variety of patterns to lengthen and cool the arc but they must be of a certain predetermined cross sectional area to quickly and effectively extinguish the arc.

It is, therefore, one object of the present invention to provide a new and improved arc interrupting device in which the arc is constricted in a predetermined manner as it passes through an arc chute.

Another object of this invention is to provide a new and improved arc extinguishing device in which a relatively high current arc having a relatively low arc voltage is transformed into a relatively low current arc having a relatively high arc voltage to rapidly and efficiently extinguish the arc.

A further object of this invention is to provide a new and improved arc extinguishing device in which the arc is constricted in a predetermined manner before it is driven through a plurality of apertures of a predetermined cross sectional area to rapidly lengthen, cool and extinguish the arc.

A still further object of this invention is to provide an arc chute which controls the arc current and arc voltage to rapidly interrupt the arc in a manner heretofore unknown.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 is a view in cross section, of a magnetic blowout type circuit breaker employing the present invention;

Fig. 2 is an exploded view of one group of the stack of barrier plates illustrated in Fig. 1;

Fig. 3 is an end view of the group of barrier plates illustrated in Fig. 2;

Fig. 4 is an exploded view of a modification of the barrier plate assembly illustrated in Fig. 2;

Fig. 5 is an end view of the group of barrier plates illustrated in Fig. 4;

Fig. 6 is a graph of the voltage gradient characteristic of an air magnetic circuit breaker arc chute vs. diameter of round holes in the barriers;

Fig. 7 is an exploded view of another modification of the barrier plate assembly illustrated in Fig. 2;

Fig. 8 is an end view of the group of barrier plates illustrated in Fig. 7; and

Fig. 9 is an exploded view of a modified group of the barrier plates illustrated in Fig. 7.

Referring more particularly to the drawings by characters of reference, Fig. 1 illustrates a magnetic blowout type of circuit breaker including as elements thereof a pair of terminal studs 16 and 17 for connecting the circuit breaker to line conductors (not shown). Although in general, circuit breakers of the type considered in Fig. 1 are provided with a plurality of similar pole structures, only one for each phase of a polyphase electric circuit, only one such pole structure is shown in the drawing and the circuit breaker will be described in detail as if it was of the single pole unit type.

The circuit interrupter or breaker in Fig. 1 comprises essentially means for opening the circuit to form the interrupting arc and an arc extinguishing structure. Specifically, the circuit opening means comprises a fixed contact assembly supported on an insulator 15 and including a current carrying contact 18, tertiary contacts 19, and arcing contact 20, cooperating with a moveable contact 21 comprising current carrying, tertiary and arcing contact combined in a single structure. Arcing contact 21 is mounted on a lever 22 which is pivotally mounted at 23 on an extension 24 of the circuit breaker stud 16 and is operated by means of a reciprocally movable rod 25. The operating rod 25 is suitably connected to an actuating medium (not shown) for operating the moveable contact between closed and open circuit positions. Fig. 1 illustrates the moveable contact 21 in closed position.

The arcing contacts are electrically connected to the lower ends of terminal studs 16 and 17. Accordingly, when the breaker is connected in series in a power circuit and the arcing contacts are separated, an arc may be initiated across the gap formed between the contacts.

For the purpose of interrupting this power arc, an arc extinguishing structure, such as an arc chute 30, may be mounted so as to receive the power arc which is
under the influence of a magnetic blowout means. The arc chute preferably is disposed directly above the arcing contacts, as shown, when the blowout means act upward, but may be mounted in any other suitable location when the blowout means act in other directions. The switch or arcing contacts and the magnetic blowout structure can assume any preferred form so that a brief description thereof will be sufficient. The magnetic blowout means may comprise a core 31, poles 32, and a coil 33. The latter is electrically connected to the terminal stud 17 and, through a strap 28, to arcing contacts 20 and to a metallic arc runner 34 so that the arc current (as the arc travels along the runner) flows through the blowout coil in a manner well known in the art.

Normally the current is carried in the closed circuit position of the breaker by contact 21 and the spring biased contact 18. While the movable arcing contact 21 is actuated to open circuit position, current is shunted from fixed contact 18 first to fixed contact 19 and then to fixed arcing contact 20. As the arc is drawn by the movable arcing contact 21, the arc terminal on arcing contact 20 is transferred to arc runner 34 which is adjacent to and connected to contact 20 but separated therefrom by a gap 29. The arc terminal is driven across gap 29 to reach the flat plate of arc runner 34. When the movable arcing contact 21 approaches a predetermined position in its opening stroke, the other arc terminal transfers from the movable arcing contact 21 to an arc runner 35 which directs the arc into the arc chute 30. When the movable arcing contact 21 parts from contact 19, the flow of current is transferred from contact 19 to contacts 20 through the blowout coil 33. The movable arcing contact 21 subsequently parts from contact 20 to draw an arc. Accordingly, the blowout coil is already energized at the inception of the arc interruption to influence the arc in a well known manner, i.e., to drive it into the arc chute in an expanding spiral. It will be apparent to one skilled in the art that the blowout field can be utilized in the most efficient manner by disposing the iron poles 32 so as to cooperate with the blowout coil in the conventional manner outside of the arc chute.

In accordance with the invention claimed, arc chute 30 is provided with a plurality of slotted spaced insulating barrier plates 36 and 37 (more clearly shown in Figs. 2 and 3) arranged to extend longitudinally of the axis of arc chute 30. The most advantageous values for the thickness and the spacing of the barrier plates are determined by experiment. It has been found that the barrier plates are preferably 0.005 of the distance to 0.004 thick and spaced 0.002 apart in circuits breakers for interrupting alternating currents up to 50,000 amperes at 2,500 volts. Each of barrier plates 36 and 37 is provided with a wide mouth V-shaped slot 35 arranged adjacent the arc contacts to form an arc passage 39. The closed end of slot 38 is formed as a narrow elongated U-shaped portion. These barrier plates are arranged in a plurality of groups which restrict the arc as it moves toward the exhaust end of the arc chute. Each group may comprise a first barrier plate 36 and a second barrier plate 37.

Barrier plate 36 is provided with a cluster of spaced apertures of substantially equal cross sectional area arranged adjacent the closed end of slot 38 and extending in a straight line on one side of the axis of symmetry of the slot toward the exhaust end of arc chute 30. Barrier plate 37 is provided with a cluster of spaced apertures 42 arranged adjacent the closed end of slot 38 but forming a mirror image of the other barrier plate 36. The barrier plates may be mounted in any other sequence and still remain within the scope of this invention. For example, the barrier plates may be mounted in groups having the following sequence: plates 36, 36, 37, 37.

By arranging the lines of apertures in adjacent plates so that they extend from the slot toward adjacent corners of the barrier plates 36 and 37, a zigzag path may be provided through each row of apertures which restricts and lengthens the arc in the direction of arc movement.

Under normal interrupting conditions an arc is initiated immediately upon separation of the arcing contacts 20 and 21. The terminal of the arc on fixed arcing contact 20 is driven over arc runner 34 by the magnetic blowout means and the thermal effect of the arc. As movable arcing contact 21 nears its fully open position the other terminal of the arc is moved from contact 21 to arc runner 35 and is also driven by the blowout means and the thermal effect of the arc toward the exhaust end of arc chute 30.

As the arc terminals move along the arc runners 34 and 35 toward the exhaust end of arc chute 30, the arc is driven into passage 39 formed by the slots 38 of the barrier plates.

The arc rises in passage 39 under the influence of the blowout means and the thermal effect of the arc and is constricted by the inverted V-shaped slot 38. The sides of slot 38 are arranged to effect sufficient arc constriction to convert high current arcs into lower current arcs. The narrow U-shaped slot portion retains the arc's constricted size during movement of the arc through such portion. This pretreatment of the arc results in a higher arc voltage. High arc voltage is a relative term, but in this disclosure it means a voltage in excess of thirty percent of the circuit voltage of the line being interrupted. Voltages substantially above thirty percent of the circuit or line voltage are desirable because they result in reduced arc energy. High arc voltage may be achieved in the barrier plate slot, but if not it will be achieved in the plurality of apertures arranged adjacent the closed end of the slot.

Apertures 42, arranged adjacent the closed end of slots 38, are provided to effect progressive constriction of the arc because of the size of the circumference or cross sectional area, which is substantially equal or less than the circumference or cross sectional area of the preconstricted arc. The particular geometrical configuration of the apertures in a plate and adjacent plates may further constrict the arc in its passage through the arc chute. The current may flow through a barrier plate 36 or 37 through one of apertures 42 thereof in the form of a single arc, or the flow may be divided into a plurality of parallel arcs threaded through a plurality of apertures 42.

The luminous portion of the arc, when arrested at the narrow slot end, has a definite shape which can be photographed by means of the high speed motion picture camera and measured. By measuring the length of the horizontal diameter, and the length of the vertical diameter of the arc one may calculate approximately the circumference of the arc.

Although slots 38 have been described as arc constricting slots, nevertheless slots 38 may be so dimensioned that the arc is not constricted in the slots and is constricted in the apertures immediately adjacent the closed end of the slot.

In accordance with the invention claimed apertures 42 are all of substantially the same size, that is, the critical size determined by the size of the filamentary or preconstricted arc in slots 38 and the thickness of the barrier plates 36 and 37.

Sufficienly extensive study of the use of holes in barrier plates of an air magnetic circuit breaker arc chute has been made to indicate that there is a maximum and a minimum diameter of hole for any particular thickness of barrier plate of the first barrier plate 36.

When speaking of a single aperture or hole or a plurality of apertures or holes in general, the criterion of hole size, or hole size with respect to plate thickness can best be expressed in terms of voltage gradient of the arc.

The holes are primarily a means of establishing a value of nonlinear resistance which is effective in developing a value of arc voltage during the period of power current flow in the chute, and, by the same token, is effective in
controlling the leakage current following the interruption of power current flow. By inspection it can be easily realized that if a hole diameter is increased to the point where it becomes very large with respect to the diameter of the core of an arc and its surrounding field of ionization, the effect on the voltage gradient of the arc in passing the arc through that hole approaches the effect in free air. By the same token, if the diameter of the hole is reduced to the point where it becomes very small with respect to the plate thickness and approaches zero, it becomes increasingly difficult and finally impossible to pass the arc through the hole. In both limits, therefore, the voltage gradient is the same as in free air.

When the diameter of the hole is varied through a range of values within the maximum limit where effect on the voltage gradient is first detectable and the minimum limit where an arc cannot be caused to burn in the hole, it can be shown that there is an optimum diameter which will provide the maximum voltage gradient. A range of values of diameters therefore can be obtained which will produce a voltage gradient of sufficient value to permit developing the maximum arc voltage within the practical limitations of a given arc chute structure when used with a given circuit voltage. The critical hole diameter for any particular plate thickness and the values immediately surrounding the critical value show a marked increase in the voltage gradient for a small change in hole diameter. Fig. 6 graphically illustrates the voltage gradient for various hole diameters.

Test values of one type of arc chute employing a spaced stack of $\frac{3}{4}''$ barrier plates having a particular hole and slot configuration were used to obtain the data for plotting the curves shown in Fig. 6. Arcs burning in air at atmospheric pressure have a very low gradient and are indicated as the extremities of the curve. The arcs forced into the confinement of slots have a slightly greater gradient as at point 50 on the curve (the slot provides confinement in all but one side and in that respect approaches a hole). The arcs passing through $\frac{1}{4}''$ holes have a still greater increase in voltage gradient as at point 51 on the curve, and arcs being passed through $\frac{3}{8}''$ holes show substantial increase in gradient as represented at points 52 or 53 on the curve. In causing very high currents to burn repeatedly through holes of $\frac{3}{8}''$ diameter in this particular structure, I have increased the hole diameter of $\frac{3}{8}''$. The change in voltage gradient between $\frac{3}{8}''$ and $\frac{5}{8}''$ diameter holes was too small for measurement. I believe that this may indicate a decrease in slope in the vicinity of point 53 of the curve for the particular material and thickness of plate, hole geometry and test conditions. These values may be on either side of the critical value represented by point 54 on the curve for maximum voltage gradient for the particular thickness of plate and geometry tested.

From tests results obtained on several geometries of arc chutes used on air magnetic circuit breakers for interrupting arc currents up to 50,000 amperes it was determined that the critical size of aperture or hole was found to be within the range of $\frac{3}{8}''$ of an inch diameter to $\frac{5}{8}''$ of an inch in diameter (or equivalent area) or from one-quarter of the barrier plate thickness to twice the barrier thickness. Another way of defining the aperture or hole diameter was found to be by the sum of the distance between adjacent barrier plates and one barrier plate thickness. The size and arrangement of the apertures or holes may be so chosen that the apertures form effective shielding means for trapping the products of arc ing flowing in a direction substantially parallel to the longitudinal axis of the arc.

Figs. 4 and 5 illustrate a modification of the barrier plate structure shown in Figs. 2 and 3. Barrier plate 50 is a mirror image of barrier plate 61. Apertures 62 formed in barrier plates 60 and 61 are arranged adjacent the closed end of a slot 63 formed by the combination of barrier plates 60 and 61. Apertures 62 effect progressive constriction of the arc because their cross sectional area is substantially the same size as or less than the cross sectional area of the preconstricted arc space formed in barrier plates 60 and 61. Apertures 62 and 64 are modifications of the barrier plates illustrated in Figs. 2 to 5. Plate 40 is provided with a plurality of apertures 43 of a given cross sectional area and a plurality of apertures 44 of a lesser cross sectional area arranged adjacent the closed end of slot 63. Apertures 43 and 44 are illustrated as square but they may have any geometrical configuration which has greater than $(1/16)^{2} \times \frac{3}{4}$ square inches but less than $(3/8)^{2} \times \frac{3}{4}$ square inches.

Plate 41 is provided with a plurality of apertures 43 and 44 arranged adjacent the closed end of slot 45 and are mirror images of plate 40. Plate 46 is provided with only a slot 45 of greater length than the slots in plates 40 and 41.

Fig. 9 illustrates a modification of the sequence of barrier plates illustrated in Figs. 7 and 8 and may be used in combination with similar groups to form the arc chute barrier plate structure.

Although a few embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made wherein without departing from the spirit of the invention or from the scope of the appended claims.

Features disclosed but not claimed herein are claimed in applications Serial No. 180,258 of Julius W. Timmerman, filed August 5, 1950, and Serial No. 209,302 of Julius W. Timmerman, filed February 3, 1951.

It is claimed and desired to secure by Letters Patent:

1. An electric circuit interrupter comprising arcing contacts for initiating an arc and an arc chute for receiving and extinguishing the arc, said chute comprising a plurality of slotted spaced insulating plates arranged to extend longitudinally of the axis of said chute with the slots arranged adjacent the arcing contacts to form an arc passage, each one of said plates being provided with a plurality of apertures of substantially equal cross sectional area arranged in lines diverging from the slot toward one of the corners of the plate near the exhaust end of said chute for providing a plurality of secondary arc passages, each slot comprising a wide mouth V-shaped portion arranged adjacent said arcing contacts for gradually constricting the arc to a predetermined cross sectional area to convert the arc from a relatively high current arc having a relatively low arc voltage to a relatively lower current arc having a relatively high arc voltage and a narrow elongated U-shaped portion adjacent said apertures for retaining the arc's constricted size during its movement through the second portion of said slot, said apertures each having a cross sectional area substantially equal to the cross sectional area of the constricted arc at the closed end of the slot for providing a plurality of secondary arc passages.

2. An electric circuit interrupter comprising arcing contacts for initiating an arc and an arc chute for receiving and extinguishing the arc, said chute comprising a plurality of slotted insulated plates having a predetermined thickness spaced apart from each other a predetermined distance and arranged to extend longitudinally of the axis of said chute with the slots arranged adjacent the arcing contacts to form an arc passage, said slots gradually constricting the arc in a direction normal to the direction of arc movement to a diameter substantially equal to the sum
of said plate thickness and the distance between adjacent plates, a number of said plates being provided with a plurality of apertures of substantially equal cross sectional area arranged adjacent the closed end of said slots, the cross sectional area of each of said apertures being not substantially greater than the cross sectional area of the constricted arc.

3. An electric circuit interrupter comprising arcing contacts to initiate an arc and an arc chute for receiving and extinguishing the arc, said chute comprising a plurality of spaced insulating plates substantially three-sixteenths of an inch thick arranged to extend longitudinally of the axis of said chute and providing a slot adjacent said arcing contacts to form an arc passage, said slot gradually constricting the arc to a predetermined cross sectional area, a number of said plates being provided with a plurality of apertures of substantially equal cross sectional area arranged adjacent the closed end of said slot, the diameter of each of said apertures being greater than \( \frac{3}{8} \) of an inch but less than \( \frac{3}{4} \) of an inch for arc current up to 50,000 amperes.

4. An electric circuit interrupter comprising arcing contacts to initiate an arc and an arc chute for receiving and extinguishing the arc, said chute comprising a plurality of spaced insulating plates having a predetermined thickness arranged to extend longitudinally of the axis of said chute and providing a slot adjacent said arcing contacts to form an arc passage, said slot gradually constricting the arc to a predetermined cross sectional area, a number of said plates being provided with a plurality of apertures of substantially equal cross sectional area arranged adjacent the closed end of said slot, the diameter of said apertures being at least one-quarter of the plate thickness but not greater than twice the plate thickness for arc currents up to 50,000 amperes.

5. An electric circuit interrupter comprising means for drawing an arc and an arc chute for receiving and extinguishing the arc, said chute comprising a plurality of slotted spaced insulating plates substantially three-sixteenths of an inch thick arranged to extend longitudinally of the axis of said chute with the slots adjacent said arcing contacts to form an arc passage, a number of said plates being provided with a plurality of apertures arranged near the closed end of the slot, the diameter of some of said apertures being greater than \( \frac{1}{36} \) of an inch but less than \( \frac{1}{2} \) of an inch.

6. An electric circuit interrupter comprising means for drawing an arc and an arc chute for receiving and extinguishing the arc, said chute comprising a plurality of slotted spaced insulating plates arranged to extend longitudinally of the axis of said chute with the slots adjacent said arcing contacts to form an arc passage, a number of said plates being provided with a plurality of apertures arranged near the closed end of said slot, the cross sectional area of each of a number of said apertures being greater than

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\left(\frac{1}{10}\right)^2 \times \frac{\pi}{4}
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of a square inch but less than

\[
\left(\frac{3}{8}\right)^2 \times \frac{\pi}{4}
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of a square inch and the cross sectional area of each of the remainder of said apertures being greater than

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\left(\frac{1}{10}\right)^2 \frac{\pi}{4}
\]

of a square inch but less than

\[
\left(\frac{1}{4}\right)^2 \times \frac{\pi}{4}
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of a square inch.

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