

March 20, 1945.

W. M. LEEDS

2,372,094

CIRCUIT INTERRUPTER

Filed Aug. 12, 1942

3 Sheets-Sheet 1

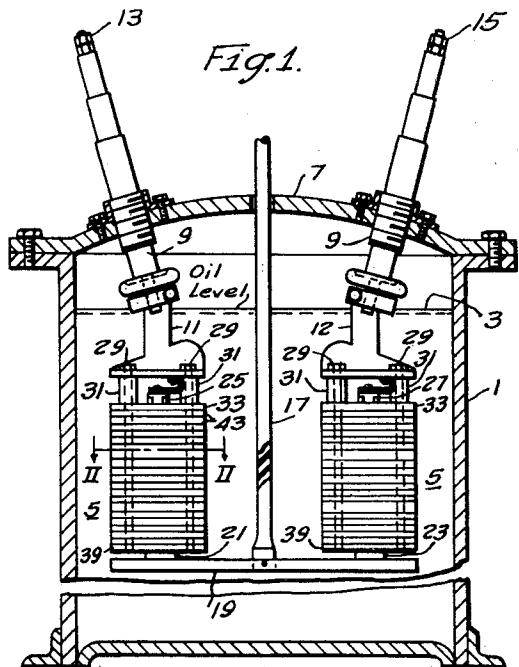


Fig. 1.

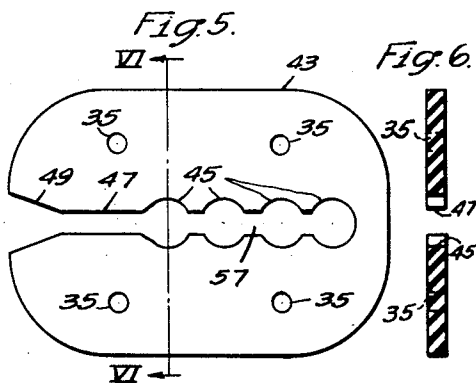


Fig. 5.

Fig. 6.

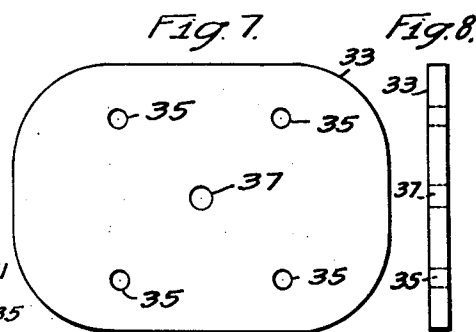


Fig. 7.

Fig. 8.

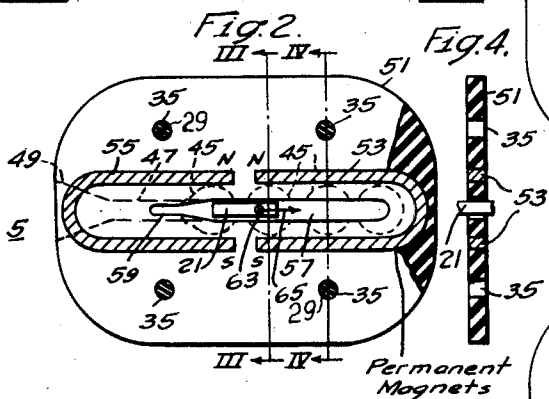


Fig. 2.

Fig. 4.

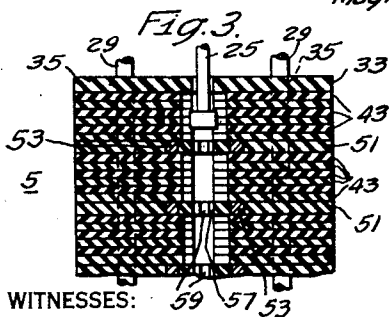


Fig. 3.

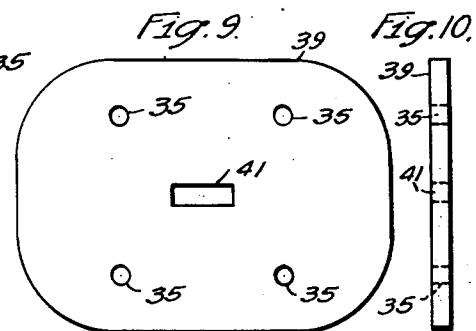


Fig. 9.

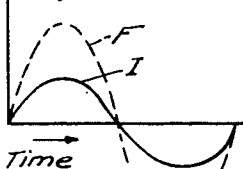
Fig. 10.

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Fig. 11.



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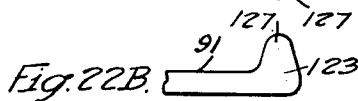
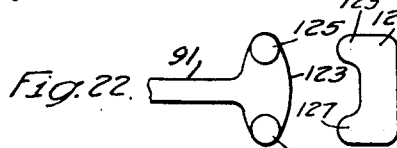
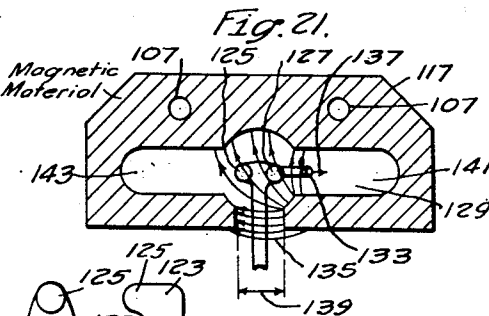
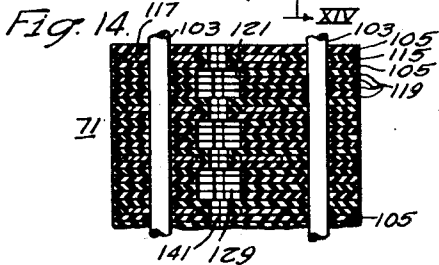
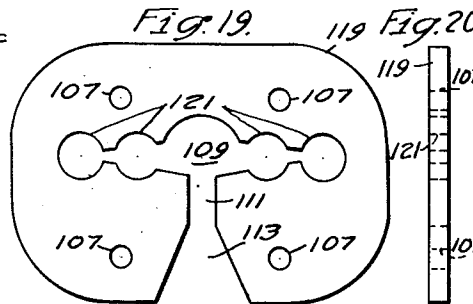
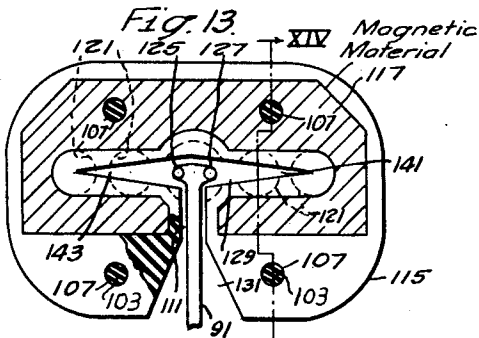
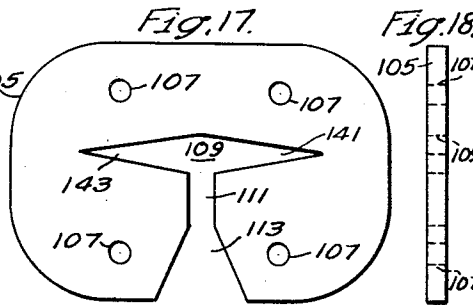
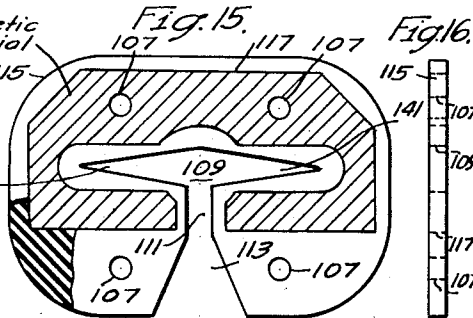
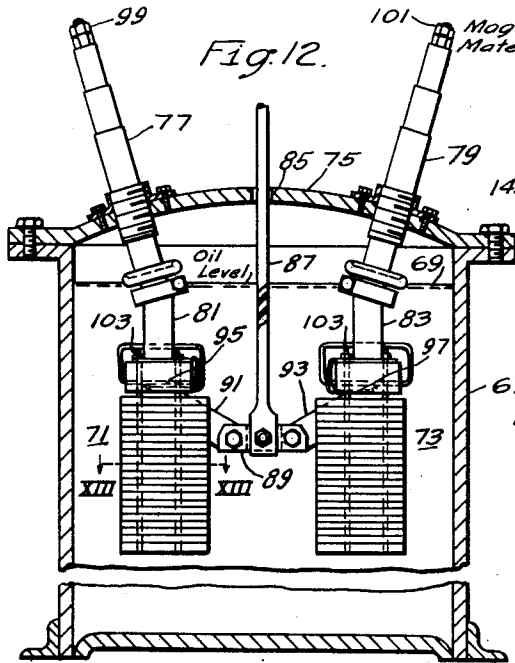
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2,372,094

CIRCUIT INTERRUPTER

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3 Sheets-Sheet 2



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2,372,094

CIRCUIT INTERRUPTER

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3 Sheets-Sheet 3

Fig. 23.

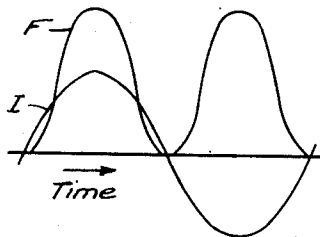


Fig. 24.

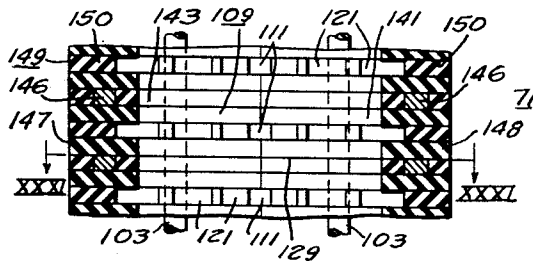


Fig. 25.

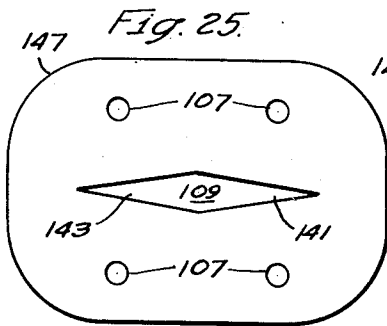


Fig. 26.

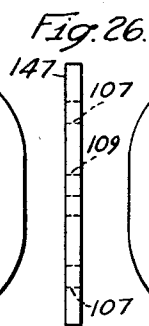


Fig. 29.



Fig. 30.

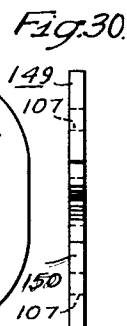


Fig. 27.

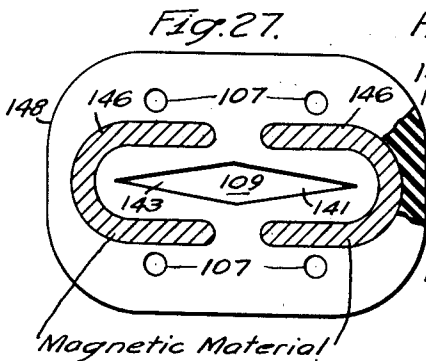


Fig. 28.



Fig. 31.

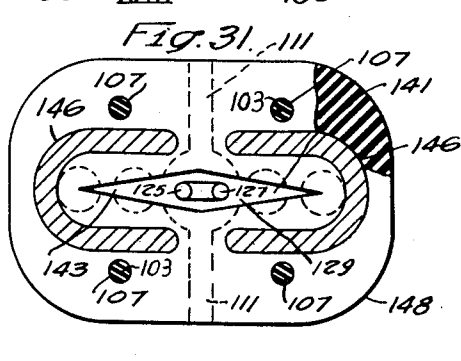


Fig. 32.

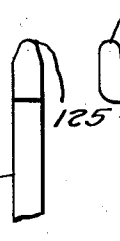
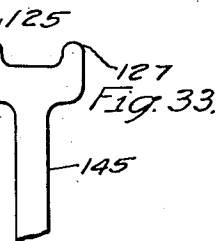


Fig. 33.



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UNITED STATES PATENT OFFICE

2,372,094

CIRCUIT INTERRUPTER

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Application August 12, 1942, Serial No. 454,514

20 Claims. (Cl. 200—150)

This invention relates to circuit interrupters in general, and, more particularly, to a method and structure for effecting the rapid extinction of alternating current arcs. More specifically the invention concerns alternating current circuit interrupters of the type wherein an alternating current arc is drawn in an elongated slot or passage and therein subjected to the deionizing action of gaseous or liquid particles.

More particularly, the present invention is concerned with an arc extinguishing structure which establishes an alternating current arc in an elongated passage and causes the lateral oscillation of said arc by magnetic means.

The lateral oscillation of the arc may be caused by the use of a unidirectional magnetic field. One or more permanent magnets may be employed suitably shaped and so disposed within the arc extinguishing structure in relation to the arc that the arc is constantly under the influence of a unidirectional magnetic field. It will be evident, therefore, that in an alternating current circuit interrupter utilizing one or more of such permanent magnets the arc stream will be forced laterally in one direction during one half cycle of the alternating current wave, and forced laterally in the opposite direction during a subsequent half cycle in the alternating current wave. Obviously a direct current magnet could be used in place of the permanent magnets to create the unidirectional magnetic field.

The lateral oscillation of the arc stream may also be produced by opposing magnetic and gas blast forces, each acting in a constant direction but first one and then the other predominating in magnitude. The magnetic force in this case may be produced by suitably shaped plates of magnetic material, such as iron, suitably disposed adjacent to the arc stream. The lateral gas blast may be obtained by utilizing the gaseous products of decomposition generated by the arc itself and directed by suitably shaped insulating plates forming the walls of the arcing chamber.

More particularly, my invention concerns an improved method of arc interruption comprising simultaneously establishing and lengthening an alternating current arc, providing for a lateral oscillation of said arc, the oscillations being such that during the lateral movement of the arc in one direction a suitable arc extinguishing gas is generated by the arc, and during the subsequent lateral movement of the arc in the opposite direction the arc is located in the most favorable position for interruption by a turbulent blast from the

gas formed during the previous lateral movement of the arc.

My invention is also concerned with an improved method of arc interruption which comprises simultaneously lengthening and oscillating the alternating current arc in an arc extinguishing medium.

The main object of my invention is to provide an improved structure for the interruption of alternating current arcs.

It is also an object of my invention to provide in the improved arc extinguishing structure of my invention an improved method of arc interruption as outlined above.

It is also an object of my invention to draw an alternating current arc in an elongated slot or passage, and to laterally oscillate said arc with a frequency substantially equal to the frequency of the alternating current circuit being interrupted.

Because of the consecutive alternate direction of the lateral arc motion favorable conditions are obtained for most effectively bringing into play the extinguishing influence of gaseous or liquid particles.

Another object is to provide in either an air-break or a liquid-break alternating current circuit interrupter one or more permanent magnets suitably shaped and so disposed in relation to the arc stream as to furnish a unidirectional magnetic field across said arc stream.

Another object is to provide in either a liquid-break or an air-break circuit interrupter a plurality of U-shaped permanent magnets, the magnets being disposed in pairs substantially surrounding the arcing slot with like poles lying adjacent one another to furnish a unidirectional magnetic field transversely of the arcing slot. Gas is produced during the lateral motion of the arc in one direction, by the arc itself acting upon gas-evolving material or upon a suitable liquid, such as oil, and during the subsequent lateral movement of the arc stream the arc is located in the most favorable position for interruption by a blast of gas formed by the arc itself during the previous lateral movement of the arc.

Another object is to provide a pair of interrupting structures of the narrow slot type closely positioned with respect to one another, so that arcs may be extinguished alternately in one of said structures and then in the other of said structures, in effect doubling the life of the interrupter over that of the separated individual structures.

Another object is to provide a pair of cooperating structures of the narrow slot type and to use

in conjunction therewith a movable contact of such shape that the arc to be interrupted in the twin structure will be extinguished just about as many times in one of said cooperating structures as in the other, thus doubling the life of the combined interrupting structure.

Another object is to provide a twin structure of the foregoing type in which during a single interrupting operation the arc may be thrown completely from one of the separate structures to the other, thus utilizing the combined interrupting capacity of both structures.

Another object is to use in a twin structure of the foregoing type a movable contact with two conducting buttons fixed thereon, so that as one of said buttons is worn down when only one of the structures is used during an interrupting operation, upon a subsequent opening of the interrupter the arc will be drawn at the other conducting button to utilize the structure which was not previously used.

Another object is to use a twin structure similar to the foregoing of either the air-break or liquid-break type, in which is provided one or more substantially U-shaped plates composed of a magnetic material surrounding the arcing slots of both structures, to bias the arc into one or the other of said structures depending upon the location of said arc when initially drawn.

I am well aware that my invention is applicable to air-type circuit interrupters in which a gaseous arc extinguishing medium is produced by the utilization of gas-evolving material. However, merely for purposes of illustration only I describe my invention in connection with its use in liquid breakers of the oil immersed type.

Further objects and advantages of my invention will become apparent upon a consideration of the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a side elevational view, partially in section, of a liquid type circuit interrupter constructed in accordance with the principles of my invention and shown in the closed-circuit position;

Fig. 2 is an enlarged cross-sectional view of one of the grid structures shown in Fig. 1 and taken along the line II—II of Fig. 1 looking in the direction of the arrows at a time when the movable contact has separated from the stationary contact thus drawing an arc therebetween;

Fig. 3 is a fragmentary cross-sectional view of the grid structure shown in Fig. 2 taken along the line III—III of Fig. 2 and looking in the direction of the arrows;

Fig. 4 is a cross-sectional view of the top fiber plate shown in Fig. 2 taken on the line IV—IV of Fig. 2 with the tie rods 29 omitted;

Fig. 5 is an enlarged plan view of one of the fiber plates used in the grid structure of Fig. 1;

Fig. 6 is a cross-sectional view of the fiber plate shown in Fig. 5 taken on the line VI—VI of Fig. 5;

Fig. 7 is an enlarged plan view of the top fiber plate used in the grid structure shown in Fig. 1;

Fig. 8 is a side elevational view of the top fiber plate shown in Fig. 7;

Fig. 9 is an enlarged plan view of the bottom fiber plate used in the grid structure of Fig. 1;

Fig. 10 is a side elevational view of the bottom fiber plate shown in Fig. 9;

Fig. 11 shows two curves of arc current and magnetic force acting thereon in the circuit interrupter shown in Fig. 1;

Fig. 12 is a side elevational view, partly in sec-

tion of a circuit interrupter embodying a modification of my invention and shown in the closed-circuit position;

Fig. 13 is an enlarged cross-sectional view of one of the grid structures shown in Fig. 12 taken along the line XIII—XIII of Fig. 12 and looking in the direction of the arrows;

Fig. 14 is a fragmentary cross-sectional view of the grid structure shown in Fig. 13 taken along the line XIV—XIV of Fig. 13 and looking in the direction of the arrows;

Figs. 15 through 20 are enlarged plan and side views of fiber plates used in one of the grid structures shown in Fig. 12;

Fig. 21 is an enlarged plan view of one of the magnetic inserts used in the grid structure shown in Fig. 12;

Figs. 22, 22A and 22B consist of three enlarged fragmentary views of the end of the movable contact shown in Fig. 12;

Fig. 23 shows two curves of arc current and the lateral magnetic force acting thereon as a function of time, these curves being illustrative of action taking place in the interrupter shown in Fig. 12;

Fig. 24 is an elevational view, in central longitudinal section, of a modified type grid embodying the principles of my invention;

Figs. 25 through 30 show plan and side views of fiber plates used in the grid shown in Fig. 24;

Fig. 31 is a cross-sectional view taken along the line XXXI—XXXI of Fig. 24; and

Figs. 32 and 33 show the configuration of the end of the movable contact used in the grid shown in Fig. 24.

Referring to Figs. 1 to 11 inclusive, and more particularly to Fig. 1, the reference numeral 1 designates a tank structure containing a suitable arc extinguishing liquid 3, such as oil, in which is immersed two serially related grid structures, each of which is indicated generally by the reference numeral 5. The two grid structures 5 are supported from a cover 7 by means of the terminal bushings 9 and the stationary contact structures 11, 12 which may be of any conventional design. The external terminals 13, 15 are used to connect the circuit interrupter into the circuit to be controlled.

The circuit interrupter is operated by means of the reciprocating longitudinal movement of an insulating lift rod 17, at the lower end of which is a conducting bridging member 19. At the ends of the conducting bridging member 19 are two movable contacts 21, 23 of blade-like configuration, which cooperate with two stationary contacts 25, 27 to open and to close the electrical circuit through the breaker.

When the breaker is in the closed-circuit position, as is illustrated in Fig. 1, the electrical circuit therethrough consists of the external line terminal 13, the stationary contact structure 11, the stationary contact 25, the movable contact 21, the conducting bridging member 19, movable contact 23, stationary contact 27, stationary contact structure 12 and external line terminal 15.

Each of the grid structures 5 comprises a plurality of fiber plates compressed together by suitable tie rods 29, and spaced a proper distance below the stationary contact structures 11, 12 by the spacing sleeves 31.

The top fiber plate 33 of each grid structure 5 is more clearly shown in Figs. 7 and 8. The top fiber plate 33 contains apertures 35 for the reception of the tie-rods 29, and a central aperture 37 through which extends the stationary

contact 25 or 27 which may be resiliently mounted. The clearance is slight between the stationary contact 25 or 27 and the central aperture 37 in the top fiber plate 33, the purpose for which will appear more fully hereinafter.

The bottom fiber plate in each of the two grid structures 5 is designated by the reference numeral 39, and is shown more clearly in Figs. 9 and 10. The bottom fiber plate 39 has bored therein apertures 35 for the reception of the tie-rods 29, and is also provided with a rectangular central aperture 41, through which moves the movable contact 21 or 23, as the case may be. It will be noticed that again there is very slight clearance between the rectangular central aperture 41 and the movable contact 21 or 23, the purpose for which will also appear hereinafter.

Immediately below the top fiber plate 33 (see Fig. 3) are a plurality, in this instance six, fiber plates 43, more clearly shown in Figs. 5 and 6, and herein designated pocket plates. These fiber plates 43 are designated pocket plates because each of them is provided with a series of pockets 45. When the grid structure 5 is immersed in the liquid 3, the pockets 45 serve to retain adjacent the arc path a readily available quantity of liquid, such as oil, upon which the arc may react. The pocket fiber plates 43 also are provided with apertures 35 to accommodate the tie-rods 29. It will be noticed that the pocket fiber plates 43 are also provided with a throat portion 47, which leads into a flared vent opening 49, as more clearly seen in Fig. 5.

Immediately below the top group of six pocket plates 43 is a fiber insert plate 51, the configuration of which is more clearly shown in Figs. 2 and 4. It will be noticed that the fiber insert plate 51 contains two U-shaped permanent magnets 53, 55 inserted in the fiber insert plate 51, the purpose for which will appear more clearly hereinafter. The two U-shaped permanent magnets 53, 55 are inserted in the fiber insert plate 51 with the two north poles lying adjacent one another and the two south poles lying adjacent one another, as indicated in Fig. 2. It will therefore be apparent that a unidirectional magnetic field is provided between the two north poles and the two south poles, said unidirectional magnetic field extending substantially transversely across an arcing slot 57. It will be noticed in Fig. 2 that the arcing slot 57 narrows somewhat at 59 in the insert plate 51 and is closed therein. The restriction 59 serves to hold the higher current arcs during the peak of the alternating current wave, when their cross-sectional areas are large, outside of the restriction 59 in the widened portion of the slot 57. But near a current zero, when the cross-sectional area of the higher current arc is relatively small, then it will enter the restriction 59. The smaller current arcs with their smaller cross-sectional areas may, however, freely enter the restriction 59 even during the peak of the current wave. The arcing slot 57 is vented to the left in the pocket plates 43.

When all the fiber plates are assembled upon the tie-rods 29 in their respective groupings, as shown in Fig. 3, it will be observed that all of the apertures 35 align for the accommodation of the tie-rods 29, and, as more clearly shown in Figs. 2 and 3, the fiber plates form the longitudinal arcing slot 57.

When the insulating lift rod 17 is moved downwardly to separate the movable contacts 21, 23 from the stationary contacts 25, 27 two serially

related arcs are drawn. Considering only the arc drawn between the stationary contact 25 and the movable contact 21, in the left hand grid structure 5 as viewed in Fig. 1, it will be apparent that the arc, designated by the reference numeral 63, will be drawn in the arcing slot 57, and therein subjected to the influence of the strong unidirectional magnetic field produced by the pairs of U-shaped permanent magnets 53, 55.

Let it be supposed that during the first half cycle of arcing the instantaneous current in the arc 63 is flowing upward from the movable contact 21 to the stationary contact 25 in the left hand grid structure 5 of Fig. 1. The direction of the unidirectional magnetic field will then be such as to force the arc 63 to the right, as indicated by the arrow 65 in Fig. 2. Since liquid, in this instance oil, is disposed within the arcing slot 57, and also retained in the pockets 45, the arc 63 will react upon the oil in the right hand end of the slot 57, as viewed in Fig. 2 to produce a considerable quantity of gas. Since there is slight clearance between the stationary contact 25 and the central aperture 37 in the top fiber plate 33, and also slight clearance between the movable contact 21 and the rectangular central aperture 41 in the bottom fiber plate 39, the gas which is produced by the action of the arc 63 on the oil contained in the right hand end of the arcing slot 57 must be vented sooner or later out of the left hand end of the slot 57, as viewed in Fig. 2.

When the instantaneous current in the first half cycle of arcing decreases, the arc 63 will begin to retreat toward the middle of the slot 57 where it was initially drawn, due to the force of the expanding gases produced by the arc 63 when it was in the right hand end of the slot 57. When the instantaneous current reaches zero, that is, at the first current zero of the arcing period, there is a good opportunity for the extinction of the arc 63, as the gas streams through the arc toward the left, cooling the arcing space, and carrying away ionized particles.

If the arc 63 restrikes, the instantaneous current during this half cycle will be in the opposite direction than the direction considered above during the first half cycle of arcing. Now the direction of the instantaneous current will be such that the unidirectional magnetic field will force the arc 63 to the left, as viewed in Fig. 2, toward the narrow restriction 59 in the fiber insert plate 51 of Fig. 2. However, the arc 63 will be retained within the arcing slot 57 because the slot 57 in the fiber insert plate 51 is closed at its left-hand end, as viewed in Fig. 2. The arc 63, is, consequently, held in the constricted space 59 in the fiber insert plates 51 and in the throat portion 47 of the pocket fiber plates 43.

During the second half cycle of arcing when the arc 63 is forced by the unidirectional magnetic field to the left, as viewed in Fig. 2, it will be noted that the arc 63 is placed at the most favorable position for interruption by a turbulent blast of gas which was generated by the arc 63 itself during the previous half cycle of arcing. During the peak value of instantaneous current of the second half cycle of arcing, when the arc 63 is at the extreme left hand end of the arcing slot 57, it will be noticed that the width of the throat 47 formed in the pocket fiber plates 43 is such that there is sufficient space on both sides of the arc stream 63 to permit a relatively free passage of gas, oil particles, and oil out of the

arcing slot 57 through the flared openings 49, on both sides of the arc 63.

Consequently, the continuity of the arc stream 63 during the peak value of instantaneous current is not unnecessarily disturbed, but as the instantaneous current during the second half cycle of arcing decreases, the lateral streaming of gas, oil and oil particles to the left adjacent the arc column becomes more effective to cause rapid de-ionization of the arc space, raising the dielectric strength at current zero so that the arc 63 will not restrike. Since the arc 63, during high instantaneous values of arcing current, does not receive the full effect of a lateral blast of gas at the center of the arc column, there is a corresponding lowering of the arc voltage and less decomposition of oil as compared to conditions in a more restricted slot construction.

Should the arc 63 restrike for a third half cycle of arcing, it would this time be thrust to the right by the unidirectional magnetic field. The ionized gas which was produced during the first half cycle of arcing, when the arc 63 was forced to the right, will have had some opportunity to recombine with the oil disposed in the pockets 45 of the pocket fiber plates 43 before the arc 63 during the third half cycle of arcing is again forced to the right hand end of the arcing slot 57, repeating the process described above. Since the arc 63 is being continuously lengthened by the downward motion of the movable contact 21 this brings about conditions more favorable for extinction at each successive current zero until interruption is obtained.

Cobalt steel permanent magnets may be designed which may be exposed to alternating currents of 5,000 to 10,000 amperes without being demagnetized. Therefore, there need be no danger that the unidirectional magnetic field produced by the U-shaped permanent magnets 53, 55 will be weakened by currents of magnitudes which the breaker was designed to interrupt.

As previously mentioned above, it is essential for the best operation of the breaker that the top of the grid structure 5 around the stationary contact 25 be completely enclosed, and that the bottom of the stack also have an aperture only large enough to just admit the moving contact 21. With such a construction the vertical flow of gas and oil is reduced to a minimum, and the lateral flow of the gas and oil is correspondingly increased, which lateral flow helps in the extinction of the arc 63.

It will be apparent to one skilled in the art that instead of using an oil breaker with the fiber plates 43 and 51, my invention may well be incorporated in an air-type circuit breaker which utilizes gas-evolving plates composed of horn fiber, boric acid or other gas-evolving material. The lateral motion of the arc 63 could be used to engage the arc 63 with the plates composed of gas-evolving material to produce the requisite amount of arc extinguishing fluid necessary for interruption of the arc 63. My invention is also applicable to breakers of the compressed fluid type.

A direct current magnet may be used to produce a unidirectional magnetic field across the arcing slot 57 instead of using the U-shaped permanent magnets 53, 55 as shown. The latter arrangement is preferable inasmuch as it is simpler and free of circuit connections which would have to be insulated from the high voltage part of the interrupter.

Fig. 11 shows a cycle of the alternating cur-

rent I through the arc 63 as a function of the time. The curve F represents the magnitude of the magnetic force acting laterally on the arc 63. The magnetic force is equal to a constant times the first power of the instantaneous current, and therefore holds up very well in the neighborhood of the current zero periods as shown in Fig. 11.

Referring to the breaker embodying my invention shown in Figs. 12 to 22 inclusive, and more particularly to Fig. 12, the reference numeral 67 designates a tank containing a suitable arc extinguishing liquid 69, in this instance oil, in which are submerged two grid structures, generally designated by the reference numerals 71, 73. A cover 75 for the tank 67 supports two terminal bushings 77, 79 from which depend the stationary contact structure 81, 83.

The cover 75 contains a central aperture 85 through which extends the insulating lift rod 87 carrying a conducting bridging member 89 at the ends of which are securely mounted the movable contacts 91, 93. The movable contacts 91, 93 engage in the closed-circuit position of the breaker, as shown in Fig. 12, the stationary contacts 95, 97. External line terminals 99, 101 are provided to connect the breaker in the circuit to be interrupted. In the closed-circuit position as shown in Fig. 12, the electrical circuit through the breaker includes the line terminal 99, stationary contact structure 81, stationary contact 95, movable contact 91, conducting bridging member 89, movable contact 93, stationary contact 97, stationary contact structure 83, and external line terminal 101.

Each of the grid structures 71, 73 comprises a plurality of fiber plates compressed together by tie rods 103. In each grid structure there may be provided three types of plates. Referring particularly to Fig. 14 the top fiber plate shown therein is called a fiber guard plate 105 and is more clearly shown in Figs. 17 and 18. It will be noticed that the fiber guard plate 105 is provided with four circular apertures 107 for the reception of the tie-rods 103. The fiber guard plate 105 also is provided with a slot, generally indicated by the reference numeral 109 which vents into a passage 111. The passage 111 itself vents into a flared opening 113, the purpose for which will appear hereinafter.

Immediately below the top fiber guard plate 105 is a fiber insert plate 115, more clearly shown in Figs. 15 and 16. The fiber insert plate 115 contains a C-shaped plate 117 composed of magnetic material, in this instance iron, the configuration of which is shown more clearly in Fig. 21. The fiber insert plate 115 is formed for the insertion of the magnetic plate 117 therein, and therefore to distinguish it from the other plates forming the grid structure 71, it is herein designated as an insert plate. The fiber insert plate 115 contains circular apertures 107 for the reception of the tie rods 103. The fiber insert plate 115 is formed with a slot 109 identical to the slot 109 provided in the top fiber guard plate 105 previously described. Immediately below the fiber insert plate 115 is a second fiber guard plate 105. The two fiber guard plates 105 protect the magnetic plate 117 from the action of the arc drawn in the grid structure 71. Therefore, they are herein designated as guard plates.

Immediately below the second fiber guard plate 105 are a plurality, in this instance four, fiber pocket plates 119, the configuration of which is more clearly shown in Figs. 19 and 20. The fiber

pocket plates 119 contain circular apertures 107 for the reception of the tie rods 103. They also contain a plurality, in this instance four, pockets 121, which as in the previous embodiment of my invention provide a readily available quantity of oil adjacent the arc path. The fiber insert plate 115 and the fiber pocket plates 119 also contain a passage 111 which leads to a flared opening 113.

Immediately below the four fiber pocket plates 119 is a second grouping of two fiber guard plates 105, between which is a fiber insert plate 115, as more clearly shown in Fig. 14. Below this second grouping the successive groupings of plates down to the bottom of the grid structure 71 are repeated as previously described.

The ends of the movable contacts 91, 93 are identical, and Fig. 22 shows the configuration of the end of the movable contact 91. It will be noticed that at the extremity of the movable contact 91 is a conducting support member 123 disposed at right angles to the movable contact 91 and at the ends of which are two upstanding rounded contact buttons 125, 127, the purpose for which will appear hereinafter. When the breaker is in the closed position, as is illustrated in Fig. 12, the rounded contact buttons 125, 127 engage in abutting relation the stationary contact 95, which may be a flat plate of metal resiliently mounted.

When the fiber plates are assembled upon the tie rods 103, the passages 111, the flared openings 113 and the slots 109 align to form a longitudinal arcing slot indicated by the reference numeral 129 in Fig. 13. During the operation of the breaker the movable contact 91 moves longitudinally of the slot 131 shown in Fig. 13, created by the alignment of the passages 111 and openings 113 in the fiber plates.

The pockets 121 in the fiber pocket plates 119 retain a sufficient quantity of readily available oil along the walls forming the arcing slot 129.

The manner in which the breaker operates will now be described. When it is desired to open the circuit passing through the breaker, or when external overload conditions require the breaker to be opened, suitable mechanism, not shown, may be actuated to move the insulating lift rod 87 in a downward direction as viewed in Fig. 12. The movable contacts 91, 93 separating respectively from the stationary contacts 95, 97 will draw two serially related arcs, one arc in each grid structure.

As was mentioned previously the stationary contacts 95, 97 may be in the form of flat metallic plates resiliently mounted to withstand the shock of closing. The contact buttons 125, 127, provided at the ends of the movable contacts 91, 93, engage the flat metallic plates constituting the stationary contacts 95, 97 in abutting relation during the closed-circuit position of the breaker. It will be apparent, therefore, that by the provision of two contact buttons 125, 127, the arc drawn will be drawn between the stationary contact and one of said buttons.

Consider only the grid structure 71. Assume that the direction of the instantaneous arcing current drawn in the grid structure 71 is in a downward direction, as viewed in Fig. 12 and as indicated by the X in Fig. 21 and that it is increasing in magnitude. Assume further that the arc 133 (see Fig. 21) drawn in grid structure 71 is drawn between the stationary contact 95 and the contact button 127. It will therefore be drawn off center in grid structure 71 and positioned slightly in the right hand end 141 of the arcing slot 129. Then as the instantaneous arcing cur-

rent in the arc 133 increases during the subsequent half cycle, the magnetic flux in the iron plate 117 builds up in the direction indicated by the arrows 135 in Fig. 21. The magnetic field surrounding the arc 133 is distorted by the presence of the magnetic plates 117, and the arc is biased to the right looking at Fig. 21 and as indicated by the arrow 137.

With an air gap of such relative magnitude as shown at 139 in Fig. 21 saturation does not occur in the iron plate 117, and the lateral biasing force exerted by the distorted magnetic field upon the arc 133 is hence proportional to the square of the instantaneous arcing current. In other words, the lateral biasing magnetic force exerted on the arc 133 follows the relation: $F=kI^2$, where F is the magnetic force acting laterally on the arc 133, k is a constant and I is the magnitude of the instantaneous current passing through the arc 133. Fig. 23 shows graphically the curves I and F as a function of time.

As the instantaneous current in the arc 133 increases during the first half cycle of arcing the increasing magnetic force will bias the arc 133 laterally farther into the closed right hand end 141 of the arcing slot 129. It will be noticed that the presence of the two contact buttons 125, 127 at the end of the movable contact 91 not only draws the arc 133 off center in the grid structure 71 to avoid hesitation of the arc 133, but also the contact buttons 125, 127 assist to bring the arc 133 farther into the ends of the arcing slot 129 and hence into a stronger part of the magnetic field.

While the arc 133 is in the right hand end 141 of the arcing slot 129 it will react upon the oil contained in the pockets 121 in the fiber pocket plates 119 to produce a considerable quantity of arc extinguishing gas under pressure. As the instantaneous current in the arc 133 decreases near the end of the first half cycle of arcing, the lateral biasing magnetic force will correspondingly decrease until the pressure of the gas in the right hand end 141 of the arcing slot 129 overcomes the magnetic force to throw the arc 133 back toward the center of the arcing slot 129, adjacent the slot 131 (see Fig. 13).

It will be observed that the magnetic force is a function of the second power of the instantaneous current through the arc 133, and therefore will drop considerably in magnitude near the end of the first half cycle of arcing (see Fig. 23) to readily permit the expansive force of the decomposed oil gases to carry the arc 133 back toward the center of the arcing slot 129 adjacent the passages 111 in the fiber plates constituting the grid structure. At this position the arc 133 has a relatively small cross-section, because of the low magnitude of instantaneous arcing current at this time, and the streaming of gas and oil particles past the centrally positioned arc 133 and out the vent passages 111 in the fiber plates creates a very favorable condition for extinction of the arc 133.

If the arc 133 is not extinguished completely at the end of the first half cycle of arcing, but re-strikes, it may do one of two things depending upon its position. If it is off-center and slightly to the right, looking at Fig. 21, it may be drawn back toward the closed end 141 of the arcing slot 129 to repeat its former movement. The decomposed oil gases which were left in the right hand end 141 of the arcing slot 129 will have had some chance to mix with fresh oil retained in the pockets 121 in the fiber pocket plates 119 to be ready for the next onslaught. It will be noticed that the force F in Fig. 23 is positive during both

half cycles of arcing current to indicate that the arc 133 was again forced to repeat its former movement into and out of the right hand end 141 of the arcing slot 129. This lateral movement of the arc 133 into and out of the right hand end 141 of the arcing slot 129 may continue until extinction of the arc 133 occurs, each time the arc 133 being thrown back toward the center of the arcing slot 129 conditions favorable for extinction, as previously described, reoccurring because of the small cross-section of the arc 133 at this time and because of the streaming of the gas and oil particles past the arc 133 in their venting through the passages 111 out of the grid structure.

It may happen, however, that at any time when the arc 133 is thrown back toward the center of the arcing slot 129, it may be thrown so far by the expanding force of the decomposed oil gases that it will be positioned off-center to the left adjacent the left hand end 143 of the arcing slot 129. In this event the arc 133 will be drawn into the fresh oil disposed in the left hand end 143 of the arcing slot 129 because of the presence of the magnetic inserts 117. The position of the arc 133 when it is thrown back toward the central portion of the arcing slot 129 will largely determine whether it will repeat its movement during the previous half cycle of arcing, or whether it will move into the opposite end of the arcing slot 129 to engage fresh oil retained in the pockets 121. In either event conditions are favorable for extinction at the end of any half cycle of arcing.

It should be noticed that if only one end of the arcing slot 129 is used during the extinction process the contact button for that end may be worn down sufficiently so that during a subsequent opening operation of the interrupter the other contact button will leave the stationary contact last to result in drawing the arc at the other contact button. In this manner the life of the grid structure 71 is prolonged by insuring that the arc will be drawn just about as many times in one end of the arcing slot 129 as it is drawn at the other end of the arcing slot 129.

It will be observed that the direction of the magnetic flux across the main air gap 139 (see Fig. 21) is such as to keep the arc 133 from getting out of the grid structure 71.

The embodiment of my invention shown in Figs. 24 to 33 inclusive is substantially the same as the embodiment of my invention just described. However, a blade-like moving contact 145 is used similar to the blade-like moving contact 21 used in the interrupter shown in Fig. 1. Also in place of the C-shaped magnetic insert 117 used in the breaker shown in Fig. 12, a pair of U-shaped inserts 146 composed of magnetic material, such as iron, are employed.

The fiber guard plate 147 has no vent passages 111 as did the fiber guard plates 105 of Fig. 17. The fiber insert plate 148 also has no vent passages 111. The fiber pocket plate 149 is composed of two identical halves 150, which when assembled on the tie-rods 103 provide two lateral vent passages 111, as more clearly shown in Fig. 31.

The grouping of the fiber plates in the grid structure 71 (see Fig. 24) may comprise a fiber pocket plate 149 between two groups of plates, each group consisting of an insert plate 148 positioned between two guard plates 147. The groupings may be repeated to the bottom of the grid structure 71. It is advisable to minimize the longitudinal flow of gas and oil in this embodiment

of my invention. Consequently the top and bottom fiber plates used in the grid structure 71 of Fig. 24 may provide only slight clearance between the movable contact 145 and the stationary contact (not shown) and apertures provided in the top and bottom plates (not shown) similar to the fiber plates 33 and 39 shown respectively in Figs. 7 and 9 of the interrupter shown in Fig. 1.

The method of operation of this embodiment of my invention is similar to that described in connection with the interrupter shown in Fig. 12. By enclosing the grid structure 71 (see Fig. 24) more than was done with the interrupter shown in Fig. 12, and providing restricted lateral venting through the passages 111 improved operation is obtained.

It will be apparent to one skilled in the art that gas-evolving fiber plates could be used in place of a liquid, and that features of my invention may be applied to compressed-fluid interrupters. When the term "fluid" is used herein and in the appended claims it is meant to include gases, liquids, vapors and sprays.

Although I have shown and described specific structures, it is to be clearly understood that the same were merely for purposes of illustration and that changes and modifications may be made by those skilled in the art without departing from the spirit and scope of the appended claims.

I claim as my invention:

1. In an alternating current circuit interrupter, means having a passage therein vented only along one side, means for establishing an arc within said passage, and means for oscillating said arc laterally within said passage with a frequency substantially the same as the circuit.

2. In a circuit interrupter for interrupting an alternating current circuit, means defining an arcing passage vented only along one side, means for establishing an arc within said passage, and means for oscillating said arc laterally with a frequency substantially the same as the frequency of said alternating current circuit, the lateral motion of the arc in one direction being toward the vented side of the passage.

3. In a circuit interrupter, means providing an arcing chamber vented only along one side and immersed in a liquid, relatively movable contacts for establishing and lengthening an arc within said chamber, and means for simultaneously causing the lateral oscillation of said arc within said chamber, with a frequency substantially the same as the circuit, the lateral motion of the arc in one direction generating gas which is used to facilitate the extinction of the arc.

4. In a circuit interrupter for interrupting an alternating current circuit, means defining an arcing slot, the slot being vented only along one side, relatively movable contacts for establishing and lengthening an arc within said slot, an arc extinguishing liquid disposed adjacent to said arc, and magnetic means for causing the lateral oscillation of said arc with a frequency substantially the same as the frequency of said alternating current circuit.

5. In a circuit interrupter for interrupting an alternating current circuit, an insulating structure comprising a plurality of insulating plates pressed together, said insulating structure being immersed in an arc extinguishing liquid, said insulating plates defining an arcing slot, the slot being vented only along one side, means for establishing an arc within said slot, magnetic means comprising one or more plates of magnetic ma-

terial disposed adjacent said slot to provide a unidirectional magnetic field adjacent said arc, said magnetic means causing the lateral oscillation of said arc with a frequency substantially the same as the frequency of said alternating current circuit.

6. In a circuit interrupter for interrupting an alternating current, means defining an arcing passage, the passage being vented only along one side, means for establishing an arc within said passage, one or more permanent magnets disposed adjacent said passage for creating a unidirectional magnetic field across said passage to cause the lateral oscillation of said arc.

7. In a circuit interrupter for interrupting an alternating current, means providing an arcing slot, means for establishing an arc within said slot, one or more pairs of U-shaped permanent magnets, each pair substantially surrounding said slot and having like poles adjacent one another for creating a unidirectional magnetic field across said slot for oscillating said arc laterally.

8. In a circuit interrupter for interrupting an alternating current, an insulating structure comprising a plurality of insulating plates compressed together, said insulating structure being immersed in an arc extinguishing liquid, said insulating plates forming an arcing slot, means for establishing an arc within said slot, one or more pairs of U-shaped permanent magnets, each pair substantially surrounding said slot and disposed with like poles adjacent one another for creating a unidirectional magnetic field across said slot, said magnetic field causing the lateral oscillation of said arc within said slot with a frequency substantially the same as the frequency of said alternating current.

9. In a circuit interrupter for interrupting an alternating current, an insulating structure comprising a plurality of insulating plates, said insulating structure being immersed in an arc extinguishing liquid, said insulating structure providing an arcing slot, means for establishing an arc within said arcing slot, means for venting said arcing slot along one side thereof, said venting means providing a relatively restricted slot in which said arc may be positioned during at least part of the interrupting process, one or more pairs of U-shaped permanent magnets disposed adjacent said arcing slot and having like poles facing one another to create a unidirectional magnetic field across said arcing slot, the arrangement being such that the alternating current arc which is established within said arcing slot is oscillated laterally by said unidirectional magnetic field, said alternating current arc generating arc extinguishing gas during one half cycle and being positioned in said relatively restricted slot during the subsequent half cycle to receive the flow of said arc extinguishing gas.

10. In a circuit interrupter, insulating means defining an arcing slot, means for establishing an arc within said slot, means comprising magnetic material substantially surrounding said arcing slot, said arcing slot being vented only intermediate the ends thereof.

11. In a circuit interrupter, means defining an arcing slot, means for establishing an arc within said arcing slot, one or more members of C-shaped magnetic material substantially surrounding said slot to cause the lateral oscillation of said arc, said arcing slot being vented only intermediate the ends thereof.

12. In a circuit interrupter, an insulating structure comprising a plurality of insulating plates,

said plates having aligned openings therein to provide an arcing slot, one or more C-shaped plates of magnetic material substantially surrounding said slot, means for establishing an arc within said arcing slot comprising relatively movable contacts, at least one of said contacts having two upstanding contact portions to position said arc initially off center within said arcing slot.

13. In a circuit interrupter, an insulating structure comprising a plurality of insulating plates, said insulating plates having aligned openings to form an arcing slot, venting means venting said slot intermediate the ends thereof, said insulating structure being immersed in an arc extinguishing liquid, a contact disposed at one end of said arcing slot, a cooperating movable contact movable through said venting means and away from said first-mentioned contact, said movable contact having two upstanding conducting portions to establish and lengthen an arc within said slot, one or more C-shaped members of magnetic material substantially surrounding said arcing slot and having their open portions adjacent said venting means, said C-shaped members tending to cause the lateral oscillation of said arc in a direction substantially perpendicular to the center line of said venting means, said upstanding conducting portions functioning to position said arc initially off center in said slot.

14. In a circuit interrupter, an insulating structure defining a slot, means for establishing an arc in said slot, one or more pairs of U-shaped members composed of magnetic material disposed adjacent to said arcing slot with the open ends of each pair facing one another, means providing opposed vent passages extending from the center of said slot to the region outside said insulating structure.

15. In a circuit interrupter, insulating means for defining two or more substantially closed arcing slots having a common entrance portion, means for establishing an arc within said entrance portion, and magnetic means for moving said arc into any one of said arcing slots.

16. In a circuit interrupter, insulating means for defining two or more arcing slots having a common entrance portion, means for establishing an arc within said entrance portion, magnetic means for moving said arc into any one of said arcing slots, and means tending to bias said arc into different arcing slots on successive opening operations for increasing the life of said interrupter.

17. In an alternating-current circuit interrupter, means for establishing an arc, means for establishing a unidirectional magnetic field for causing a lateral oscillation of the arc, gas producing substance with which the arc contacts during its lateral movement in one direction to produce gas, the produced gas facilitating the extinction of the arc during its lateral movement in the opposite direction.

18. In an alternating current circuit interrupter, means forming a slot having a restricted portion, means for establishing an arc within the slot, means for providing a unidirectional magnetic field for causing a lateral oscillation of the arc within the slot, gas producing substance with which the arc contacts during its lateral movement in one direction to produce gas, the arc being forced into the restricted portion during its lateral movement in the opposite direction, the produced gas facilitating the extinction of the arc

after the latter has been forced into the restricted portion.

19. In an alternating current circuit interrupter, means forming a slot having a relatively widened portion and a relatively restricted portion, means for establishing an arc in the slot within the widened portion, means providing a unidirectional magnetic field for causing a lateral oscillation of the arc within the slot, gas producing substance with which the arc contacts during its lateral movement in one direction to produce gas, the arc being forced during its subsequent lateral movement in the opposite direction toward the restricted portion of the slot, the restricted portion preventing entry of the arc therein during relatively high instantaneous values of arcing current, the arrangement being such that the produced gas is utilized to effect

the extinction of the arc after it has entered the restricted portion.

20. In an alternating current circuit interrupter, means forming a slot having a restricted portion, venting means disposed adjacent the restricted portion, means for establishing an arc within the slot, means providing a unidirectional magnetic field for causing a lateral oscillation of the arc within the slot, gas producing substance with which the arc contacts during its lateral movement in one direction to produce gas, the arc being forced into the restricted portion during its lateral movement in the opposite direction, and the produced gas passing out of the slot through the venting means to facilitate the extinction of the arc after the latter has entered the restricted portion.

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