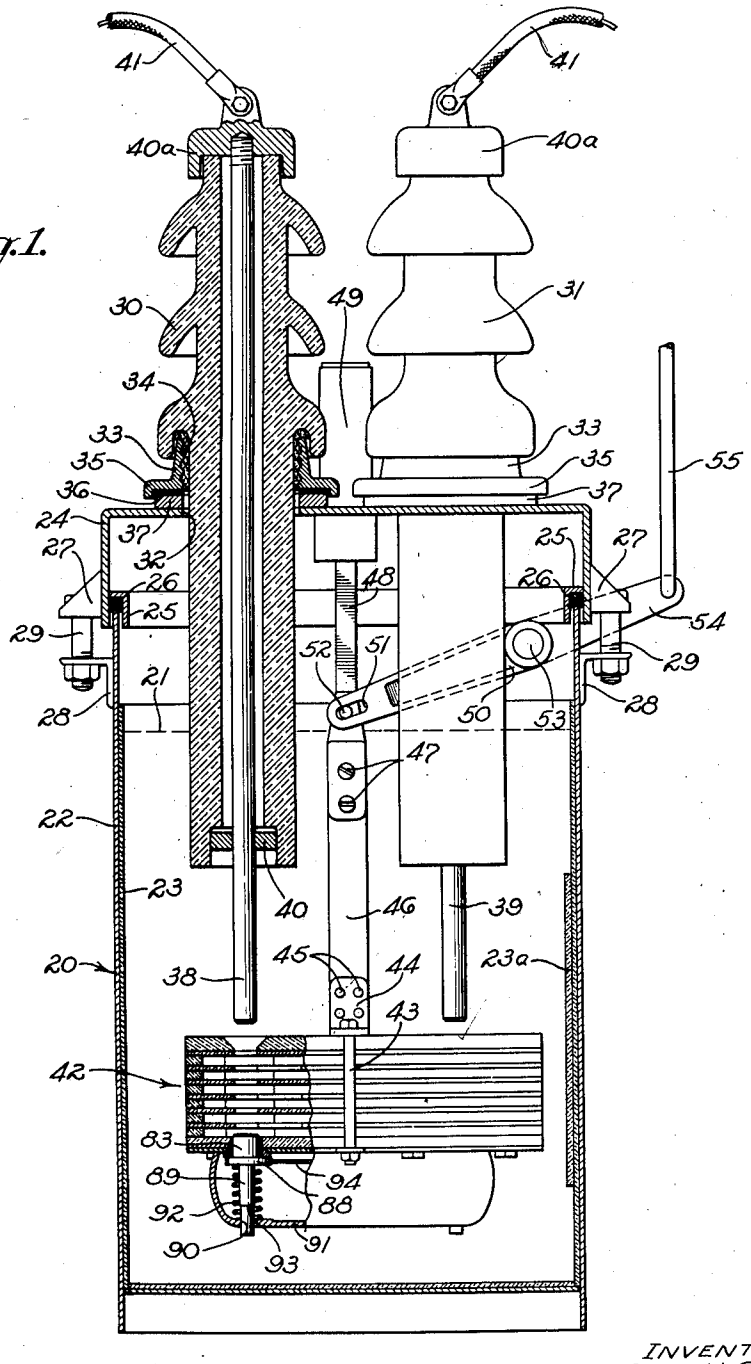
May 2, 1939. F. H. COLE 2,156,450

APPARATUS FOR INTERRUPTING AN ELECTRIC CIRCUIT

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Fig. 1.



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Fig. 2.

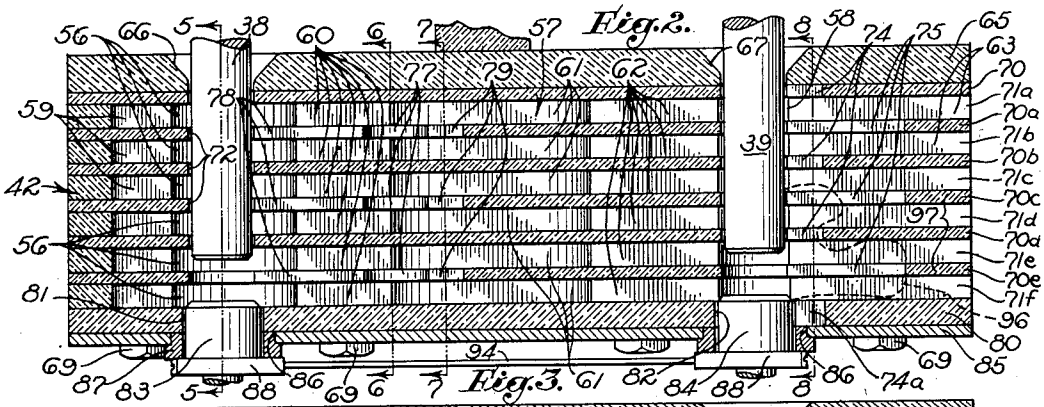


Fig. 3.

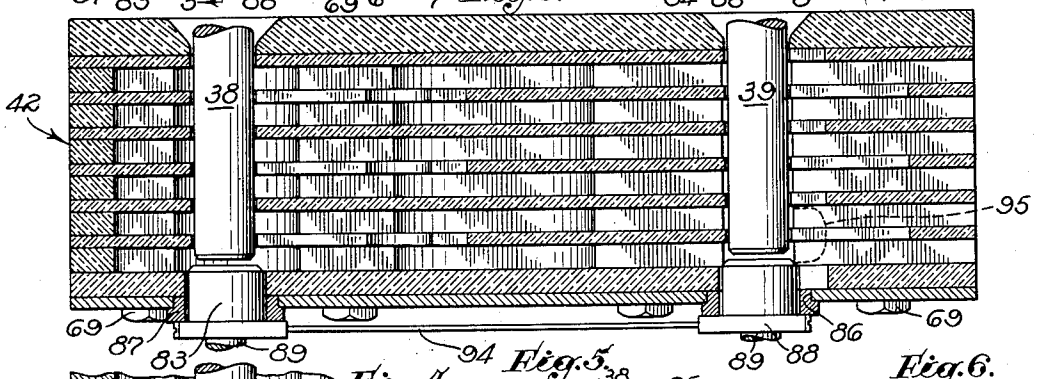


Fig. 4.

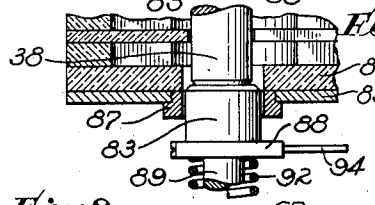


Fig. 5.

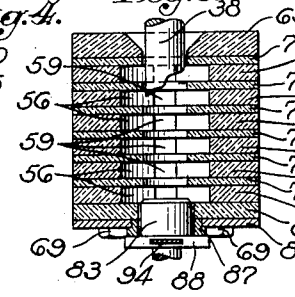


Fig. 6.

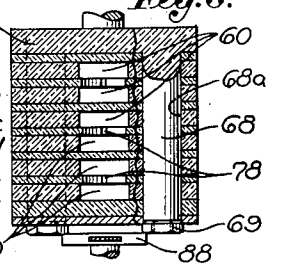


Fig. 9.

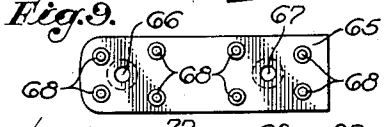


Fig. 12.

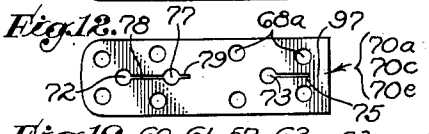


Fig. 10.

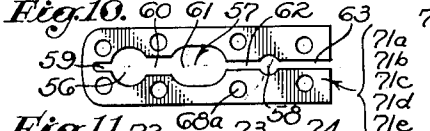


Fig. 11.

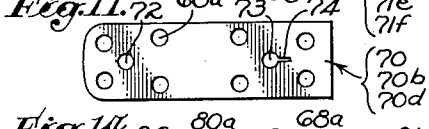


Fig. 14.

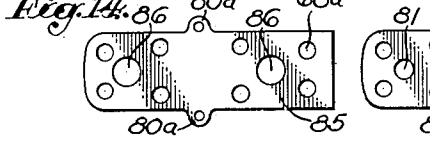


Fig. 7.

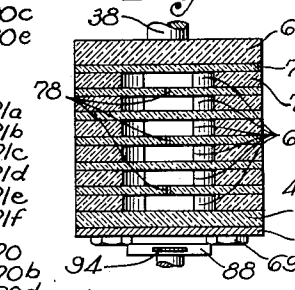


Fig. 8.

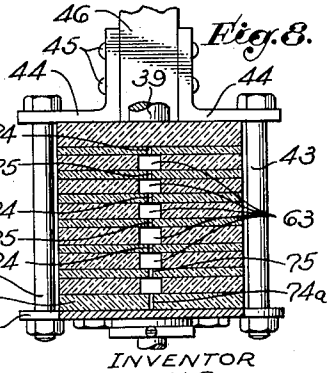
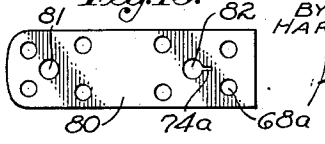


Fig. 13.



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Fig. 15.

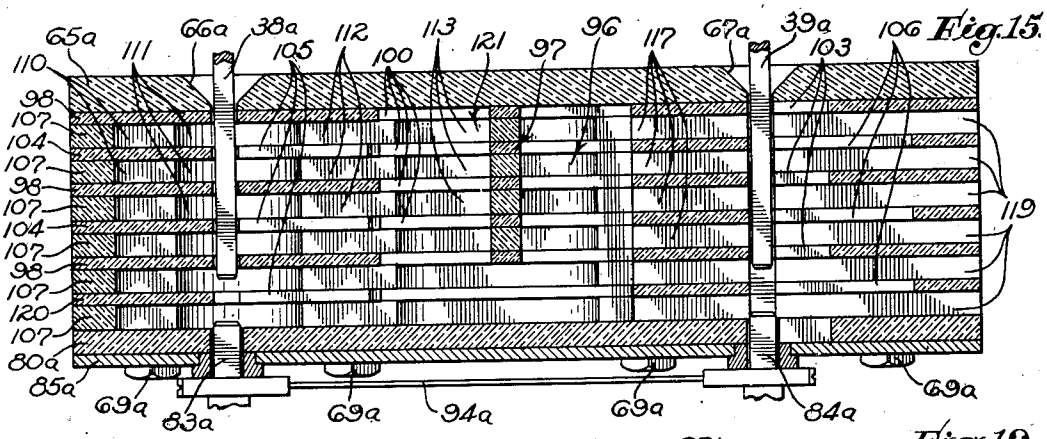


Fig. 19.

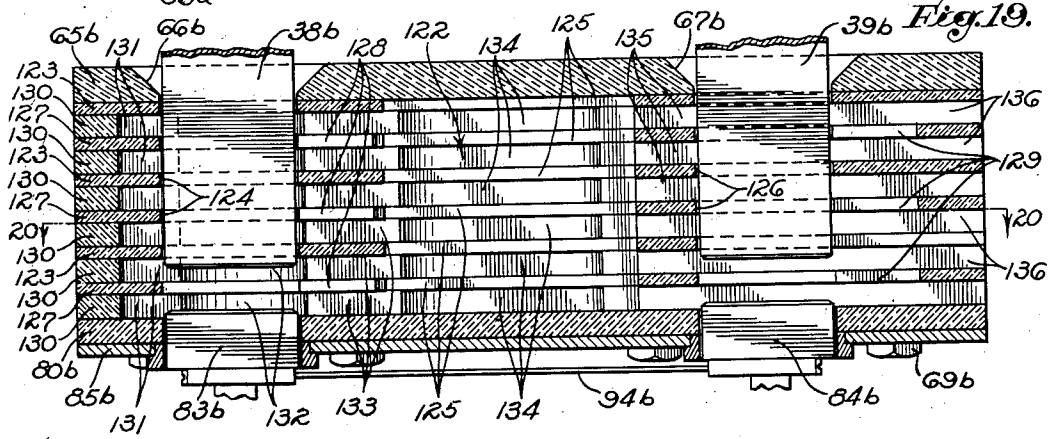


Fig. 16.

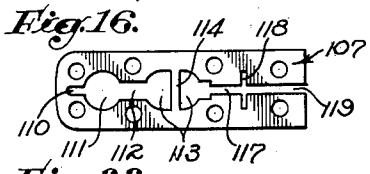


Fig. 20.

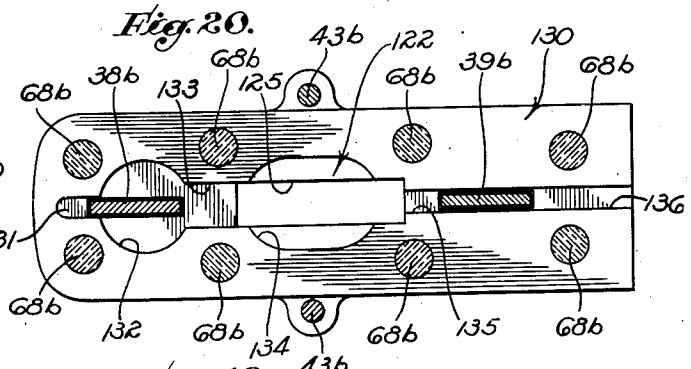


Fig. 22.

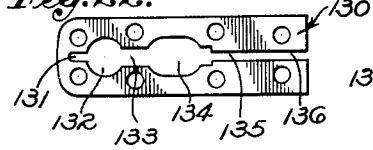


Fig. 17.

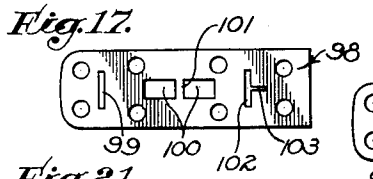


Fig. 18.

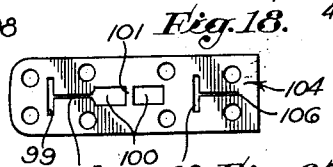


Fig. 21.

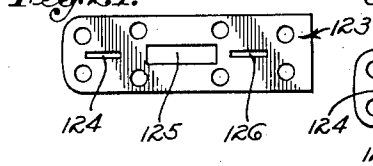
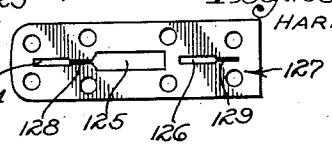


Fig. 23.



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Patented May 2, 1939 2,156,450

UNITED STATES PATENT OFFICE

2,156,450

APPARATUS FOR INTERRUPTING AN ELECTRIC CIRCUIT

Fred H. Cole, Glendale, Calif., assignor, by mesne assignments, to General Electric Company, a corporation of New York

Application June 7, 1937, Serial No. 146,786

18 Claims. (Cl. 200—150)

My invention relates to circuit breakers, particularly circuit breakers of the oil-blast type, and is directed to improvements in means for providing blasts of dielectric liquid and for relating such blasts to an arc for efficient extinction of the arc.

In circuit interrupters of the type involved here, one arc in a circuit is employed to gasify a liquid dielectric, thereby to generate a blast for extinguishing one or more other arcs in the circuit. In some circuit breakers the gas so generated is applied as a blast directly to the arc to be extinguished. In the present invention it is contemplated that the blast applied directly to the arc to be extinguished will be substantially completely liquid, and that the gas provided by vaporization of the liquid will have the function of actuating the extinguishing blast of liquid.

If a relatively cool fluid of high dielectric strength is forced through an arc to extract energy therefrom at a greater rate than energy is supplied by the arc, the arc space will become cooler. It has been determined experimentally that if the temperature of the arc space is brought below that necessary to maintain conduction or below the ionization point and the waste products are removed, the arc will be extinguished and prevented from re-establishing. The general object of the present invention is to employ a blast of a high dielectric liquid for efficient cooling of an arc and spaces associated therewith, the purpose being to provide such rapid transfer of heat from the arc and removal of waste and ionized products from the vicinity of the arc, that within a desirable time interval the temperature of the arc will drop below the level necessary to sustain the arc.

A further object of my invention is to provide for subjecting successive charges of liquid to the action of the generating arc, thereby causing the oil blast to be delivered in a series of high pressure spurts. The oil blast is characterized by sharp pulsations that account to an important extent for the exceptional results achieved with a given amount of gas generated. It is my purpose to provide such a multiplicity of blast impulses as to favor the occurrence of one or more impulses near or simultaneously with current zero in the arc to be quenched.

In my device, I contemplate the employment of a series of blast passages to direct the blast impulses into various points in the path of the arc to be quenched. It is an important object of my invention to provide such communication between two or more successive passages that the following results will ensue: pressure equalization between the passages preventing escape of oil from the path of advance of the leading end of the generating arc; pressure development in a passage prior to the direct action of the generating arc through that passage; delivery through a passage after the initial blast impulse therethrough of one or more subsequent blast impulses originating in subsequently effective passages.

In the preferred form of my invention, I propose to provide successive groups of passages inter-related for pressure equalization as indicated, whereby the series of phenomena resulting from such inter-relation of passages may be repeated during opening operation of the circuit breaker.

In my invention, I employ a hollow arc-quenching member of suitable insulating, and preferably organic, material to provide the voids, such as pockets, slots and passages, required to produce the desired blast effects, and one of my objects is to achieve those effects by applying certain principles to the configuration and disposition of those voids in relation to the arcs involved as will be illustrated by my ensuing disclosure. For example, I have discovered that the minimum cross-sectional dimension of a space into which a loop of an arc may be forced is approximately one-half inch, and the design of my arc-quenching member takes into consideration this fact.

In the circuit-breaking operation of the preferred embodiment of my invention, I have the object of causing the arc-quenching member to move out of the field of electrical stress between the contacts that remain connected with the circuit, leaving that field occupied almost entirely by dielectric liquid. By such arrangement, I accomplish the further object of avoiding mechanical members interconnecting said contacts that would offer paths of reduced electrical resistance therebetween. If the arc-quenching member were to remain between high voltage poles, it would probably flash over after a number of interruptions as a carbon path would build up on this member. A further object here is to cause the arc-quenching member to move through the dielectric liquid to discourage the accumulation of deposits of relatively low resistance on the exterior and interior surfaces of the member.

An advantage of moving the arc-quenching member, instead of the contacts permanently in the circuit, is that the arc-quenching member is relatively light and therefore may be moved with relatively light and simple mechanism. The difference in the cost of construction is substan-

tial, but more important is the fact that the arrangement permits extremely rapid operation of the circuit breaker.

Another object of my invention is to provide a simple laminated arc-quenching member constructed of flat plates, thereby avoiding certain problems associated with cylindrical construction, including the tendency on the part of cylindrical walls of oil-blast members to warp out of shape.

While the principles of my invention may be embodied in oil-blast circuit breakers of various types and ratings, they are particularly applicable to two-break circuit breakers of approximately 66 kv. rating or lower, and to illustrate these principles, I shall direct my specific disclosure to such a circuit-breaker.

The above and other objects and advantages of my invention will be apparent in my detailed description to follow, taken with the accompanying drawings, in which:

Fig. 1 is a view partly in section of a tank-type circuit breaker incorporating my invention, the circuit breaker being in circuit-breaking position;

Fig. 2 is a vertical medial section of the arc-quenching member with the contacts somewhat separated;

Fig. 3 is a similar view with the contacts only slightly separated;

Fig. 4 is a fragment of a similar view showing a pair of contacts in completely closed position;

Fig. 5 is a vertical transverse section on a somewhat reduced scale taken as indicated by the line 5—5 of Fig. 2, one of the contacts being broken away to show the construction of the oil-blast member;

Fig. 6 is a similar view taken along the line 6—6 of Fig. 2;

Fig. 7 is a similar view taken as indicated by the line 7—7 of Fig. 2;

Fig. 8 is a similar view taken along the line 8—8 of Fig. 2;

Figs. 9 to 14 are bottom plan views on a reduced scale of various plates employed to assemble the arc-quenching member;

Fig. 15 is a longitudinal vertical section of a modified form of my arc quencher;

Figs. 16 to 18 are plan views on reduced scale of plates employed in the construction shown in Fig. 15;

Fig. 19 is a longitudinal vertical section of another modification of my arc quencher;

Fig. 20 is a horizontal section on a somewhat reduced scale taken along the line 20—20 of Fig. 19; and

Figs. 21 to 23 are plan views on reduced scale of plates employed in the construction shown in Fig. 19.

In Fig. 1 showing one type of circuit breaker that may be employed to practice the invention, the usual tank, generally designated by the numeral 20, is filled with a suitable oil or other dielectric liquid to a level indicated by the numeral 21. The tank shown is rectangular in configuration, comprising an outer casing 22 and an inner liner 23. The cover 24 of the tank has an inner angular flange 25 adapted to retain a suitable packing member 26 that is normally compressed between the cover and the upper edge of the casing 22. By means such as suitable ears 27 integral with the cover, angle clips 28 mounted on the casing 22, and coacting bolts 29, the cover may be removably secured to the casing. A vent (not shown) may be added to the cover in the customary manner if desired.

A pair of insulating bushings 30 and 31 of a conventional type is shown mounted on the cover 24, each bushing extending downward through an aperture 32 in the cover. In the particular construction indicated, a supporting bushing 33 embraces each of the insulating bushings 30 and 31 and retains a packing sleeve 34 against the periphery of the insulating bushing. An overhanging flange 35 at the bottom of each supporting bushing 33 rests upon a packing ring 36, which ring in turn rests upon a metal ring 37 around the cover aperture 32.

The insulating bushings 30 and 31 are shown in simplified form to be tubular in construction, encasing respectively stationary contacts 38 and 39 in the form of rods of conducting material extending into the tank below the lower ends of the insulating bushings. Each of the two contacts 38 and 39 has an annular spacer 40 and is threaded into a metallic cap 40a at the top of the corresponding insulating bushing, each cap being connected to a wire 41 of the circuit controlled by my device. Preferably, the contacts 38 and 39 are constructed of some arc-resistant material, such as silver-tungsten or copper-tungsten alloys.

An arc-quenching member generally designated by the numeral 42 of insulating, and preferably organic, material is adapted for movement with respect to the stationary contacts 38 and 39, but it is to be understood that the operativeness of the arc quencher does not depend upon movement on its part and the principles of my invention may well be applied to constructions in which the arc quencher is stationary.

The arc-quenching member 42 is preferably constructed by assembling a series of plates, each of which will be described later, the assembled plates being held together by a pair of bolts 43, one of the bolts being on each side of the arc-quenching member. The bolts are secured respectively to angle clips 44, the clips being in turn secured as by rivets 45 to opposite sides of a vertical bar 46. The bar 46 is mounted as by screws 47 to a guide shank 48 of square or rectangular cross-sectional configuration, the shank being slidably embraced by a complementary guide sleeve 49 mounted in the tank cover 24. By virtue of this construction, the arc-quenching member 42 is guided along a vertical linear path and prevented from rotation during its movement.

In the simplified construction shown, vertical movements of the arc quencher 42 are controlled by a rocker arm 50, the rocker arm having a suitable slot 51 in engagement with a pin 52 associated with the guide shank 48. A shaft 53, to which the rocker arm 50 is keyed, extends through the wall of the casing 22, being suitably journalled therein, and carries on the exterior of the tank a second rocker arm 54. This second rocker arm is operatively connected to an actuating mechanism (not shown) through the medium of a suitable connecting rod 55.

Preferably, I provide a plate 23a on the interior of the tank liner 23, opposite the path of movement of the arc-quenching member 42, the plate being of suitable insulating and heat-resistant material to protect the liner.

The principle upon which the arc-quenching member 42 is constructed and the functions of such construction may best be understood by referring at the outset to Fig. 10 and stating that I contemplate providing in vertical sequence a

series of horizontally disposed voids, each void including a gas-generating chamber **56** and a blast passage generally designated by the numeral **57** leading from that chamber to an arc-space **58**. The purpose of each chamber **56** is to cooperate with one of the arcs formed in the opening operation of the circuit breaker to generate gas by vaporization of the entrapped oil, and the purpose of each blast passage is to direct the stream of liquid oil driven by the gas into a second arc formed in the arc-space **58**.

In the preferred form of my invention shown, a somewhat narrow pocket **59** is formed in the side wall of the generating chamber **56** opposite from the passage **57** and is disposed in the direction of the tendency of the generating arc to loop outward from the second arc. Preferably, the blast passage is not of uniform cross-section, but comprises, first, a relatively wide passage **60** leading from the generating chamber **56**, then, an expanded portion **61**, this expanded portion being followed by a restricted passage **62**, which may be referred to as the throttle of the blast passage. It is apparent that this restriction of the blast passage favors a high velocity of the blast discharge into the arc-space **58**, and further favors prolongation of the time interval in which the blast is effective. The arc-space **58** communicates with an exhaust passage **63** leading to the exterior of the arc-quenching member.

Various constructions may be employed to provide the required series of voids including generating chambers and blast passages. A feature of my invention in the preferred form is the employment of a laminated construction for the arc-quenching member **42**, the member being assembled from a plurality of plates variously shaped as indicated, for example, by Figs. 9 to 14 inclusive. While my invention will operate with complete satisfaction if the plates are made of such non-absorbent, inorganic materials as glass and porcelain, I prefer to employ some organic fibrous material well known for such use.

The uppermost plate **65** in the assemblage as shown in bottom plan in Fig. 9, has two beveled apertures **66** and **67** to receive respectively stationary contact rods **38** and **39**. For the purpose of unifying the assemblage, a plurality of downwardly projecting pins **68** of insulating material may be mounted on the bottom of the plate **65** to project downward through complementary openings **68***a* in the remaining plates, the pins being provided with suitable nuts **69** at the bottom of the assemblage. Beneath this uppermost plate **65**, relatively thin plates forming walls or partitions alternate with relatively thick plates that are shaped to provide the required series of generating chambers and blast passages. Thus, in the drawings thin plates **70**, **70***a*, **70***b*, **70***c*, **70***d* and **70***e* alternate with thick plates **71***a*, **71***b*, **71***c*, **71***d*, **71***e*, and **71***f*, each thin plate providing a horizontal wall above a generating chamber **56** and its associated blast passage **57**.

Each of the thin plates **70** is provided with a contact-receiving opening **72** above a generating chamber **56**, the opening being preferably displaced from the center of the generating chamber toward the wall opposite from the blast passage **57**, so that the forces generated in the chamber tend to be directed toward such passage, and so that the generating arc itself offers minimum interference with the escape of gas from the generating chamber. It may be noted that when the contact rod **38** extends downward through the arc-quenching member **42**, it fits into openings **72** with sufficient closeness to effectively isolate the generating chambers from each other, and that as the arc-quenching member is withdrawn from the contact **38**, the openings **72** and the generating chambers **56** are successively uncovered to form a continuous space for the generating arc.

Each of the thin plates **70** also has a second contact-receiving opening **73** complementary to the second contact rod **39**. It is contemplated here that when the circuit breaker is closed, the contact **39** will fit with sufficiently close clearance into the openings **73** to effectively seal or blast passages **57** from each other, and that in the opening operation of the circuit breaker, the arc-spaces **58** and the holes **73** will be uncovered successively to form a continuous space for the arc associated with the contact **39**. It is further contemplated that the dimensions of the arc-spaces **58** with respect to the diameter of the contact **39** will be such that within the extremely short time intervals of operating time, the contact will in effect close off the blast passages **57** in the manner of a valve. Since the passages **57**, together with the generating chambers **56**, constitute in effect blind passages, it is apparent that fluids therein are trapped until released by withdrawal of the contacts **38** and **39**.

Thin plates **70**, **70***b*, and **70***d* have very narrow and relatively short slots **74** extending outward from the contact-receiving openings **73**, as shown in plan in Fig. 11, and the alternate thin plates **70***a*, **70***c*, and **70***e* have similar but longer slots **75**, as shown in plan in Fig. 12.

A feature of my invention, as heretofore mentioned, is the inter-relation of voids of adjacent levels to provide for the transmission of pressure from one level to another. By preference, such provision for pressure equalization will be made only between certain levels so that the plurality of levels as a whole will be divided into groups of inter-related passages. In this manner I provide for repeating, during the opening operation of the circuit breaker, whatever useful phenomena are incidental to pressure equalization between adjacent levels. In the preferred form of my invention set forth in the drawings, I inter-relate the levels by pairs and provide three of such inter-related groups. Thus, the plates **70***b* and **70***d*, being of the configuration shown in Fig. 11, provide continuous partitions between the contact-receiving openings **72** and **73** to isolate the generating chambers and blast passages on either side of those plates to an effective extent; but, the plates **70***a*, **70***c*, and **70***e* that separate levels within a group are provided with equalizing openings **77**, as shown in plan in Fig. 12. Preferably in each of these plates there is a relatively narrow slot **78** extending from the pressure-equalizing opening **77** to the contact-receiving opening **72**, and a second relatively narrow slot **79** extending a short distance from the pressure-equalizing opening toward the other end of the plate, as indicated in Fig. 12.

Immediately below the plate **71***f* is a relatively thick plate **80**, as shown in plan in Fig. 13, the plate having apertures **81** and **82** to receive respectively lower contacts **83** and **84** that are complementary to the upper stationary contacts **38** and **39**. The plate **80** has a short, narrow slot **74***a*, corresponding to slots **74** of the plates **70**, **70***b* and **70***d*. Immediately below the plate **80** is a thinner plate **85** (Fig. 14) having relatively large openings **86** registering with the openings of the plate **80** and having ears **80***a* to receive

bolts 43. Bushings 87 loosely surrounding the contacts 83 and 84 are fixedly mounted in these openings 86.

Each of the contacts 83 and 84 has a lower integral flange 88 that seats against the corresponding bushing 87 when the contact itself extends to the level represented by the upper face of the plate 80, as shown in Figs. 2 and 3. Each of the two contacts 83 and 84 has a guide stem 89 that extends downward into sliding engagement with a guide aperture 90 in a closed contact housing 91 mounted on the bottom of the arc-quenching member 42 (Fig. 1). A suitable spring 92 acting between the housing 91 and the flange 88 serves to urge the contact continuously upward, and a shoulder 93 on the contact stem 89 is dimensioned to engage the housing 91 to limit the downward movement of the contact. The two contacts are interconnected by a conducting member 94 to close the circuit between the two pairs of contacts.

When the circuit breaker is in its normal, i. e., closed circuit position, the stationary contacts depress the corresponding lower contacts as indicated in Fig. 4. By virtue of this yielding arrangement for the lower contacts, proper engagement between the contacts is insured and the shock of closing the contacts is cushioned. The fact that the contact housing 91 constitutes a closed receptacle prevents the escape of fluids downward past the lower contacts 83 and 84.

If a relatively low current arc is submerged in a dielectric fluid, the gas generated by vaporization of the fluid forms a large bubble that isolates the arc from the liquid and tends to reduce the rate of gas generation, in which case the amount of gas generated may be too low to provide sufficient energy to extinguish an arc. On the other hand, a submerged arc energized by relatively high current tends to wander energetically about the surrounding liquid with the result that the quantity of gas generated is vastly in excess of the energy required to extinguish the arc. For satisfactory circuit interruption through a range of currents, it is required, therefore, that the arc-quenching structure provide a relatively large amount of blast energy per ampere for small currents, but a substantially smaller ratio for large currents. An arc quencher designed solely with considerations for the requirements of interrupting large currents probably would not develop sufficient energy to extinguish a low current arc; and an arc quencher designed solely to meet the requirements of low current operation would probably develop a disastrous amount of gas pressure when extinguishing a high current arc. Since it is my object to break the circuit towards the end of a half cycle near a current zero when the energy of the circuit is most apt to be at a minimum, the problem of large current operation is to avoid such violent blast action as would break the current in the middle of a half cycle when the energy of the circuit may be disastrously high.

A feature of an arc quencher constructed in accordance with my design is that while it favors generation of a relatively large quantity of gas with a low current arc by preventing the formation of large bubbles, by insuring in a positive manner intimate association of the arc with the liquid, by trapping the liquid to be gasified, and by providing for subjecting successive charges of liquid to the arc, it also controls the gas-generating activities of high current arcs by confining such arcs to a limited zone of action and by limiting the quantity of oil exposed to the arc.

When the contacts first begin to separate, as indicated by the positions of the contacts shown in Fig. 2, the oil in the lowermost level of voids is immediately acted upon by the generating arc. Even when the contact 39 is raised, as shown in Fig. 2, clear of the lowermost level of voids the formation of the generating arc is so rapid, the inertia of the oil body so great relatively, and the lowermost throttle passage 62 has such a retarding action, that the oil cannot escape the arc in the extremely short time interval involved in breaking a circuit.

Rapidity of gas generation is enhanced by the fact that the generating arc is magnetically moved outward into the lowermost oil pocket 59 and by the fact that the arc and the surrounding liquid are confined to spaces of restricted cross-sectional dimensions.

A further factor in determining the rate of gas generation is that the surfaces of oil-soaked, organic material bounding the generating chambers 56 and bounding the blast passages 57 within the range of the generating arc are relatively extensive. It will be noted that the narrowness of the pocket 59 and the width of the passage 60 adjacent the generating chamber both favor the intimate exposure of surfaces to the arc.

The continuity of blasting forces to insure favorable conditions for arc extinction at a succession of current zeros is insured, primarily by the fact that isolated oil bodies in the successive levels are successively released to the gas-generating action of the arc as the contact 38 withdraws to successive levels. In this connection an important function of the equalizing openings 77 may be pointed out. When the contacts are in the positions indicated by Fig. 3, the pressure from below exerted upward around the contact 38 tends to move the oil body in the next level away from that contact. This tendency is neutralized, however, by the fact that pressure from the lowermost level is also transmitted through the lowermost pressure-equalizing opening 77 to the second level, so that pressure on the oil in the second level immediately around the contact 38 is effectively equalized.

Further factors favoring continuous blast forces are that each blast passage provides an adequate volume of oil for sustained flow against the arc to be extinguished. The fact that each blast passage is throttled or restricted at 62 is of importance here as prolonging the release of this oil to the desired extent.

An important function of the equalizing openings 77 should be noted. When the contact 38 rises to the uppermost level of a group of levels, the blast forces generated in that uppermost level will be transmitted through the associated pressure-equalizing means to lower levels of the group and cause blast forces to be exerted through those levels. As a result, there will be effective blast forces exerted through a lower level subsequent to the initial blast through that level originating in its own generating chamber. Thus, when the contacts are in the positions shown in Fig. 3, an initial impulse originating in the lowermost generating chamber will be directed outward through the lowermost throttle passage 62, and when the contacts separate to the extent shown in Fig. 2, a subsequent impulse through the lower throttle passage 62 will be transmitted from the generating chamber of the second level through the lowermost pressure-equalizing opening 77. Also,

noted here as contributing to this phenomenon is the fact that the throttle **62** of the lowermost level serves to maintain pressure in the lowermost level, the result being that the full effect of the blast impulse from the upper level is felt immediately at the discharge end of the passage.

With respect to efficiency in the utilization of a given amount of blast energy without consideration of the efficiency with which that blast energy is generated, it may be pointed out that I increase the effectiveness of the blast energies available by transmitting those energies as a succession of explosive impulses directed into the body of the arc to be extinguished. The multiplicity of these impulses is accounted for by the fact that successive fresh bodies of oil are subjected to the action of the generating arc, and the fact that where there is a pressure-equalizing means immediately below the impulse force originating in a given level, that impulse force is exerted simultaneously on a plurality of levels.

Slots **78** and **79** associated with the equalizing openings may enter into various phases of the operations described, by serving to retain oil for blast-generation and by offering additional surfaces of gas-evolving material.

I have found that a loop of an arc subject to the force of an oil blast cannot be driven into a passage of substantially less than one-half inch in cross-sectional dimension. For example, a passage no larger than three-eighths of an inch in cross-section would be inoperative. If the spaces provided for displacement of the arc to be extinguished are substantially less, they serve no purpose; on the other hand, to provide spaces of much greater cross-sectional dimension is to make the arc-quenching member of unnecessarily large size. For efficiency of operation as well as economy of material, I prefer to make the relatively thick plates **71***a*, **71***b*, **71***c*, **71***d*, **71***e*, and **71***f* approximately one-fourth inch in thickness and the thin plates **70**, **70***a*, **70***b*, **70***c*, **70***d*, and **70***e* approximately one-eighth inch in thickness. It will be apparent, then, that two adjacent levels in the arc quencher provide a space of sufficient cross-sectional dimension to permit displacement of the arc by the forces of the oil blast, a narrow slot such as a slot **74** or a slot **75** not interfering with such displacement.

When the contacts of the circuit breaker initially separate to the extent indicated by Fig. 3, gases generated in the lowermost generating chamber **56** rise extremely rapidly to an effective pressure exerted against the relatively cool oil in the associated blast passage between the two pairs of contacts, and the oil in the blast passage is moved towards the arc between the contacts **39** and **84** and, in effect, acts as a liquid piston driven by the generated gas. Since the contacts **39** and **84** are slightly separated at the instant under consideration, the force of the oil blast from the lowermost level is exerted not only through the exhaust passage **63** of that level, but also upward through the narrow slots above that passage. As a result of such forces, as well as of the magnetic forces involved, the arc to be extinguished will probably bow outward as indicated by the dotted line **95** of Fig. 3.

When the opening movement of the circuit breaker progresses to the point indicated by Fig. 2, extending the arc into the generating chamber of the second level, the new charge of oil in the second generating chamber and the associated pocket **59** will be vaporized in an explosive manner and cause a powerful spurt of oil in the second level of the arc quencher. By virtue of the equalizing opening **77** between these two levels the same forces will also be exerted against the liquid piston in the lower level so that jets of oil will be discharged into the arc space **58** at two levels simultaneously.

At this point in the opening movement of the circuit breaker the arc to be extinguished may be displaced into an irregular loop as indicated by the dotted line **96** in Fig. 2. Under the forces of the oil blasts of the two levels the arc has been extended in length at a considerably faster rate than the rate of opening movement of the circuit breaker.

It will be noted that each pair of exhaust passages **63**, having in common a slot **75**, constitutes a space for the displacement of the arc, since the two passages measured through the slot are more than one-half inch in cross-sectional dimension; but beyond the slot the end portion **97** of the intervening plate (Fig. 12) serves as a barrier to limit the displacement of the arc. The electric arc tends to avoid the oil blast but, being confined to the same channels as the oil blast, cannot escape the effects of the blast. In this connection it will be apparent that barriers **97** not only tend to confine the arc to the exhaust passages but also serve to retard the escape of oil from the interior of the arc quencher. In the meantime, the arc having been displaced to the new path indicated in Fig. 2, the cooling action of fresh oil is effective on the original path and immediately completely de-ionizes the zones initially occupied by the arc. It will be apparent that fresh cool oil is continuously moved into the arc to deprive it of heat and ions.

In the performance of the circuit breaker described, an arc of as high as 15 kv. will always be extinguished before the second level of the arc-quenching member is reached, and an arc of as high as 66 kv., the full rating of the circuit breaker, will not exist past the third and fourth levels of the arc quencher.

The modification of my arc quencher shown in Fig. 15, the circuit breaker being partly open, is similar in general to my preferred arc quencher previously described, corresponding numerals being employed to indicate corresponding parts. The important features of this modification are the employment of relatively narrow contacts and the provision of equalization through all the levels of the arc quencher.

Upper contacts **38***a* and **39***a*, as well as lower contacts **83***a* and **84***a*, are relatively narrow in cross-sectional configuration with their long dimensions extending transversely of the arc quencher. The lower contacts **83***a* and **84***a* are yieldingly mounted on the arc quencher in the manner previously described and are interconnected by a conductor **94***a*.

The arc quencher is constructed preferably by assembling a number of flat plates, the assembly being held together by nuts **69***a* engaging pins as in the previously described construction. The top plate **65***a* of the assembly is provided with tapered apertures **66***a* and **67***a* to receive respectively the stationary contacts **38***a* and **39***a*. At the bottom of the arc quencher is a thick plate **80***a* and a thin plate **85***a*, both suitably apertured to conform with the cross-sectional configurations of the two lower contacts **83***a* and **84***a*.

Between the top plate **65***a* and the lower plate **80***a*, thin plates alternate with thick plates to provide passages at successive levels and to provide an equalizing chamber generally designated

by the numeral 96 that is common to all of these levels. I prefer to provide this equalizing chamber with a transverse barrier generally designated by the numeral 97, the barrier extending downward from the top of the chamber to a point spaced from the bottom thereof.

Thin plates 98 have the configuration indicated in Fig. 17, each plate having a contact-receiving opening 99 for the contact 39a, a pair of equalizing openings 100 separated by a transverse wall 101 to constitute a part of the barrier 97, a contact-receiving opening 102 for the contact 39a, and a slot 103 extending from the opening 102 longitudinally of the plate. Thin plates 104 have the configuration indicated by Fig. 18. The plates 104 are similar to plates 98 in having contact-receiving openings 99 and 102 and in having the equalizing openings 100 separated by the wall 101; they differ, however, in having longitudinal slots 105 extending from the opening 99 to the first equalizing opening 100 and differ in having slots 106 substantially longer than the corresponding slots 103 of the plates 98.

Thick plates 107 of the levels through which the barrier 97 extends have the configuration indicated by Fig. 16, each plate providing an oil pocket 110, a blast-generating chamber 111, a passage 112 having an expanded portion 113, a transverse wall 114 across the expanded portion of the passage to constitute a portion of the barrier 97, a restricted passage 117, a contact-receiving opening 118, and an exhaust passage 119.

A thin plate 120 has the same configuration as the plates 104 previously described, but the transverse wall 101 is omitted with the result that the plate has a single equalizing opening 100 instead of two. Since the pressure equalization provided by the chamber 96 extends through all the levels of the arc quencher, the arc quencher may be considered as comprising a single group of interconnected passages as distinguished from the plurality of groups of passages in the arc quencher first described.

As the generating arc is extended upward in the arc quencher shown in Fig. 15, the barrier 97 prevents generated gas from moving directly across the upper levels of the arc quencher. The barrier 97 deflects the gas into a circuitous path, or it may be said that gas generated at the upper levels is trapped in the portion of the equalizing chamber generally designated by the numeral 121. By such arrangement I eliminate the possibility of directing hot gases instead of relatively cool liquid into the arc to be extinguished.

Emphasis is given in the description of the first form of my invention to the desirability of rapidly filling with liquid the widening gap between the contacts forming the arc to be extinguished. It will be apparent that by providing relatively narrow contact members I reduce the length of fluid flow necessary to fill this widening gap and thereby reduce the time required for cooling that gap.

The purpose of including in my disclosure the modification shown in Fig. 19 is to illustrate, by way of example, how the arc quencher of Fig. 15 may be modified by omitting the transverse barrier in the equalizing chamber and/or by turning the relatively narrow contacts into longitudinal alignment with the arc quencher. The construction shown in Figs. 19 and 20 is similar to the construction previously described, corresponding numerals being employed to designate corresponding parts. In Fig. 19 upper contacts 39b and 39b are stationary while lower contacts 39b and 84b are yieldingly mounted in the arc quencher, the two contacts being interconnected by a conductor 94b.

As in the previously described constructions, the arc quencher is constructed preferably by assembling a number of flat plates, the assembly being held together by nuts 69b engaging pins 68b and being connected to actuating mechanism by means such as previously described, including a pair of bolts 43b. The top plate 65b of the assembly is provided with tapered apertures 66b and 67b to receive respectively the stationary contacts 38b and 39b. At the bottom of the arc quencher is a thick plate 80b and a thin plate 85b suitably apertured to conform with the cross-sectional configurations of the two lower contacts 83b and 84b.

Between the top plates 65b and the lower plates 80b, thin plates alternate with thick plates to provide passages at successive levels and to provide an equalizing chamber generally designated by the numeral 122, the chamber being common to all of these levels. Thin plates 123 have the configuration indicated in Fig. 21, each plate having a contact-receiving opening 124, an equalizing opening 125, and a second contact-receiving opening 126 for the contact 39b. Each thin plate 127 is similar to thin plates 123 in having the contact-receiving opening 126 and equalizing opening 125, but differs in having a slot 128 extending from the first contact-receiving opening to the equalizing opening and in having a second slot 129 extending longitudinally from the second contact-receiving opening.

Thick plates 130 have the configuration indicated by Fig. 22, each plate providing an oil pocket 131, a blast-generating chamber 132, a passage 133 having an expanded portion 134, and a restricted passage 135 that is continued as an exhaust passage 136.

This form of the invention operates in the same manner as the form shown in Fig. 15 with the exceptions involved in omitting the transverse barrier in the equalizing chamber and in turning the contacts into longitudinal alignment. The fact that the contacts 39b and 84b are aligned with the slots 129 is believed to be an advantage, since the slots are conveniently accessible to the arc.

Changes providing other forms and modifications of my invention within the scope of my conception are suggested by the specific examples herein set forth. I reserve the right to all such variations that properly come within the purview of my appended claims.

I claim as my invention:

1. A circuit breaker having in combination: an arc-quenching member of insulating material containing a dielectric liquid; means for forming a plurality of arcs in said arc-quenching member in the circuit to be interrupted; a plurality of passages in the arc-quenching member leading from the path of one of said arcs to the path of another of said arcs whereby pressure of gas generated by the first arc will cause blasts of liquid to be directed across the path of the second arc; and pressure-equalizing openings intermediate the two arcs interconnecting at least some of said passages.

2. A circuit breaker having in combination: means to form two arcs in a circuit; an arc-quenching member of insulating material containing a dielectric liquid; a plurality of blind passages in said member terminating at their in-

ner ends in the vicinity of the path of one of said arcs and directed outward across the path of the other arc; and pressure-equalizing openings interconnecting said passages.

3. A circuit breaker having in combination: an arc-quenching member of insulating material containing a dielectric liquid; means for forming a plurality of arcs in said arc-quenching member in the circuit to be interrupted; a plurality of passages in the arc-quenching member leading from the path of one of said arcs to the path of another of said arcs whereby pressure of gas generated by the first arc will cause blasts of liquid to be directed across the path of the second arc, said passages being divided into separate groups of passages; and pressure-equalizing means interconnecting the passages of each of said groups.

4. A circuit breaker having in combination: an arc-quenching member of insulating material containing a dielectric liquid; means for forming a plurality of arcs in said arc-quenching member in the circuit to be interrupted; a plurality of passages in the arc-quenching member leading from the path of one of said arcs to the path of another of said arcs whereby forces generated by the first arc drive blasts of liquid across the path of the second arc, said passages being divided into separate groups of passages and said passages being throttled at their discharge ends; and pressure-equalizing means interconnecting the passages of each of said groups.

5. A circuit breaker having in combination: means to form two arcs having tendencies to loop outward away from each other; an arc-quenching member of insulating material containing dielectric liquid; a plurality of blind passages in said member terminating at their inner ends in the vicinity of the path of one of said arcs and directed outward across the path of the other arc; pockets at the inner ends of said passages disposed in the path of the looping tendency of the corresponding arc; and pressure-equalizing openings interconnecting at least some of said passages.

6. A circuit breaker having in combination: means to form two arcs having tendencies to loop outward away from each other; an arc-quenching member of insulating material containing dielectric liquid; a plurality of blind passages in said member terminating at their inner ends in the vicinity of the path of one of said arcs and directed outward across the path of the second arc; pressure-equalizing openings interconnecting some of said passages; a plurality of spaced barriers in the arc-quenching member disposed on the looping side of the second arc; and narrow slots in said barriers disposed in the path of the looping tendency of the second arc and terminating short of the end of the arc-quenching member.

7. A circuit breaker having in combination: an arc-quenching member immersed in a dielectric liquid; a plurality of gas-generating chambers in said member; contact-receiving openings interconnecting said chambers; contact means operative through said openings with sufficiently close fit to substantially seal off said chambers from each other when the circuit breaker is closed, said means being adapted to draw an arc into said chambers successively; a plurality of blast passages leading from said chambers to the exterior of the arc-quenching member; contact-receiving openings interconnecting said passages; a second contact means operative through said last openings with sufficiently close fit to substantially seal off said passages from each other in the closed position of the circuit breaker, said means being adapted to draw an arc across said passages, each of said passages being dimensioned so as to be substantially closed by said second contact means; and pressure-equalizing means interconnecting at least some of said passages intermediate the two contact means whereby pressure generated by the arc in the chamber associated with one passage will be effective in a second passage prior to the generation of pressure in the chamber associated with the second passage.

8. A circuit breaker having in combination: an arc-quenching member containing dielectric liquid; a plurality of gas-generating chambers in said member; a plurality of blast passages from said chambers to the exterior of said member; means to draw an arc across said passages; means to draw an arc through said chambers to generate gas to cause successive blasts of liquid to extinguish the first arc; arc-receiving pockets in the wall of said chambers opposite from said passages; and arc-receiving slots in the walls separating said passages.

9. A circuit breaker having in combination: an arc-quenching member containing dielectric liquid; a plurality of gas-generating chambers in said member; a plurality of blast passages from said chambers to the exterior of said member; means to draw an arc across said passages; means to draw an arc through said chambers offset from the centers of said chambers to be adjacent the walls thereof opposite from said passages whereby forces will be directed toward said passages to propel liquid therethrough to extinguish the first arc; and pressure-equalizing openings interconnecting some of said passages.

10. A circuit breaker having in combination: a stationary set of contacts submerged in a dielectric liquid; a movable set of contacts also submerged in the dielectric liquid and forming pairs of contacts with said stationary set; a movable arc-quenching member in said liquid normally encompassing said contacts in their closed positions; a plurality of pockets in said member in the vicinity of one of said pairs of contacts to provide liquid for generation of gas by an arc across said pair of contacts in the opening movement of the circuit breaker; said pockets being progressively uncovered in accordance with said opening movement; a plurality of passages in said member leading from said pockets respectively past a second pair of said contacts to provide liquid for liquid blasts driven by said generated gas; and means to move both said arc-quenching member and said second set of contacts to provide the opening and closing movements of the circuit breaker, said means moving the arc-quenching member entirely clear of the stationary contacts.

11. A circuit breaker having in combination: a receptacle containing a dielectric liquid; an arc-quenching member movably mounted for movement in said liquid; a plurality of pockets in said member entrapping liquid for progressive generation of gas by the action of a generating arc; a plurality of passages individually communicating with said pockets respectively containing liquid for the extinction of a second arc; a pair of contacts comprising a contact fixedly mounted in the receptacle and a contact mounted on the arc-quenching member, said contacts being disposed to form a generating arc in said pockets succes-

sively; a second pair of contacts including a stationary contact mounted in the receptacle and a contact mounted on the arc-quenching member, said contacts being disposed to draw an arc to be extinguished across said passages successively; and means to move said arc-quenching member towards and away from said stationary contacts.

12. A circuit breaker having in combination: a receptacle containing a dielectric liquid; an arc-quenching member movably mounted in said liquid; a plurality of voids in the arc-quenching member for the generation and direction of arc-extinguishing blasts, said voids opening to the exterior of the arc-quenching member; contact-receiving openings communicating with said voids disposed to accommodate an arc to generate gas for blast energy and an arc to be extinguished by said blasts; pressure-equalizing openings interconnecting some of said voids; contacts in said openings carried by the arc-quenching member; corresponding contacts permanently connected with the circuit to be interrupted and fixedly mounted in the receptacle in alignment with said openings; and means to move the arc-quenching member towards and away from said fixed contacts to open and close said circuit.

13. A circuit breaker having in combination: an arc-quenching means of insulating material immersed in a dielectric liquid; contact means to draw a generating arc in said arc-quenching member; contact means to draw an arc to be extinguished in said arc-quenching member; an equalizing chamber in said arc quencher intermediate said contact means; a plurality of passages leading from said first contact means to the euqalizing chamber; and a plurality of passages leading from said equalizing chamber past said second contact means.

14. A circuit breaker having in combination: an arc-quenching means of insulating material immersed in a dielectric liquid; contact means to draw a generating arc in said arc-quenching member; contact means to draw an arc to be extinguished in said arc-quenching member; an equalizing chamber in said arc quencher intermediate said contact means; a plurality of passages leading from said first contact means to the equalizing chamber; a plurality of passages leading from said equalizing chamber to said second contact means; and a gas-deflecting barrier in the equalizing chamber.

15. A circuit breaker having in combination: an elongated passage having a cross-sectional dimension of not substantially less than one-half inch at its entrance and having maximum cross-sectional dimensions substantially under one-half inch at its exit; means to draw an arc across the entrance of said passage; and means to direct a blast of fluid into said passage in a manner to force a loop of the arc into the passage.

16. A circuit breaker having in combination: means to generate an arc to be extinguished; means providing a passage having an entrance adjacent said arc, the entrance of said passage and a substantial portion thereof near the entrance being not substantially less than one-half inch in cross-sectional dimension to accommodate a loop of said arc, said passage being restricted to substantially less than one-half inch in cross-sectional dimension towards the exit thereof to prevent extension of said arc loop beyond said exit; and means providing a fluid blast to drive said loop of the arc into said passage.

17. A circuit breaker of the fluid blast type comprising means forming an interrupting arc within an arc-extinguishing fluid upon opening of the circuit, an insulating exhaust passage extending transversely from the path of said arc and having an entrance portion into said arc which can be looped by a blast of said fluid, said passage having a portion restricted as compared with said entrance portion toward the exhaust part of said passage for limiting the extent of looping of said arc, and means for creating said fluid blast for driving said arc into said passage.

18. A circuit breaker of the oil blast type comprising a pair of contacts for forming an interrupting arc within an arc-extinguishing liquid, an insulating exhaust passage extending transversely from the path of said arc and having an entrance portion approximately one-half inch in cross-sectional dimension into which said arc can be looped by a blast of said liquid, said passage having a restricted portion substantially less than one-half inch in cross-sectional dimension toward the exhaust of said passage for limiting the extent of looping of said arc, and means for driving said liquid through said passage.

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