

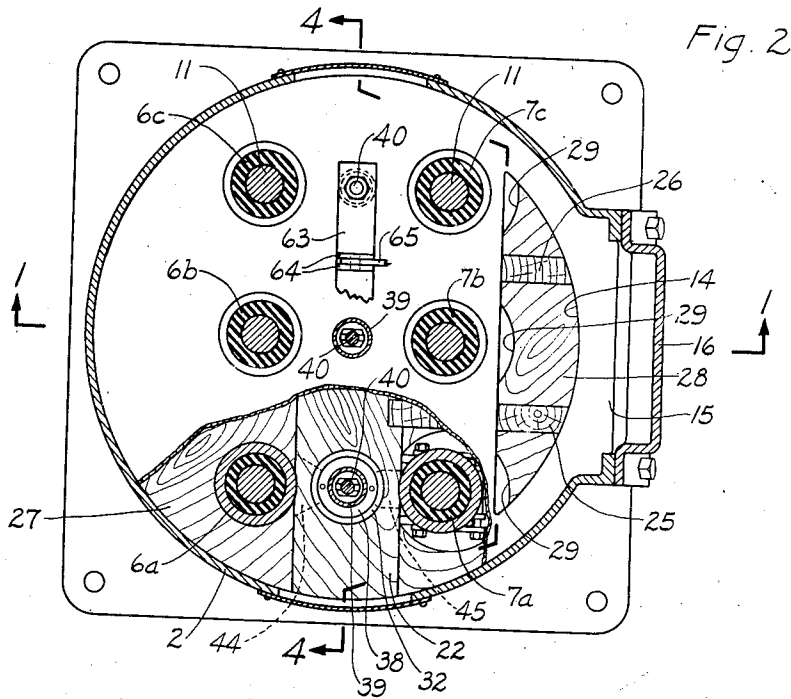
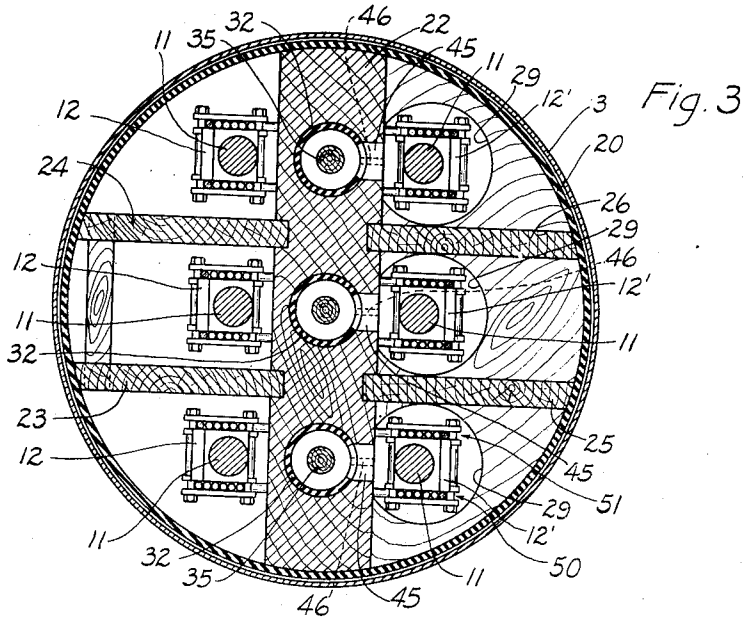
Aug. 19, 1941.

A. M. ROSSMAN
ELECTRIC CIRCUIT BREAKER

2,252,983

Filed Feb. 9, 1938

6 Sheets-Sheet 2



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6 Sheets-Sheet 3

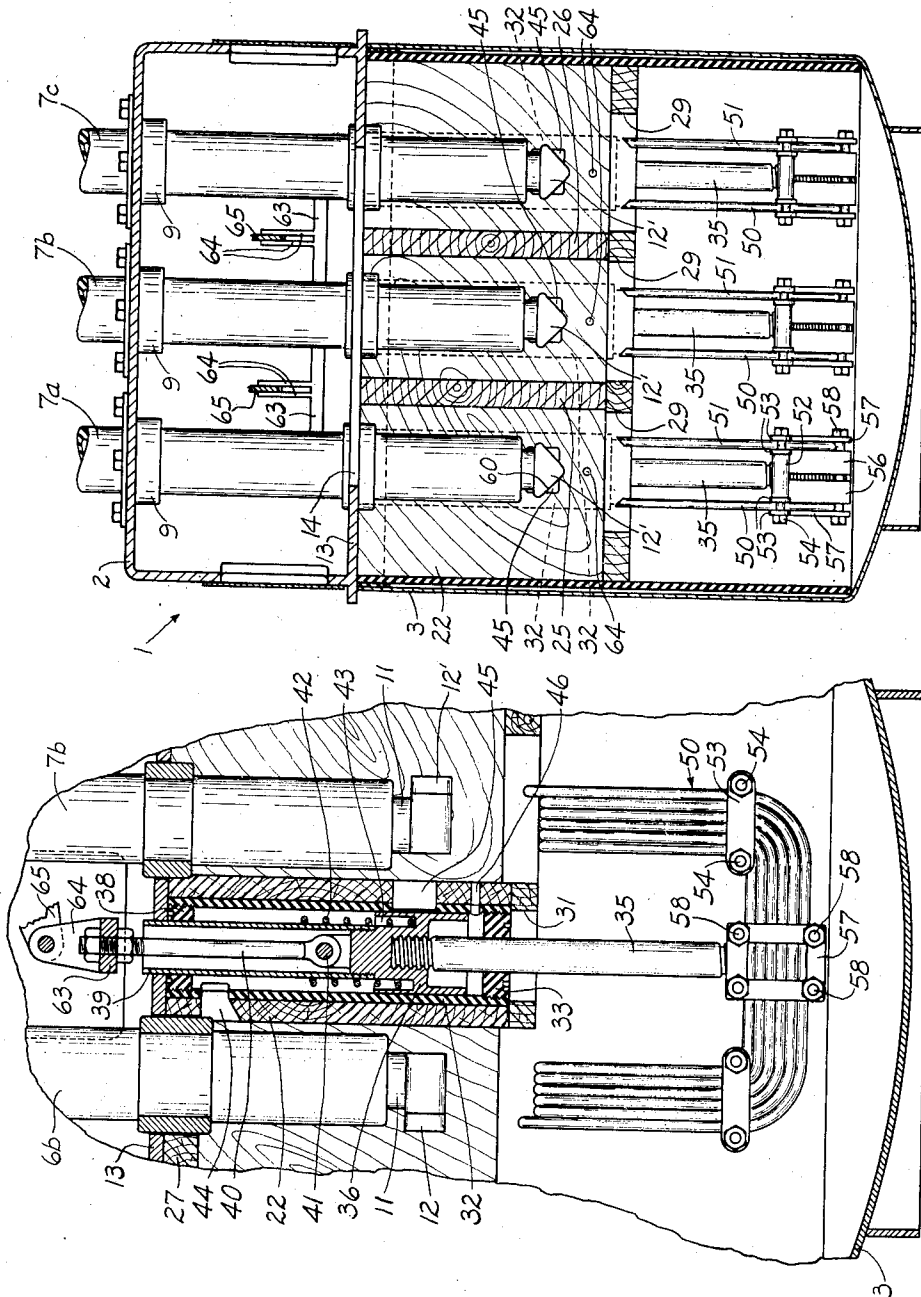


Fig. 4

Fig. 5

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6 Sheets-Sheet 4

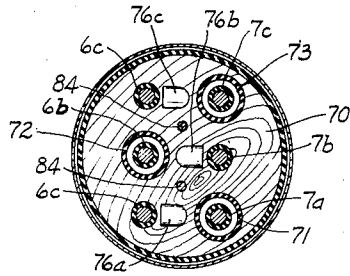


Fig. 6

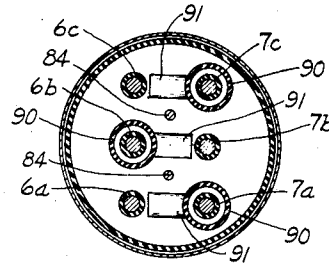


Fig. 8

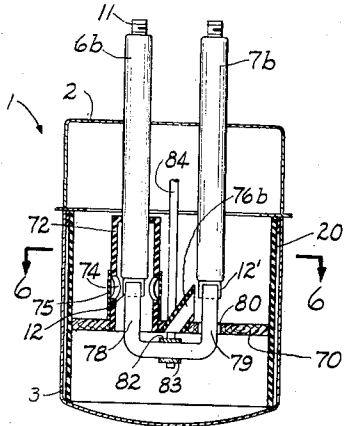


Fig. 7

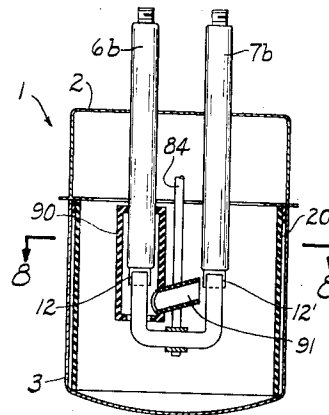


Fig. 9

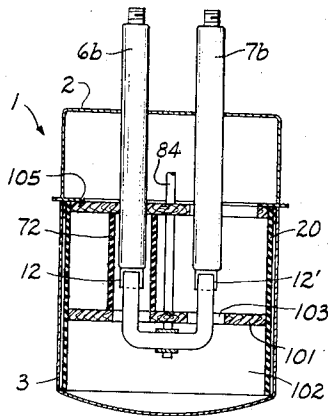


Fig. 10

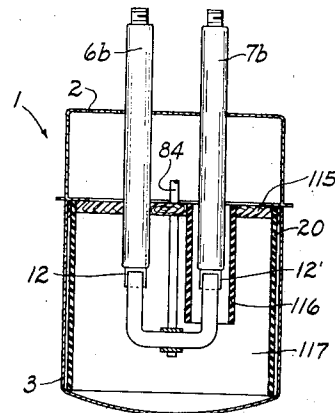


Fig. 11

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6 Sheets-Sheet 5

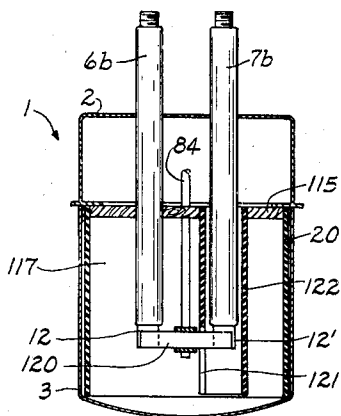


Fig. 12

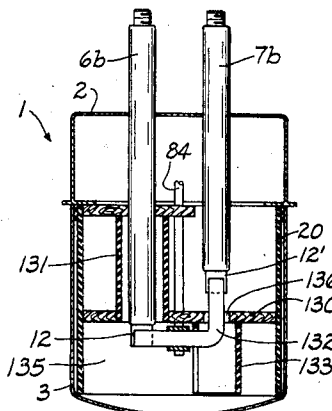


Fig. 13

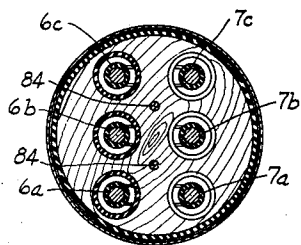


Fig. 14

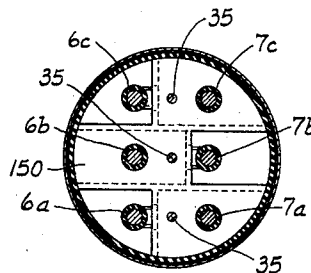


Fig. 16

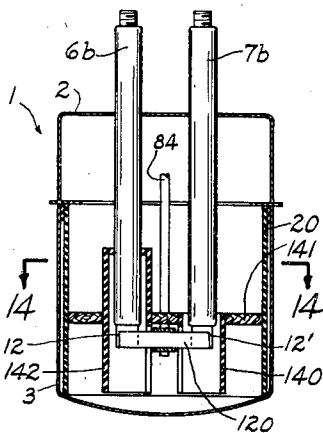


Fig. 15

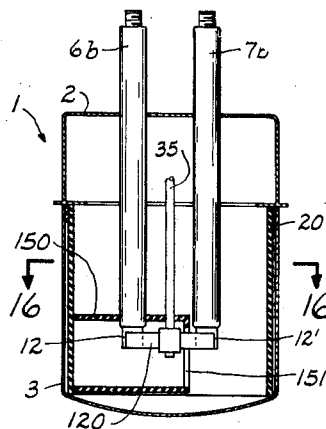


Fig. 17

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6 Sheets-Sheet 6

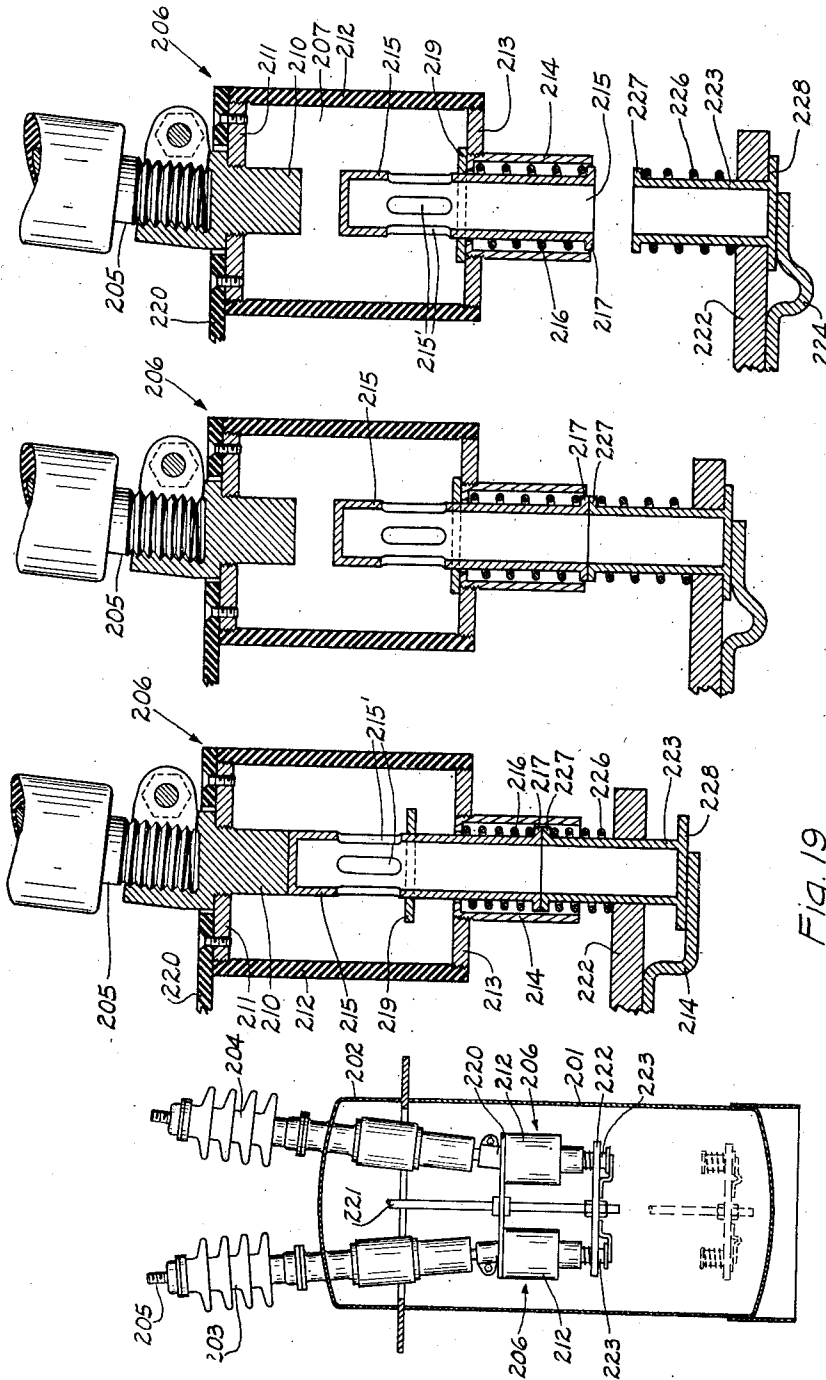


Fig. 21

Fig. 20

Fig. 19

Fig. 18

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UNITED STATES PATENT OFFICE

2,252,983

ELECTRIC CIRCUIT BREAKER

Allen M. Rossman, Wilmette, Ill.

Application February 9, 1938, Serial No. 189,615

24 Claims. (Cl. 200—150)

This invention relates to electric circuit interrupters, or circuit breakers, of the type wherein the circuit is opened by drawing a number of arcs in series and utilizing the pressure developed by one of the arcs to effect a flow of insulating fluid for extinguishing another arc, thereby interrupting the circuit. More particularly, this invention deals with circuit breakers of the above character wherein the circuit is interrupted in a bath of insulating liquid, such as oil for example.

In interrupting an electric circuit, particularly one of high kilovoltampere capacity, in oil, the resulting arc produces a gas bubble, and follows a path of ionized gas through the bubble. In an alternating current circuit, both the current the voltage across the gap and through the bubble pass through a zero value and reverse their direction twice during each cycle. The arc will be reestablished after each current reversal provided the resistance of the gap to breakdown is sufficiently low to permit the voltage to establish a path of ionized gas through the gap. Ultimate extinguishment of the arc results when the resistance of the gap to breakdown is sufficiently high to prevent the establishment of a path of ionized gas through the gap. This latter condition results when the separation of the terminals is sufficiently great to prevent the reestablishment of a path of ionized gases either through a medium which is composed exclusively of gas or through a medium which is composed partly of gas and partly of liquid. As the voltage required to break down a given thickness of liquid such as oil, is many times that required to break down the same thickness of gas, it follows that the interposition of a layer of liquid between the two terminals greatly increases the resistance to breakdown of the path between them and for a given peak value of voltage between terminals, requires a less separation of the contacts to prevent the reestablishment of the arc after it has been broken. Furthermore, the cooling effect of the body of oil around the arc bubble acts to deionize the same. In those circuit breakers wherein the arrangement is such that the magnetic forces produced by the current flow urge the arc towards the wall of the bubble, the cooling action and the consequent deionization is facilitated because the arc through the gas bubble is forced into the region of the bubble wall thus accelerating the cooling action at the place where the ionization is the greatest. Circuit breakers relying primarily upon the length-

ening of the arc gap and the magnetic blowing of the current path through the bubble towards the wall of the bubble have been relatively successful for low and medium KVA capacity breakers. However, with breakers of high KVA capacity other means are desirable to prevent the reestablishment of a broken arc. One known type of circuit breaker provides means whereby cool oil is blown through one of the arc paths, the pressure for blowing that oil through the arc path being developed by the other arc in series therewith. It is with this type of circuit breaker that the present invention is primarily concerned.

In a circuit breaker of the above type one of the arcs may be termed the circuit interrupting arc and the other may be termed the pressure developing arc. Oil is caused to flow under pressure created by the pressure developing arc into the path of the other arc. However, the circuit interrupting arc also develops a pressure and therefore, in the prior constructions, the pressure developing arc had to develop sufficient pressure to force oil through the circuit interrupting arc against the pressure developed by the circuit interrupting arc. It is one of the objects of the present invention to provide a simple circuit breaker structure of the above mentioned character wherein the arrangement is such that the circuit interrupting arc develops a comparatively small pressure in a direction resisting the flow of insulating liquid set up by the other arc. This is accomplished by providing an arrangement such that the flow of oil in the region of the circuit interrupting arc under the pressure developed by the other arc moves the arc bubble in the same direction as the arc bubble of the circuit interrupting arc would move if the pressure developing arc were absent. By this arrangement the resulting motion of the arc bubble at the circuit interrupting arc is under the cumulative action of the buoyancy of the arc bubble, and the force of pressure developed by the pressure developing arc.

It is a further object of the present invention to provide a circuit breaker of the above type wherein the circuit interrupting arc is in a loop circuit so that resulting magnetic action tends to sweep the arc towards the wall of the gas bubble and wherein the buoyancy of the gas bubble and the force of the oil blast are both in the same direction so that all three forces act simultaneously to inhibit arc reformation after

the current through the arc has passed through a zero value.

It is a still further object of the present invention to provide a circuit interrupter of the above character wherein the buoyancy of the arc bubble is utilized and at the same time there is substantially no action of the arc bubble to push the oil blast out of its path of maximum utility. By this arrangement practically all of the oil of the oil blast is utilized for displacing and cooling the arc gas bubble, the arc gas bubble assisting or at least not substantially interfering with the freedom of movement of the oil under the action of the pressure developing arc.

It is another object of the present invention to provide a circuit breaker wherein the entire mass of oil that is set into motion by the pressure developing arc can be utilized for effecting a movement of oil through or around the circuit interrupting arc.

In accordance with one of the principles of the present invention substantially the entire bulk of the body of insulating liquid of the tank is between the pairs of contacts that are being separated. One of the sets of contacts produces an arc in a pressure developing chamber that is substantially devoid of gas or other compressible media so that the pressure developed by the arc therein can expel a maximum amount of oil from that chamber into an arc extinguishing chamber. All of the oil thus expelled pushes the great mass of the body of oil of the tank ahead of it so that a like quantity passes from the pressure developing chamber into the other chamber and into the path of the other arc. The circuit interrupting arc is entirely outside of the pressure chamber so that none of the oil in the pressure chamber is dissipated by the other arc for non-blast producing purposes.

It is a further object of the present invention to produce an oil circuit breaker of the above mentioned character which will be simple in construction and reliable in its action and which will be economical of manufacture.

It is another object of this invention to provide an arrangement whereby certain types of non-oil-blast circuit breakers may be converted into oil blast breakers with a minimum of change in the breaker arrangement and at a minimum of cost.

It is a still further object of the present invention to provide an improved retarding mechanism for decelerating the movement of the contact making members as the same approach the switch open position without interfering with the initial switch opening movement, thus allowing a high speed initial opening movement with a cushioned stop at the end of the opening operation.

The attainment of the above and further objects of the present invention will be apparent from the following specification taken in conjunction with the accompanying drawings forming a part thereof.

In the drawings:

Figure 1 is a longitudinal sectional view through a circuit breaker embodying the present invention, said view being taken along the line 1—1 of Figure 2;

Figure 2 is a transverse cross sectional view of the circuit breaker of Figure 1, said view being taken along the line 2—2 of Figure 1;

Figure 3 is a sectional view taken along the line 3—3 of Figure 1;

Figure 4 is a view at right angles to Figure 1, said view being taken along the line 4—4 of Fig-

ure 2, and showing the switch in its open position;

Figure 5 is a fragmentary view of a part of Figure 1, and illustrating the switch in its open position;

Figure 6 is a sectional view taken along the line 6—6 of Figure 7;

Figure 7 is a diagrammatic view of another circuit breaker, illustrating another embodiment of the present invention;

Figures 8 and 9 are views corresponding to Figures 6 and 7 and illustrating another embodiment of the present invention, Figure 8 being a section taken along the line 8—8 of Figure 9;

Figures 10, 11, 12, 13, 15 and 17 are diagrammatic views illustrating other embodiments of the present invention;

Figure 14 is a sectional view taken along the line 14—14 of Figure 15;

Figure 16 is a sectional view taken along the line 16—16 of Figure 17;

Figure 18 is a longitudinal sectional view through a single phase high voltage circuit breaker embodying the present invention;

Figure 19 is an enlarged longitudinal sectional view of one of the contact structures and pressure chambers of the circuit breaker of Figure 18; and

Figures 20 and 21 are views corresponding to Figure 19 and illustrating different positions of the contact making structure.

Similar reference numerals throughout the various figures of drawings indicate similar parts.

Reference may now be had more particularly to the circuit breaker illustrated in Figures 1 to 4 inclusive. The circuit breaker is indicated in general by the reference numeral 1, and includes a dome or head 2 from which is suspended the usual tank 3 in the usual manner, the tank 3 forming a fluid tight fit with the head. The circuit breaker here illustrated is a three phase circuit breaker. The top of the head or dome has three pairs of insulating bushing openings through which insulating bushings 6a, 6b and 6c, and 7a, 7b and 7c extend, the bushings being held in place by the usual collars 9 bolted or otherwise suitably secured to the top of the circuit breaker. Through each insulating bushing extends a conductor 11 that terminates at its bottom in a switch contact, indicated at 12 and 12' in Figure 1. The bottom of the circuit breaker head is provided with a horizontally extending base plate 13 forming an integral part of the head and which base plate is provided with a large opening 14 at one side thereof to permit free communication between the space on the inside of the circuit breaker head and the circuit breaker tank. At its side the circuit breaker head 2 has an opening 15 through which extend the operating links and levers for operating the circuit breaker. A closure 16 closes the opening 15 and provides bearings for a rotary operating shaft 17 that is oscillated by a link or crank 18 on the outside circuit breaker head to oscillate the shaft and, through the links and levers within the head 2, to cause movement of the circuit breaker contact making member, to be presently described.

Within the tank 3 there is provided the usual cylindrical insulating liner 20 which forms a substantial sealing fit with the top of the tank 3, by means of a ring gasket or the like 21.

Means is provided on the interior of the circuit breaker tank for dividing the circuit breaker into two separate communicating chambers.

This means comprises a vertically extending centrally located barrier 22, of wood or other suitable insulating material, which extends across the tank making a sealing fit with the liner 20 and projecting downwardly a substantial distance from the base plate 13. Vertical insulating partitions 23, 24, 25 and 26 extend from the central barrier 22 to the liner 20 between adjacent phases and act as barriers to preclude all possibilities of arc-over between adjacent phases, as is apparent from Figure 3. At the top of the partitions 23-24 there is provided an arcuate wooden spacer 27 that extends from the insulating liner 20 to the central barrier 22. At the bottom of the partitions 25-26 there is an arcuate wooden partition 28 having three oversized openings 29, one for each phase. The compartments formed by the partitions 25-26 communicate at the top with the circuit breaker head through the opening 14, and communicate at their bottom with the interior of the circuit breaker tank through the openings 29.

Within the central insulating barrier 22 there are formed three vertically extending circular openings, one for each phase, indicated at 31, through each of which extends an operating rod and dash pot arrangement to be presently described. In each vertically extending opening there is mounted an insulating tube or liner 32 closed at its bottom by a screw plug 33 having an opening 34 through which an insulating operating rod 35 is slidable. The operating rod 35 is secured to a piston 36 at its upper end. At the upper end of the tube or liner 32 there is threaded a closure plug 38 which is provided with a central opening through which a tube 39 slides with a sealing fit. The tube 39 is screw threaded to the top of the piston 36. The piston 36 also has a connecting rod 40 joined thereto about a pivot pin 41. A spring 42 extends from the bottom of the plug 38 to the piston for accelerating the initial switch opening movement and reducing the amount of force required to start the opening movement. This spring also cushions the closing operation. The spring extends into a circular groove 43 in the piston.

The barrier 22 and the tube or liner 32 are each provided with a large opening 44 above the piston and with a large opening 45 below the piston when the piston is in the position illustrated in Figure 1. The opening 45 is covered by the piston as the piston approaches its switch open position. A restricted opening 46 is provided in the barrier 22 and tube or liner 32 below the lowermost limit of travel of the piston 36.

The central barrier plate 22 with the vertical partitions 23, 24, 25 and 26, and the cover plate 27 and partition 28 are secured together as an assembly and then bolted or otherwise rigidly secured to the base plate 13 of the circuit breaker head so that thereafter this assembly constitutes a part of the circuit breaker head.

The switch operating rod 35 supports and operates a bridging member which is adapted to be moved into and out of bridging relationship to the contacts 12-12' of the same phase. The contact making structure comprises two groups of U-shaped wires 50 and 51 (Fig. 4) the wires of each group being nested together, as indicated in Figure 1. The group of nested wires are secured together in spaced relationship by tubular spacers 52, inner and outer clamping plates 53, and through bolts 54 extending through the

clamping plates 53 and the spacer tubes 52, as illustrated in Figure 4. The bight portions of the U-shaped groups of wires are secured together in spaced relationship at their center by blocks 56, that receive the insulating operating rod 35 between them, and rectangular clamping plates 57 on the outside of the nested groups of wires 50-51. Four through bolts 58 extend through the rectangular clamping plates and the blocks 56 to secure the assembly together. The U-shaped wires are free of one another above the clamping plates 53 so that the arm of each wire is freely flexible independently of the other arms. Each U-shaped wire comprises, preferably, a jacket of copper or the like and a core of material having, preferably, a higher elasticity than copper, such as ordinary steel. If a non-magnetic core is desired then the core may be formed of non-magnetic steel alloy, or of bronze or the like. The groups of wires 50-51 embrace each contact 12-12' on opposite sides thereof, the contact serving to spread the wires of the two groups slightly and by said spreading action to cause each wire to exert a spring pressure against the contact. The outermost wire of the U-shaped group of wires is somewhat longer than the others so that all of the arcing will take place at the outermost wire.

Each contact stud 12-12' is of a generally triangular shape, as may be seen in Figure 4, so that when the wires ride up on the inclined surfaces 60, during the switch closing operation, the spreading action of the wires will be gradual and the wires will act as a resilient cushion or spring to reduce any shock that might otherwise be incident to the switch closing operation.

The three connecting rods 40 of the respective phases are interconnected at their top by a cross bar 63. A clevis 64 is secured to the cross bar 63 between the B and C phase and a similar clevis is similarly secured to the cross bar between the A and B phase. Operating beams 65 are secured to the respective clevises and suitably interconnected, and connected to suitable linkages to a crank 66 on the shaft 17 so that oscillation of the shaft 17 causes reciprocation of the connecting rods 40 to move the circuit breaker to its open or closed position. The provision of the pivot joints 41 eliminates the necessity for setting up the tubes 32 of the three phases in perfect alignment.

The circuit breaker is filled with insulating oil to a level above the bottom of the spacer 27 and, preferably, below the top thereof. The space below the spacer 27 is devoid of gas or other compressible media.

An explanation will now be given of the manner of operation of the circuit breaker thus far described. Upon downward movement of the connecting rod 40 the piston 36 causes downward movement of the operating rod 35 and downward movement of the U-shaped contact making members. At this time the top of the piston is open at 44 to pressure on one side of the circuit breaker and the bottom of the piston is open at 45 to pressure on the opposite side of the circuit breaker. As the connecting rod continues its downward movement, and gains speed, the bridging member finally separates from the contacts 12-12' and two arcs are drawn in series for each phase. The expanding gas bubble formed by the arc at the contact 12' causes the insulating oil adjacent thereto to move upwardly

through the opening 14. The expanding gas bubble formed at the contact 12 forces oil from the surrounding chamber outwardly through the openings 29. It is to be noted that the current is flowing through the two arcs in opposite directions. As a result the magnetic forces produced by the current flow will cause the two arcs to be bowed outwardly. The arc at the contact 12' is thus bowed into the path of oil flowing upwardly through the opening 29. The upwardly moving stream of oil thus serves not only to cool the arc bubble but also to force it upwardly, the moving oil assisting the natural buoyancy bubble to force the bubble upwardly and break the ionized path within the arc bubble between the contact and the contact making member. During the switch opening movement the downward motion of the piston 36 forces some of the oil from within the tube 32 outwardly through the openings 45 and 46 directly into the arc stream thus further facilitating arc extinguishment. After a substantial switch opening movement the skirt of the piston 36 commences to cover the opening 45. As the opening 45 is being covered, the egress of oil from the tube or liner 32 is being progressively restricted so that when the entire opening 45 is covered the only possible avenue of escape of oil from the tube is through the restricted opening 46. This retards further descent of the piston 36 so that the piston and the mechanism moving therewith comes to a gradual stop.

Movable members having one end in the pressure chamber and the other end outside of the pressure chamber present areas which are acted upon by the excess pressure in the pressure chamber during the switch opening operation. The forces thus set up tend to oppose opening of the circuit breaker. In the construction thus far described these forces are balanced by providing counteracting areas on the piston members 36 that are acted upon by the pressure in the pressure chamber. The excess pressure in the pressure chamber exerts a downward thrust on the upper faces of the pistons equivalent to the upward thrust of those members which have one end in the pressure chamber and the other end in the other chamber, thereby neutralizing the effect of the upward thrust. If desired the areas at the top of the pistons 36 exposed to the pressure of the pressure chamber may be made larger than is necessary for counterbalancing purposes, whereby the excess thrust due to the pressure in the pressure chamber actually assists the switch opening movement.

Of the two arcs that are drawn in series for each phase, the arc at the contact 12 is drawn inside the pressure chamber, and the arc at the contact 12' is drawn outside of the pressure chamber. This is a distinct advantage over drawing both arcs in the pressure chamber. Only the arc at the contact 12 is effective in setting up a movement of oil which is usefully employed in breaking the circuit. The movement of oil set up by the second arc, if it occurs inside the pressure chamber is detrimental. It would tend to build up within the pressure chamber an excess of pressure and tend to expel from the pressure chamber a quantity of oil with no useful effect. It would tend to oppose rather than assist the action of the first arc in breaking the circuit. When only one arc per phase is drawn inside the pressure chamber, lower pressures are involved and there is less turbulence of the oil in the pressure chamber.

It is to be noted that the insulating bushings

6 of the respective phases are centered in the base plate 13 and spacer 27 by a ring or collar secured to the bushing and which does not make a sealing fit with the base plate and the spacer. There is a small space between the collar and the base plate and between the collar and the spacer 27. As a result, any gases formed by the arc at the contacts 12 are free to ultimately escape from the pressure compartment into the space within the head of the circuit breaker.

To close the circuit breaker the mechanism is operated to raise the connecting rod 40, thus raising the piston 36 and the contact making structure until the contact making wires engage the contacts 12—12'. Thereupon further upward movement of the contacting making structure causes the contacts to ride on the triangular sides 60 of the contacts producing a spreading action of the contact making wires thus causing the wires to exert a spring pressure against the contacts.

It is desired to inspect the contacts or contact making structure of the circuit breaker above described it is merely necessary to lower the tank 3 together with the liner 29. When this is done it is apparent that the contacts and the contact making structure is fully exposed to view.

Reference may now be had to the embodiment of the present invention illustrated in Figures 6 and 7. In this embodiment of the invention the circuit breaker is divided into two compartments by a horizontally extending baffle 70 of wood or other suitable insulation which makes a liquid-tight substantially sealing fit with the insulating liner 29. Secured to the baffle and projecting upwardly therefrom are three tubes of insulation 71, 72 and 73 in staggered relationship, as illustrated in Figure 6. Each tube of insulation fits snugly into an opening at the bottom of the baffle 70. The bushings 7a, 6b and 7c extend through the closed top of the tubes 72, the tubes making a rather loose fit therewith to permit a slow egress of gases or the like from the tubes 72, when gases are generated therein. The contact structure at the bottom of the bushing 6b is within the tube 72, the tube being provided with inspection openings 74 closed by the short slidable tube 75 that may be slid upwardly on the tube 72 to uncover the opening 74 and expose the contact making structure for inspection. The contact making structure for each phase comprises two groups of U-shaped wires with the wires of each group nested together and adapted to embrace the opposite sides of the contact, in the manner illustrated in the switch previously described. Since the bridging members and the manner of making and interrupting the circuit for each of the three phases are alike, a description of the action on one phase will be sufficient. The arm 78 of the bridging member extends into the tube 72 and engages the contact at the bottom of the insulator bushing 6b. The arm 79 of the bridging members extends through a slightly oversized opening 80 in the baffle 70 into engagement with the contact at the lower end of the bushing 7b. The baffle 70 is provided with three nozzle like chutes 76a, 76b and 76c, one for each phase. Each of these chutes opens at the bottom into the chamber below the baffle 70, which is the pressure chamber, and discharges at the top into the region of the adjacent arc.

The bridging members for three phases are secured together in any desired manner, as for instance, by means of upper and lower cross bars 82—83 and supported by a pair of rods 84—84

located between the A and B phase and between the B and C phase. This construction is illustrated more fully in my pending application, Serial No. 186,177, filed January 21, 1938.

The interior of the circuit breaker above described is thus divided into two chambers. One of the chambers, which will hereafter be referred to as a pressure chamber, includes all of the space below the baffle 70 and also the space within the three tubes 72. The second chamber, which is the arc extinguishing chamber, includes all of the space above the baffle 70 except the interiors of the tubes 72.

During circuit interruption the downward movement of the bridging member opens the circuit at the contacts 12 and 12' causing two arcs to be drawn. The expansion of the gas bubble at the arc 12 creates a pressure within the pressure chamber thereby forcing cool oil from said chamber through the chutes such as 76b into the region of the arc at the contact 12'. The arc at the contact 12' is also being blown outwardly by the magnetic forces resulting from the flow of current in the arc at the contact 12 in the opposite direction to the flow of current at the contact 12'. As a result the arc bubble is forced to the right, as seen in Figure 7, by the combined action of the magnetic force and the stream of cool oil flowing upwardly from the pressure chamber through the chute 76b. The arc at the contact 12' is thus quickly extinguished, thereby causing interruption of the circuit and extinguishment of the arc at the contact 12. Thereafter the gases in the tube 72 as a result of the arc formation will slowly escape through the top of the tube.

It is to be noted that the tubes 72 and the arc chute, for the three phases, are staggered, as is clear in Figure 6. This reduces the unbalanced forces which might otherwise skew the cross bars 82-83 carrying the contact making structures for the three phases due to the fact that one end of each contact making assembly is in the pressure chamber and the opposite end is outside of the pressure chamber.

Reference may now be had more particularly to Figures 8 and 9. In this circuit breaker the contact and contact making structure is the same as in the breaker of Figures 6 and 7. Here, however the baffle 70 of Figure 7 has been entirely omitted. Instead the contact 12 has been surrounded by an oversized tube of insulation, indicated at 90, which constitutes a pressure chamber. This tube or pressure chamber has an opening in which is fitted a short tube 91, constituting a nozzle, which opens adjacent the contact 12' so that oil discharged from the pressure chamber 90 through the nozzle 91 will be blown into the region of the arc at the contact 12'. When this circuit is opened the expanding arc formed at the contact 12 forces oil from the tube 90 through the nozzle 91 to flow with great rapidity into the region of the arc at the contact 12', since the tube 90 is full of oil and devoid of compressible media. The rapid movement of cool oil from the opening 91 into the arc at 12' causes quick extinguishment of the arc at 12' and resulting circuit interruption. Non-condensing gases formed by the arc in the pressure chamber 90 slowly escape from said chamber through the top thereof, the chamber being provided with restricted openings at the top, or being made to fit around the bushing 6b with sufficient looseness to permit such escape of gas while at the same time

preventing a rapid escape of oil during circuit interruption. In this circuit breaker, as in the circuit breaker of Figures 6 and 7, the pressure chambers for the three phases are staggered on opposite sides of the longitudinal center line of the breaker thus minimizing any unbalanced forces on the switch operating mechanism. Also, the tubes of insulation around alternate contacts prevent arc-over between adjacent phases. It is also to be noted that the pressure in the pressure chamber 90 acts upon the contact making structure to force the same downwardly, which is the direction of switch opening movement. At the place where the contact making member enters the arcing chamber 90 there is provided a comparatively close fit between the movable contact making structure and the arcing chamber to prevent any appreciable loss of oil from the arcing chamber through the space between the movable structure and the chamber wall. Thus the total unbalanced force on the movable contact making structure or bridging members is of a magnitude equal to the difference of pressure on the two sides of the longitudinal center line of the breaker, due to the staggered arrangement of the arcing chambers 90.

Reference may now be had more particularly to the switch illustrated in Figure 10. In this construction the circuit breaker tank is divided in two by a horizontal partition or baffle 101 corresponding to the baffle 70 of Figure 7, and provided with an insulating tube 72 loosely surrounding the contact which generates the pressure developing arc. The essential difference between this construction and the construction illustrated in Figure 7 lies in the fact that the chute 76 has been omitted so that all of the oil which is set into motion by the pressure generating arc escapes from the pressure chamber 102 by way of an opening 103 in the baffle 101. In this construction the arc at the contact 12' is blown outwardly by the magnetic forces due to the current flow, as heretofore described, and the upwardly moving stream of cool oil flowing through the opening 103 tends to cool and blow out the arc which is formed at the contact 12'. An insulating brace 105 is provided for supporting the top portions of the three tubes 72. The oil level in the circuit breaker extends slightly above the top of the tube 72, and the top of this tube is arranged to permit the slow escape of gases therefrom which are formed during the circuit interruption. In the circuit breaker illustrated in Figure 10 the pressure generating arcs which are surrounded by the tubes 72 are arranged in staggered relationship, as in Figures 6 or 8. As a result the pressure generated during the circuit interruption is ineffective to exert undue bending stresses on the beam carrying the contact making members for the three phases, and the contacts at adjacent phases are separated by solid insulation of the tubes.

Reference may now be had to the circuit breaker illustrated diagrammatically in Figure 11. In this circuit breaker the top of the tank is closed by an insulating plate or barrier 115 which has three depending insulating tubes 116, one for each phase, in staggered relationship as in Figures 6 or 8. These tubes establish communication between the pressure chamber 117 below the barrier 115 and the non-pressure chamber which includes the space above the barrier 115 and portions of the interior of the tubes 116. The circuit breaker bridging members are of the construction illustrated in Figure 7. The pres-

sure chamber 117 is filled with oil up to the barrier 115 so that there are no gases or other compressible media within this chamber. During circuit interruption the arc formed at the contact 12 causes a pressure to be generated within the pressure chamber 117 thereby causing a rapid flow of oil from said chamber upwardly through the tube 116. This flowing oil serves to cool and extinguish the arc formed at the contact 12', which arc has been bowed outwardly by the magnetic forces, as heretofore explained. One or more restricted openings is provided in the barrier 115 to permit the slow escape of gases formed in the pressure chamber as a result of the circuit interruption. In this breaker a lowering of the tank will expose the contact 12 for inspection or repair purposes. If the contact 12' is to be inspected then the tube 116 may be forced upwardly through the barrier 115 to expose that contact.

Reference may now be had to Figure 12. This figure shows a circuit breaker arrangement similar to that of Figure 11 except that the bridging member, indicated at 120, is not of a U-shape, as in the breakers previously described. In this construction the bridging member 120 extends through a slot 121 and insulating tube 122 that loosely embraces the contact 12'. This tube is open at both the top and the bottom. The circuit breaker is filled with oil to a level slightly above the bottom of the barrier 115 so that the pressure chamber 117 is entirely devoid of gases or other compressible media. Upon circuit interruption the arc formed at the contact 12 causes oil to flow from the pressure chamber 117, through the opening 121 and the bottom opening in the tube, and upwardly through the tube 122 into cooling relationship to the arc that has been formed at the contact 12' and has been bowed outwardly by the magnetic forces. The upwardly moving cool oil thus serves to extinguish the arc and thus interrupt the circuit.

Reference may now be had to Figure 13 which shows a circuit breaker having a contact making member of an L-shape, that is, half of the contact making member is of the shape of the contact making member of Figure 7 and the other half is of the shape of the contact making member of Figure 12. In this construction the pressure chamber is formed by a horizontal insulating barrier 130 extending across the circuit breaker tank and provided with three upwardly extending tubes of insulation 131, one for each phase, around the bushing that carries the contact which is to form the pressure generating arc. The barrier 130 is provided with three openings, one for each phase, through which the arm 132 of the contact making structure extends. A tube of insulation 133, slotted at the side to permit vertical movement of the bridging member therein, is provided for the contact making structure of each phase. Oil from the pressure chamber 135 which is set into motion by the expanding arc bubble formed at the contact 12, flows through the three openings 136, adjacent the region of the arc formed at each of the contacts 12' and serves to cool and blow out those arcs. The pressure generating arcs for the three phases and the tubes 131 surrounding the corresponding bushings are staggered on opposite sides of the center of the circuit breaker to prevent the exertion of undue twisting stresses on the contact making members, and to afford solid insulation between contacts of adjacent phases.

Reference may now be had to the arrangement

illustrated in Figures 14 and 15. This circuit breaker employs a movable contact making bridging member 120, as in Figure 12, which moves through a vertical slot in a tube 140 that extends downwardly from a barrier plate 141 and a similar slot in a tube 142 that extends both upwardly and downwardly from the barrier plate 141. The oil level in this circuit breaker extends above the top of the tube 142. On opening of the circuit the pressure generated by the expanding arc bubble at the contact 12 forces fresh cool oil upwardly through the tube 140, past the region of the arc at the contact 12', and into the portion of the circuit breaker above the barrier 141. This serves quickly to cool and extinguish the arc formed at the contact 12', and thus interrupt the circuit.

In Figures 16 and 17 I have shown still another arrangement whereby the pressure generated by one arc is effective to force cool oil into the region of another arc in series therewith to interrupt the circuit. In this diagram I have shown an ordinary circuit breaker wherein one contact of each phase is enclosed in a casing 150 of insulation which extends almost but not quite to the other contact. The bridging member 120 moves through a vertical opening 151 in the casing 150. The casing 150 constitutes a pressure chamber. This chamber is full of oil and devoid of any gases or other compressible media. Upon the formation of an arc at the contact 12, upon downward movement of the bridging member 120, the expanding arc bubble forces oil from the pressure chamber 150, through the opening 151, into the region of the arc formed at the contact 12', thus blowing that arc outwardly and interrupting the circuit. The top of the pressure chamber 150 is provided with one or more restricted openings for permitting the slow escape of gases formed in the pressure chamber by the arc, but preventing any rapid escape of oil during circuit interruption.

Reference may now be had to the circuit breaker illustrated in Figure 18. This circuit breaker is a single phase breaker particularly adapted for interrupting high voltage circuits. The circuit breaker includes the usual tank 201 suspended from a circuit breaker head 202 and filled with insulating oil or other arc extinguishing liquid insulation to a level appreciably above the contacts therein, to be presently described, and only slightly below the juncture between the tank and the circuit breaker head. Inclined insulator bushings 203 and 204 extend into the breaker, through which conductors such as 205 extend. Each bushing has a contact structure and oil blast pressure chamber at the end thereof, indicated in general by the reference numeral 206, and illustrated more fully in Figures 19 to 21 inclusive. The contact structure includes a contact stud 210 screwed or otherwise secured to the conductor 205 in intimate current transfer relation. The contact 210 has a metal disc 211 threaded thereon, which disc is threaded at its outer periphery and receives an insulating cylinder 212, the inside of which constitutes the explosion chamber 207. The cylinder 212 is closed at its bottom by a metal disc 213 threaded into the cylinder and having a central bore in which is threaded a metal thimble 214. A hollow tubular contact 215 closed at its upper end and slotted at 215' is slidable through the thimble 214 and is normally maintained in the position illustrated in Figure 21, when the circuit breaker is open. It is maintained in such position by gravi-

ty assisted by a coiled spring 216. The spring bears at its lower end against a peripheral flange 217 at the bottom of the floating contact 215. A rod, disc, or other projection 219 secured to the hollow tubular contact 215 limits the downward movement of the contact 215 to the position illustrated in Figure 21. At its upper end the contact 215 is adapted to engage the contact stud 210 to establish circuit connections therewith.

The two structures 206 for the respective incoming conductors of the circuit breaker are connected together by an insulating bar 220 which serves to brace the structure. This bar also acts as a guide for a vertically movable operating rod 221 (Fig. 18) that carries a metallic bridging member 222 at its lower end. The bridging member 222 has two similar sliding contact making members 223, one at each end. The construction of the sliding contact making member 223 is illustrated more fully in Figures 19 to 21. This contact making member comprises a tube of copper that is closed at the bottom and is slidable through the bridging member 222 and connected therewith by a flexible braided or other conductor 224 that is soldered or otherwise secured to the bridging member and to the contact 223 to maintain electrical connections therebetween. A coiled spring 226 urges the contact 223 upwardly and maintains the contact in the position illustrated in Figure 21 when the circuit breaker is open. The upper end of the tubular contact 223 is provided with a flat peripheral flange 227 the top of which serves as a contact making surface.

To close the breaker illustrated in Figure 18 the operating rod 221 is moved upwardly from the dotted line position. The surface 227 of the contact 223 ultimately engages the surface 217 of the floating contact 215. This is the intermediate position illustrated in Figure 20. Further upward movement of the bridging member 222 causes upward movement of the floating contact 215 and compression of the spring 216. The top of the contact 215 ultimately engages the contact stud 210 thus establishing circuit connections. Continued further upward movement of the bridging member 222 causes compression of the spring 226 without further upward movement of the contact 223 or the contact 215. This continues until the bridging member reaches its full switch closed position, illustrated in Figure 19.

During circuit interruption the bridging member 222 is caused to move downwardly. The initial downward movement of the bridging member produces no effect upon the contacts until the bridging member has reached a position engaging the projection 228 of the contact 223. By that time the bridging member has attained a considerable velocity. Further downward movement of the bridging member causes a rapid downward movement of the contact 223. The contact 215 follows the contact 223 without disengagement of the two at the surfaces 217—227. This results in the formation of an arc between the contact 215 and the contact 210, within the pressure chamber 212. The expanding bubble of gas within the pressure chamber forces oil from the pressure chamber, through the openings 215' in the contact 215, as well as through the top opening at the tubular contact 215. This oil sets up a pressure within the continuous tube constituting the floating contact 215 and the contact 223. Should the

pressure become excessive that pressure will be effective to force the contact 223 downwardly at a speed greater than the speed of the moving bridging member 222. Ultimately the surface 227 separates from the surface 217. The separating movement may be the result of the pressure created within the explosion chamber 207 or it may be the result of the downward movement of the bridging member 222 after the downward movement of the contact 215 has been stopped by the engagement of the projection 219 with the metal disc 213. Immediately upon separation of the contact making surfaces 217—227 a second arc is formed between these surfaces in series with the arc between the contact 210 and the contact 215. Oil immediately flows from the pressure chamber, by reason of the pressure created therein by the expanding gas bubble, said oil flowing through the tubular contact 215 and out through the space between the separated contacts 215 and 223. This cool oil quickly blows out and extinguishes the last formed arc, thus interrupting the circuit and causing extinguishment of the first formed arc within the pressure chamber.

An important characteristic of the pressure chamber and contact making arrangement of the circuit breaker of Figure 18 is the impossibility of building up an excessive pressure in the oil blast chamber 207. Should the pressure exceed a predetermined value during the switch opening operation and before the tubular contact 205 has moved to its limit of travel where the projection 219 engages the metal disc 213, the pressure will be exerted against the contact 223, which is closed at the bottom thus forcing it downwardly against the restraining pressure of its spring 226, thereby opening a gap between the surfaces 217 and 227, through which gap the excess pressure is relieved. This action is similar to that of a safety valve. Furthermore, in case of a heavy flow of current this characteristic permits the gap outside of the oil blast chamber, that is, the gap between the surfaces 217 and 227, to be formed and an arc drawn there, which arc is subjected to the extinguishing action of the oil blast even before the gap inside the chamber has extended to its maximum permissible length. This characteristic tends to speed up the interruption of the circuit.

If the circuit breaker illustrated in Figure 18 is intended for carrying currents in excess of approximately 1200 amperes, the bridging member 222 may be provided with a contact which cooperates with another contact permanently electrically connected with the conductor 205, which last mentioned contacts shunt the arc extinguishing contacts previously described during the normal operation of the circuit breaker in its closed position. On commencement of the switch opening operation, that is, when the bridging member is moved downwardly from the position illustrated in Figure 19 to a point immediately preceding the engagement of the bridging member 222 with the projection 228, the shunting contacts are opened thus by-passing all of the current to the arcing contacts. Such an arrangement is illustrated in Figure 2 of the United States patent to William E. Paul, No. 1,904,519, of April 18, 1933, to which reference may be had.

In compliance with the requirements of the patent statutes I have here shown and described a few preferred embodiments of my invention.

It is, however, to be understood that the invention is not limited to the precise constructions here shown, the same being merely illustrative of the principles of the invention. What I consider new and desire to secure by Letters Patent is:

1. In a switch, a tank adapted to contain an insulating liquid, means dividing the tank into two communicating sections, cooperating contacts arranged to form two arcs in series in said tank one in one section and the other in the other section with the current in the two arcs flowing in opposite directions and each in the electromagnetic field produced by the other to produce forces tending to blow at least one of the arcs outwardly, and means whereby the fluid under pressure created by one of the arcs is directed into the path of the other arc and in an upward direction.

2. In a switch, a tank adapted to contain an insulating liquid, cooperating contacts separable in the liquid to draw an arc in a generally vertical direction, means for bowing the arc magnetically, and means including a second arc for directing a blast of insulating liquid in the region of the first arc bubble in a generally vertical upward direction whereby the blast of liquid assists the natural buoyancy of the arc gas bubble to break the bubble between the contacts.

3. A circuit breaker of the type including a tank and circuit connection in the tank including means for interrupting the circuit by drawing two arcs in series with one of the arcs in such relation to the current path through the circuit connections that magnetic forces are produced tending to force that arc in a direction at a substantial angle to the arc path, means dividing the tank into two communicating sections each containing one of the arcs, one of the sections being full of insulating liquid and devoid of substantially compressible media so that the gas bubble formed by the arc therein forces liquid into the other section, the arc in the other section being in the path of the resulting liquid flow.

4. A circuit breaker of the type including a tank and circuit connection in the tank including means for interrupting the circuit by drawing two arcs in series with one of the arcs in such relation to the current path through the circuit connections that magnetic forces are produced tending to force that arc in a direction at a substantial angle to the arc path, means dividing the tank into two communicating sections each containing one of the arcs, one of the sections being full of insulating liquid and devoid of substantially compressible media so that the gas bubble formed by the arc forces fluid into the other section, the arc in the other section being in the path of the resulting fluid flow, the two arcs being separated by substantially the entire body of insulating liquid within the tank, which body of insulating liquid is in the path of travel of liquid from one arc to the other.

5. An electric circuit breaker comprising a container, means dividing the container into two communicating chambers, an insulating bushing extending into the container and terminating in a contact member in one of the chambers, a second insulating bushing extending into the container and terminating in a contact within the other chamber, a conducting bridging member extending between the chambers and bridging the contacts, said bridging member being movable out of engagement with the contacts to draw two arcs

in series and located one in one chamber and the other in the other chamber, one of the chambers being full of an insulating liquid and devoid of gases so that the pressure generated by an arc in said one chamber forces liquid therefrom to flow into the other chamber, and the arc in said other chamber being in the path of the liquid flow.

6. A circuit breaker of the type including a tank and circuit connections in the tank including means for interrupting the circuit by drawing two arcs in series with one of the arcs in such relation to the current path through the circuit connections that magnetic forces are produced tending to force that arc in a direction at a substantial angle to the arc path, an enclosure in the tank surrounding only one of the arcs, and means including the enclosure for creating a flow of insulating fluid in the region of one of the arcs by the pressure produced by the other arc.

7. In a circuit breaker of the liquid-break type, a tank containing insulating liquid, a pressure chamber in said tank and filled with said insulating liquid and vented at the top to permit the restricted escape of the gaseous products of a circuit interruption, a switch contact in the chamber, a contact making member engaging the contact and including means retractible through the chamber within the tank for separating the contact making member from the contact and drawing an arc whereby the pressure produced by the arc within the chamber assists in the retraction of the means and thus facilitates the switch opening operation, and said chamber having a liquid discharge opening spaced from the region of the arc and from the part of the chamber through which the retractible means extends, said opening discharging liquid from the chamber into the tank, and means for drawing a second arc in said tank but outside of the chamber, said second arc being in series with the first arc and in the path of the discharging liquid.

8. In a circuit breaker of the liquid-break type, a substantially tubular arcing pressure chamber having a filling of insulating liquid and vented at the top to permit the restricted escape of the gaseous products of a circuit interruption, a switch contact in the chamber, a contact making member engaging the contact and including means retractible through the chamber for separating the contact making member from the contact and drawing an arc whereby the pressure produced by the arc within the chamber assists in the retraction of the means and thus facilitates the switch opening operation, and said chamber having an opening for the escape of liquid therefrom upon the development of pressure therein, the opening being spaced from the region of the arc and from the part of the chamber through which the retractible means extends, and means for forming an arc outside of the chamber in series with the arc within the chamber and adjacent the said chamber outlet.

9. In a circuit breaker of the liquid-break type, a container for liquid insulation, a closure barrier dividing the compartment into two sections each containing insulating liquid, said barrier having an opening therein for permitting the flow of liquid from one section into the other, circuit interrupting contacts in the path of flow of fluid through the barrier, a second set of circuit interrupting contacts, and a tubular member extending from the barrier into one of the sections and loosely surrounding one of the sets of contacts so that one arc is drawn in the tube, and the other arc is drawn outside of the tube.

10. In a circuit breaker of the liquid-break type, a tank, and an arcing pressure chamber within the tank and comprising a substantially tubular body containing insulating liquid and closed against the rapid movement of liquid from the same at the ends thereof and having a discharge opening in the tubular wall adjacent the lower end thereof and discharging into the tank.

11. A circuit breaker including a container, liquid insulation in the container, bushings extending downwardly into the liquid in the container, conductors extending through the bushings and terminating in switching contacts in the insulating liquid, a conducting bridging member bridging the contacts and movable downwardly out of bridging engagement to draw two arcs in series, a horizontal barrier across the container and dividing the same into two communicating compartments with one compartment devoid of compressible media, a tube sealed to the barrier and extending vertically therefrom into one of the compartments, said tube opening into at least one of the compartments and loosely surrounding one of said arcs, the other arc being entirely outside of the tube.

12. A circuit breaker including a container, liquid insulation in the container, bushings extending downwardly into the liquid in the container, conductors extending through the bushings and terminating in switching contacts in the insulating liquid, a conducting bridging member in bridging relation to the contacts and movable downwardly out of bridging engagement to draw two arcs in series, a horizontal barrier across the container and dividing the same into two communicating compartments with the lower compartment devoid of compressible media, a tube sealed to the barrier and extending vertically upward therefrom into one of the compartments, said tube opening at the bottom into the other compartment and being substantially closed at the top and loosely surrounding one of said arcs, the other arc being entirely outside of the tube, and the arc that is outside of the tube being above the barrier and adjacent the path of flow of insulating liquid through the barrier by the pressure developed by the arc in the tube.

13. A circuit breaker including a container, liquid insulation in the container, bushings extending downwardly into the liquid in the container, conductors extending through the bushings and terminating in switching contacts in the insulating liquid, a conducting bridging member in bridging relation to the contacts and movable downwardly out of bridging engagement to draw two arcs in series, a horizontal barrier across the container and dividing the same into two communicating compartments with the lower compartment devoid of compressible media, a tube open at both ends and sealed to and extending vertically of said barrier and providing a communicating passageway between the compartments and loosely surrounding one of said arcs, the other arc being entirely outside of the tube.

14. A polyphase circuit breaker including a container, liquid insulation within said container, means for drawing a plurality of arcs in said container, there being at least two arcs in series per phase, means dividing the container into a pressure section and another section, in communication, at least one arc per phase being located in the pressure section and at least one arc per phase being in said other section.

15. A polyphase circuit breaker including a container, liquid insulation within said container,

means for drawing a plurality of arcs in said container, there being at least two arcs in series per phase, means dividing the container into a pressure section and another section, in communication, at least one arc per phase being located in the pressure section and at least one arc per phase being in said other section, the pressure section being full of insulating liquid and substantially devoid of compressible gases whereby expanding arc gas bubbles in the pressure section force liquid therefrom into the other section, and each of the arcs in said other section being in the path of moving insulating liquid which is set into motion by the pressure created by the arcs in the pressure section.

16. A polyphase circuit breaker including a container, liquid insulation within said container, means for drawing a plurality of arcs in said container, there being at least two arcs in series per phase, means dividing the container into a pressure section and another section, in communication, at least one arc per phase being located in the pressure section and at least one arc per phase being in said other section, the means dividing the container into the two sections being of insulation and so arranged that adjacent arcs of adjacent phases are in different ones of the two sections.

17. A polyphase circuit breaker including a container, liquid insulation within said container, means for drawing a plurality of arcs in said container, there being at least two arcs in series per phase, means dividing the container into a pressure section and another section, in communication, at least one arc per phase being located in the pressure section and at least one arc per phase being in said other section, the means dividing the container into two sections including a central vertical barrier between the arcs of the same phase with one surface of the barrier in the high pressure section and an opposite surface thereof in the other section.

18. An electric circuit breaker comprising a container, means for drawing two arcs in series in the container and spaced from one another on opposite sides of a vertical line through the container, means dividing the container into a pressure section and another section, said dividing means including a vertical barrier between the arcs, said barrier terminating above the bottom of the container and having a horizontal insulator extending from the bottom of the barrier toward the container wall, the space on one side vertically of said horizontal insulator being the pressure section and on the other side vertically of said horizontal insulator being the other section, insulating liquid filling the pressure section and insulating liquid in the other section, said horizontal insulator having an opening for the flow of liquid between the sections, one of the arcs being in the pressure section and remote from the said opening whereby the pressure generated by that arc forces insulating liquid to flow from the pressure section through said opening into the other section, the other arc being in the path of said flowing liquid.

19. An electric circuit breaker comprising a container, means for drawing two arcs in series in the container, means dividing the container into a pressure section and another section, said dividing means including a vertical barrier between the arcs, said barrier terminating above the bottom of the container and having a horizontal insulator extending from the bottom of the barrier toward the container wall, the space

on one side vertically of said horizontal insulator being the pressure section and on the other side vertically of said horizontal insulator being the other section, insulating liquid filling the pressure section and insulating liquid in the other section, said horizontal insulator having an opening for the flow of liquid between the sections one of the arcs being in the pressure section and remote from the said opening whereby the pressure generated by that arc forces insulating liquid to flow from the pressure section through said opening into the other section, the other arc being in the other section and in the path of said flowing liquid.

20. An electric circuit breaker comprising a container, means for drawing two arcs in series in the container, means dividing the container into a pressure section and another section, said dividing means including a vertical barrier between the arcs, the space on one side of the vertical barrier being the pressure section and the space on the other side being the other section, insulating liquid filling the pressure section and insulating liquid in the other section, means forming a cylinder below the top of the level of insulating liquid in the container and having a piston movable therein, the part of the cylinder on one side of the piston opening into the pressure section and the part of the cylinder on the other side of the piston opening into the other section.

21. An electric circuit breaker comprising a container, means for drawing two arcs in series in the container, means dividing the container into a pressure section and another section, said dividing means including a vertical barrier between the arcs, the space on one side of the vertical barrier being the pressure section and the space on the other side being the other section, insulating liquid filling the pressure section and insulating liquid in the other section, means forming a cylinder below the top of the level of insulating liquid in the container and having a piston movable therein, the part of the cylinder

on one side of the piston opening into the pressure section and the part of the cylinder on the other side of the piston opening into the other section in the region of the arc in the other section.

22. An electric circuit interrupter comprising a tank containing insulating liquid, a pair of spaced switch contacts, and bridging means connecting the contacts and movable out of bridging relation thereto to interrupt the circuit, an insulating barrier wall between the contacts, operating means extending through the barrier and connected to the bridging means for operating the same, and means associated with the operating means within the barrier and forming a dash pot retarding the opening movement of said bridging means at a predetermined point.

23. In a circuit breaker of the liquid-break type, means forming a pressure chamber, a filling of insulating liquid therein, a contact making member movable therein to draw an arc in the chamber, a pressure relief safety valve for said chamber in series with the contact making member, said safety valve being movable outside of the chamber and drawing an arc outside of the chamber in series with the first named arc and in the path of flow of liquid through the safety valve, and means including the safety valve for moving the contact making member to the switch closed position.

24. In a circuit breaker of the liquid-break type, means forming a pressure chamber, a filling of insulating liquid therein, a contact making member movable therein to draw an arc in the chamber, a pressure relief safety valve for said chamber in series with the contact making member, said safety valve having a movement outside of the chamber and drawing an arc in series with the first named arc and in the path of flow of liquid through the safety valve, and switch actuating means for opening the safety valve to draw the second arc independently of the pressure in the pressure chamber.

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