Aug. 15, 1933. D. C. PRINCE 1,922,862

ELECTRICAL SWITCHING APPARATUS

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Fig. 1.

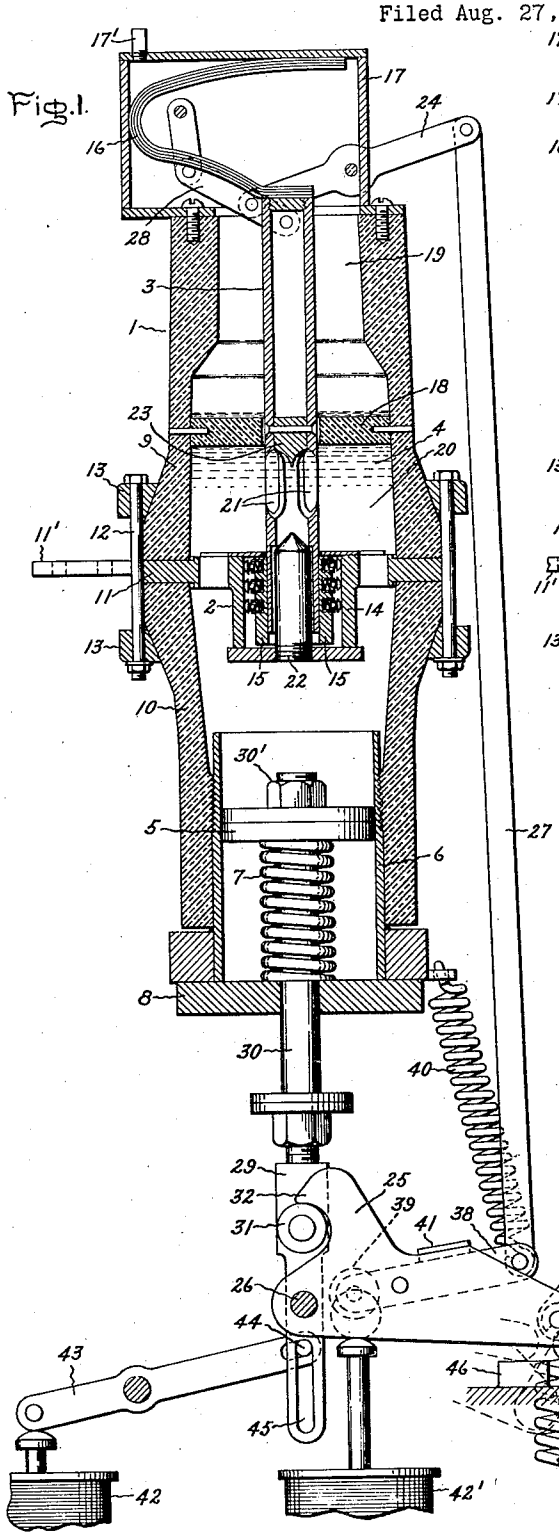
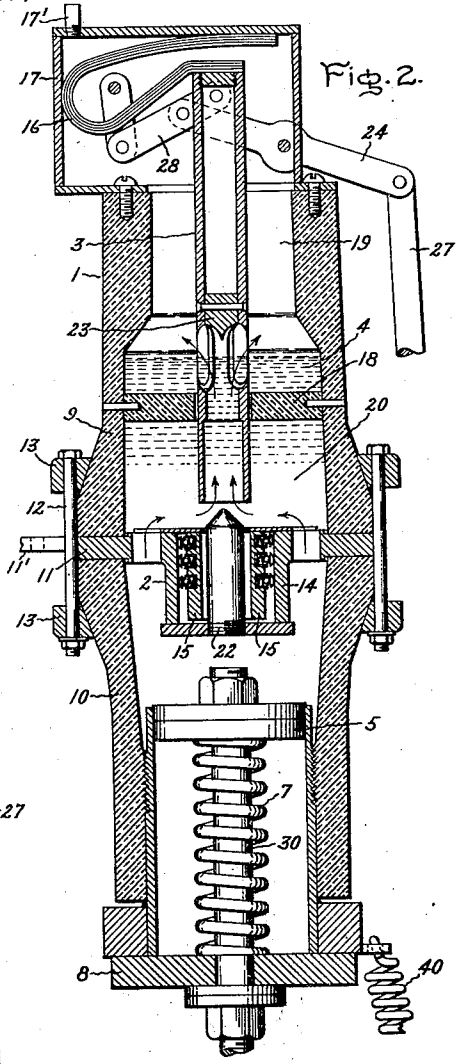
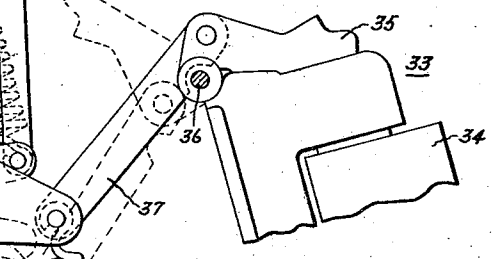


Fig. 2.





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ELECTRICAL SWITCHING APPARATUS

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Fig. 3.

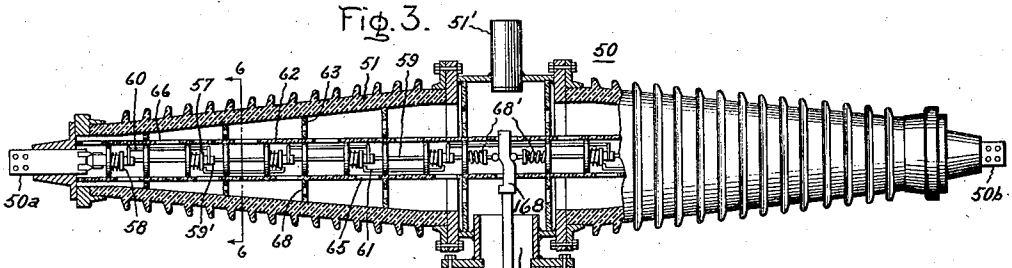


Fig. 9.

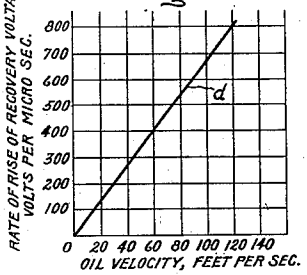
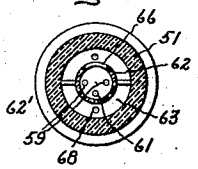


Fig. 6.



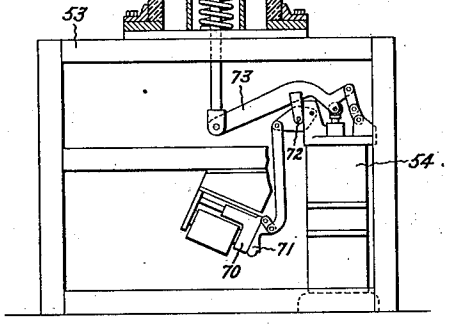


Fig. 5.

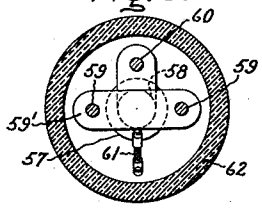


Fig. 7.

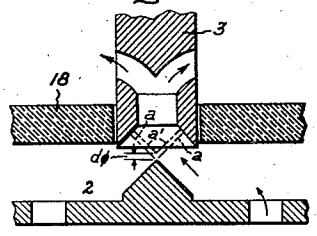


Fig. 8.

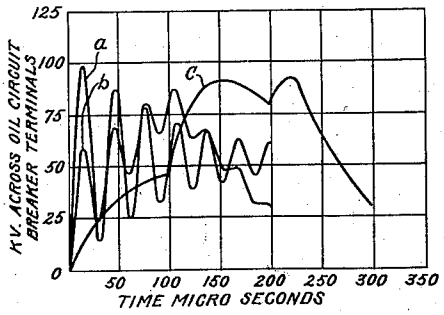
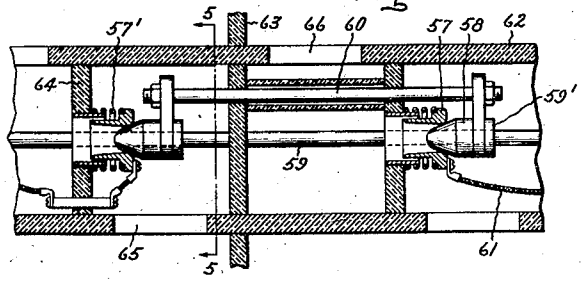


Fig. 4.



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UNITED STATES PATENT OFFICE

1,922,862

ELECTRICAL SWITCHING APPARATUS

David C. Prince, Swarthmore, Pa., assignor to General Electric Company, a Corporation of New York

Application August 27, 1931. Serial No. 559,729

13 Claims. (Cl. 200—150)

My invention relates to electrical switching apparatus, more particularly to large capacity circuit interrupters of the fluid-break type, and to a method of extinguishing the arc formed during interruption of the circuit.

This application is a continuation in part of my copending application Serial No. 466,928, filed July 10, 1930 for electrical switching apparatus.

In circuit interrupters of the aforesaid type, there has been utilized a source of pressure, as a pump for example, for forcing or introducing under impulse insulating liquid such as oil transversely or longitudinally of the arc formed between the separating contacts of the switch. Although this principle has been applied to many forms of circuit interrupters in an effort to develop a circuit breaker capable of effectively clearing the circuit under the most severe operating conditions and extinguishing arcs of great intensity, as during the interruption of a short circuit, this type of breaker, which will be referred to as the impulse type, has not heretofore been successfully developed to satisfy all operating conditions. The main difficulty in prior developments of this type of breaker resides in the fact that the oil or other insulating fluid is not directed positively in such a manner as to flow at sufficient velocity across the arcing surfaces and into the gap between the contacts while at the same time sweeping the arc products entirely out of the gap with a scavenging action and preventing the arc from moving away from or dodging the insulating liquid.

Since the interruption of the arc depends upon, for one thing, the rate at which fresh dielectric is interposed in the arc path, it will be apparent that any method of interruption utilizing a jet of insulating fluid which fails to sweep away the arc products and maintain the arc in a substantially fixed position during the process of directing the jet of insulating fluid across the arcing surfaces of or into the gap between the contacts cannot be relied upon to interrupt the arc consistently and successfully.

An object of my invention is an improved method of interrupting a high tension power circuit.

It is a further object of my invention to provide an improved circuit interrupter of the impulse type which shall have means controlling and directing a unidirectional jet of insulating liquid under impulse between the separating contacts during opening of the breaker so arranged that the arc products are swept free of the gap and the arc is entrapped and extinguished by the insulating liquid.

It is a further object of my invention to provide an improved impulse type of oil circuit breaker which shall have means for effectively interrupting the circuit in response to small relative movement of the contacts and for extinguishing the arc without developing appreciable pressure within the breaker housing or casing.

It is another object of my invention to provide an improved circuit breaker of the aforesaid type which shall have high current interrupting capacity, be simple and rugged in construction, and occupy a comparatively small amount of space.

In order more clearly to set forth the method and apparatus for carrying out my invention, the theory involved in extinguishing an alternating current arc will be considered briefly. When an alternating current arc is drawn between separating contacts in an insulating liquid such as oil, the intense heat of the arc decomposes the oil in its path forming quantities of gases which are generally highly conducting and therefore tend to sustain the arc. In plain-break oil switches, the arc drawn within the oil body is finally extinguished by the oil itself in the form of liquid or spray which breaks up the gaseous conductor due to the turbulence caused by the arc to increase the dielectric strength of the gap so that the arc is interrupted when the current passes through a zero value. The interrupting action of this type of breaker is therefore fortuitous at a given rating since the oil is not introduced at a definite rate into the gap.

The dielectric strength of clean circuit breaker oil is over 200,000 volts per inch and under voltage impulse the dielectric strength is over 600,000 volts per inch. It is, therefore, apparent that the introduction of solid oil into the gap between the contacts at the current zero presents great possibilities in circuit interruption. The time available for introducing the fresh dielectric into the gap depends upon the rate of increase of the recovery voltage, that is, the rate at which the voltage may be expected to appear across the switch terminals. When the switch is closed, the voltage drop across the switch terminals is generally of the order of but a few volts whereas in the open circuit position of the switch the full line voltage is impressed across the terminals. According to prior investigations, the line voltage may be impressed across a 15 kv. switch under the most severe operating conditions in

10 x 10^{-6} seconds. The rate of voltage rise is then

$$\frac{\sqrt{2}\times 15000}{10\times 10^{-6}}=\sqrt{2}\times 1.5\times 10^{9}$$

volts per second. For this extremely short time the oil in the circuit breaker may be said to have the dielectric strength it presents to impulse voltages, or about

$$\sqrt{2\times 6\times 10^{5}}$$

volts per inch. Therefore, if fresh dielectric is to be introduced into the gap at a rate equal to the rate of recovery voltage or voltage rise, it must be introduced at the rate

$$\frac{\sqrt{2}\times 1.5\times 10^{9}}{\sqrt{2}\times 6\times 10^{5}}=2.5\times 10^{3}$$

inches per second or about 200 feet per second. This amount of kinetic energy corresponds to a pressure of 230 lbs. per square inch, which pressure is feasible and may be readily applied in practice to special designs of circuit breakers.

High rates of recovery of applied voltage may be expected only across switches connected directly to generator or transformer terminals or to current limiting reactors. A high voltage transformer will have a voltage recovery rate corresponding to

$$\sqrt{2\times 5\times 10^{9}}$$

volts per second while the rate for a long distance 220 kv. transmission line will be about

$$\sqrt{2\times 0.8\times 10^{9}}$$

volts per second, or approximately 1128 volts per microsecond even though the full voltage corresponds to 220 kv. line to line. It is accordingly quite possible and practical to design a circuit breaker in accordance with my invention based on the foregoing principle for operating conditions in all points of a modern high tension transmission system.

Further in accordance with my invention, a complete cross section of the arc formed between separating contacts of a circuit interrupter, one of which by way of example comprises a tubular member, is traversed by an insulating liquid as oil, under controlled pressure in such a manner that the arc products are swept from the arcing surfaces of the contacts and from the arc gap into and through the tubular contact member, the gap meanwhile being filled with fresh oil. In other words, the oil under pressure rushing in on all sides of the arc therefore not only overcomes the tendency of the gases generated by the arc to expand into the region surrounding the contacts, as is generally the case in oil breakers, but forces the same with a scavenging action away from the arc source along with the oil entirely to clear the gap of the arc products. The gases and other arc products therefore exhaust at high velocity directly from the arc gap through the tubular contact, and since the flow of oil is nearly at right angles to the flow of arc gases it will be apparent that the velocity of the oil may be considerably lower than that of the gases in order to clear the gap of the arc products. Accordingly, the theoretical oil velocities above referred to may in practice be considerably reduced or modified due to the relation of the direction of oil flow to the flow of the arc gases.

My invention will be more fully set forth in the following description referring to the accompanying drawings, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Referring to the drawings, Fig. 1 is an elevational view, partly in section, of a circuit interrupter embodying my invention; Fig. 2 is an elevational view, partly in section, of the circuit interrupter shown in Fig. 1 in the open circuit position thereof; Fig. 3 is an elevational view, partly in section, of another embodiment of my invention; Fig. 4 is a sectional fragmentary view of the contact structure illustrated in Fig. 3; Fig. 5 is a cross-sectional view taken along the line 5—5 of Fig. 4, Fig. 6 is a cross-sectional view taken along the line 6—6 of Fig. 3, Fig. 7 is a simplified view of the contact arrangement, Fig. 8 is a graphical illustration of rates of voltage increase, and Fig. 9 is a graphical illustration correlating rate of voltage increase and oil velocity.

In Fig. 1 there is illustrated a circuit interrupter of the impulse type embodying and for carrying out my invention. The interrupter is shown in the closed circuit position and comprises a casing or housing generally indicated by 1, and relatively movable contacts as the stationary contact structure 2 and the movable tubular contact 3 open at its lower end and adapted to coact with the stationary contact 2. The casing 1 contains a suitable insulating fluid 4, such as oil, and is associated with a source of pressure, as a pump, comprising the piston 5 adapted for reciprocal movement within the lower part of the casing 1. The piston 5 is guided within a cylindrical member 6 secured as by threaded engagement to the casing 1, and is normally urged in a fluid-actuating or upward direction by the compression spring 7 seated at its lower end on the plate 8 forming the lower wall of the switch casing.

The switch casing in the present instance comprises a pair of hollow insulating members 9 and 10 between which is clamped, as by the bolts 12 and clamping rings 13, the mounting 11 for the stationary contact structure which comprises a spider or the like of conducting material provided with a terminal lug 11' adapted to be connected to the external circuit. The stationary contact which is mounted centrally of the switch casing comprises the retaining structure 14 and segmental contacts 15 annularly arranged in the retainer 14 and resiliently biased by suitable spring means radially towards the center of the contact. The tubular contact 3 as illustrated in Fig. 1, is adapted to be engaged at its lower outer surface by the annular row of segmental contacts in the closed circuit position of the switch. A suitable flexible connection 16 connects the tubular contact 3 to the metallic housing 17 on the upper part of the switch casing comprising the other terminal of the switch. The housing 17 has a suitable vent 17' for dissipating gases formed within the switch casing.

For the purpose of introducing the insulating liquid or oil into the gap between the separating contacts during opening of the switch and for sweeping the arc products clear of the gap, there are provided means, hereinafter described, for insuring substantially simultaneous and concurrent operation of the piston 5 and the movable contact 3 so that flow of oil is produced across the arcing surface of the stationary contact and into the movable tubular contact 3. By so directing the flow of oil radially across the contact surfaces which are separated by a short gap, the arc is entrapped and cannot shift or dodge from its cen-

tral position. In other words, the oil rushing in from all sides so as to traverse a complete cross section of the arc tends to squeeze or constrict the arc and the arc gases or so-called "gas bubble" formed thereby into a narrow path and to finally force them towards the interior of the tubular contact with a scavenging action so that the gap is swept free of the arc products which are replaced by clean oil. The continuity of the gas bubble, which is a good conductor, is therefore broken with respect to the coacting contacts. Accordingly, the arcing surfaces of both the stationary and movable contacts are traversed by the oil and the arc is finally extinguished during a current zero due to the positive and predetermined flow of oil into the gap and the resulting greatly increased dielectric strength of the gap.

To the end that the oil forced across the contact surfaces shall have positive unidirectional flow, i. e., flow in a given general direction, the casing 1 is provided with a partition or baffle 18 through which the tubular contact freely moves dividing the casing into an upper chamber 19 and a lower chamber 20. Therefore, the flow of oil from the lower chamber to the upper chamber 19 is confined to a path through the arc gap and tubular contact 3, which is provided with pressure relief openings 21 exhausting the oil and arc products into the upper chamber as illustrated in Fig. 2 when the tubular contact is in open position. In order more efficiently to direct the flow of oil across the arcing surfaces and into the tubular contact there is provided means, as the fluid deflecting member 22, mounted in the retaining structure 14 comprising a conducting cone-like structure for preventing or minimizing eddies in the oil flow between the contacts as indicated by the flow direction arrows in Fig. 2. The member 22 may be of suitable arc-resisting metal since in practice it serves as an arcing tip for the stationary contact.

Referring more particularly to Fig. 2 it will be noted that the piston 5 when actuated by the compression spring 7 to drive the oil upwardly produces a positive unidirectional flow of oil past the spider 11, radially across the upper portions of the segmental contacts 15 which comprise the arcing surface of the stationary contact, and into the lower open end of the tubular contact likewise in a direction transversely of the arcing surface thereof to exhaust by way of the pressure relief openings 21 into the chamber 19, the pressure relief openings being above the partition 18 in the open circuit position. Suitable fluid deflecting means, as the cone-shaped plug 23, may likewise be incorporated in the tubular contact for facilitating exhaust of the oil and arc products at high velocity from the lower chamber.

For the purpose of describing more clearly the method of circuit interruption, reference is had to Figs. 7, 8 and 9. There is shown in Fig. 7 a simplified view of the switch contacts in the open position thereof, the various parts being designated by reference numerals corresopinding to Figs. 1 and 2. Assuming that the circuit opening operation is in progress and that oil is being forced by the piston into the tubular contact in the manner previously described, a cone-shaped boundary surface a—a at the instant of current zero may be assumed between the arc products and the oil. In a time dt this surface advances by reason of the oil movement to a'—a' giving a minimum oil film thickness $d\phi$ over the contact tip to hold back the rising potential difference, that is, the increasing recovery voltage across the circuit breaker terminals.

The value of $d\phi/dt$ cannot well be measured directly but the rate at which the boundary surface as a whole advances is determined by the velocity of oil flow which can be determined from the piston travel record. Whether or not the shape of the boundary surface is exactly as assumed is immaterial, as the difference in results is within the probable error of the whole procedure.

Referring to Fig. 8, there are shown curves representing the rate of increase of recovery voltage across the terminals of a circuit breaker in a given rated line corresponding to different circuit characteristics. By way of example, curve a represents the rate of increase of the recovery voltage across the terminals of a circuit breaker connected directly to the transformer terminals. Since no bus structure or tap lines are involved, the rate of increase, as would be expected, is very high. It will be noted that the voltage reaches its first peak value within a comparatively short time so that the rate, expressed in volts per microsecond, is high.

Curve b represents the rate of increase of recovery voltage across the circuit breaker terminals when the circuit breaker is spaced by a short transmission line from the point of short circuit. This reduces the short circuit current and brings about a small reduction in the rate of increase of recovery voltage. A considerable reduction in the rate of rise of recovery voltage is noted in curve c wherein the transmission line is connected at a point between the circuit breaker and the principal part of the reactance limiting the short circuit current, i. e., the transformer in the present instance. It will be noted that the elapsed time for the recovery voltage to reach its peak value in curve c is several times greater than in the case of curves a and b.

The rate at which voltage recovers across circuit breaker terminals is dependent on circuit constants and nominal line voltage. This rate can be determined by measuring the inductances and capacitances, and the rate of voltage rise then calculated with considerable precision. The method of determining the rate of increase of recovery voltage for given circuit conditions is well known in the art and need not be further considered in connection with the present invention.

Heretofore failures of oil circuit breakers have been attributed to (1) current, (2) voltage peaks, and (3) a combination of the rate of incease of recovery voltage with (1) and (2). I have found that it is impossible to correlate the current and voltage peaks with the rate of introduction of dielectric into the arc gap but have found that successful operation of the circuit breaker in consistently clearing the circuit depends upon correlating the rate of rise of recovery voltage and the rate of introducing dielectric into the arc gap as graphically illustrated in Fig. 9. Referring more particularly to Fig. 9 wherein the dielectric involved is oil, I have found that there is practically a direct proportion between the oil velocity required to clear the circuit and the rate of rise of recovery voltage expressed in volts per microsecond. In other words, test results plotted on the right side of curve d represent successful performances of the circuit breaker whereas results plotted at the left side, represent failures. Accordingly, the current to be interrupted is not related to the success or failure of a circuit

breaker of the present type as has been generally supposed. A dielectric or insulating liquid as oil has a known dielectric strength under operating conditions of

$$\frac{V}{l}=\frac{\text{volts}}{\text{inches}}.$$

As above explained, a circuit provides a known rate of voltage rise after interruption of

$$\frac{V}{t}=\frac{\text{volts}}{\text{seconds}}.$$

In accordance with my invention, an oil film is introduced and established between the contacts whose thickness increases at a rate at least equal to the rate of increase of the recovery voltage, or

$$\frac{V}{t}\div\frac{V}{l}=\frac{l}{t}=\frac{\text{inches}}{\text{seconds}}.$$

As clearly indicated in Fig. 9, the breaker will fail if the rate of increase of the oil film thickness is less than that determined and will clear if the rate is equal to or greater than that determined. A significant feature of this method therefore is that the rate of oil flow is not a functon of the voltage and current but is correlated to the rate of rise of recovery voltage and may be predetermined.

It will be apparent, of course, that the tension of the spring 7 comprising the piston driving force may be suitably adjusted, as by varying the position of the nut 30', so that the desired fluid pressure may be obtained for producing a definite and predermined rate of oil flow into and through the arc path effecting efficient interruption of the circuit as above described. The relative movement of the contacts 2 and 3 is small as compared with conventional circuit breakers of equal rating and need be of the order of about an inch for a 15 kv. breaker. Furthermore, the gas pressure caused by decomposition of the oil by the arc is very small as contrasted with the conventional plain break switch, so that the switch casing need not necessarily be made of strong material such as steel, and in fact it may be constructed of well known forms of molded insulating material which is an obvious advantage. The comparatively low pressure generated within the switch casing accordingly indicates a correspondingly small amount of energy dissipated in interrupting the arc which is likewise a result greatly desired in circuit breaker operation.

For the purpose of synchronizing the action of the piston 5 and the movable tubular contact 3, there is provided mechanism interconnecting these members and common thereto comprising a centrally pivoted lever 24 operatively connected to the contact 3 and to a latch 25 pivoted at 26, the latch 25 and lever 24 being operatively connected by the link 27. The lever 24 is connected at one end to the link 27 and at its other end to the straight-line motion linkage 28 for causing reciprocal movement of the tubular contact in response to rotative movement of the lever 24. An operating extension 29 connected to the piston rod 30 which extends through the lower wall of the switch casing, is provided with a roller or the like 31 adapted to be engaged by the hook portion 32 of the latch for maintaining the spring 7 in its compressed, energy storing position. Rotation of the latch 25 in a clockwise direction about its pivot 26 is effective to release the roller 31 and cause the spring 7 to force the piston upwardly against the oil in the manner previously described. The latch 25 is held in its restraining position against the tension of a spring 25' by suitable tripping means, as the electroresponsive device 33 comprising a coil 34 and a pivoted armature 35 adapted to be released in response to a predetermined condition in the circuit to be controlled. The armature 35, which is pivoted at 36, is connected through a link 37 to an extension of the latch 25 so that when the armature is in its normal full-line attracted position illustrated in Fig. 1, the latch 25 is maintained in engagement with the roller 31 to hold the piston in its lower position.

The link 27 is connected to the latch 25 by means of a link 38 pivotally carried by the latch and provided at its free end with a roller 39. Suitable means, as a spring 40, normally tends to bias the link 38 in a counterclockwise direction about its pivot into engagement with the offset lug 41 forming a part of the latch 25, thereby to bias the link 27 upwardly for closing and maintaining closed the upper contact. Accordingly, when the electroresponsive tripping means in response to a predetermined line condition decreases the armature attracting force, permitting it to rotate counterclockwise to the dotted-line position illustrated under the influence of the spring 25' which is designed to overcome the tension of spring 40, the latch 25 is released and may move clockwise out of the way of the roller 31 aided by the force exerted by the compression spring 7. During this operation the link 38 is likewise moved downwardly by the lug 41 thereby rotating the lever 24 in a clockwise direction to raise the movable contact to open position.

With the mechanism in the open circuit position, the closing operation is effected by energizing both a closing solenoid 42 and a latching solenoid 42'. The closing solenoid 42 operates through a lever 43 having a lost motion connection, connected to the lever 43, as a pin 44 and a slot 45 in the operating extension 29 so that opening of the breaker may be independent of the closing solenoid whereas clockwise or closing movement of the lever 43 in response to energization of the solenoid 42 causes the pin 44 at the end of lever 43 to engage the lower part of the slot 45, thereby lowering the piston 5 and compressing the spring 7. The latching solenoid 42' when energizes engages the roller 39 on the link 38 causing the link 38 to bear at its other end on the fixed abutment 46 thereby causing the latch 25 to be rotated counterclockwise against the tension of spring 25' so that the latch extension 32 engages and restrains the roller 31. During this movement the armature 35 is rotated to its normal holding position and will be maintained in such position while normal conditions in the circuit obtain. A fixed abutment 46 is adapted to be engaged by the link 38 for limiting the clockwise or releasing movement of the latch.

For the purpose of interrupting high tension circuits a plurality of breaks in series is more effective than a single break, provided of course that the voltage is evenly divided between the breaks. There is illustrated in Fig. 3 another embodiment of my invention for effecting a plurality of breaks in series in the high tension circuit and for producing and directing flow of insulating fluid across the arc at each break so as to entrap and extinguish the respective arcs in the manner previously described. In the specific arrangement shown, the multiple break circuit interrupter 50 comprises an elongated housing 51 which may be in the form of a conventional insulating bushing such as used in high tension cir-

cuit breakers. The insulating bushing is mounted upon and in communication with the interior of a hollow insulating structure 52 which is in turn mounted upon a frame 53 housing the operating mechanism generally indicated at 54. The insulating structure 52, which is closed at its lower end, contains oil or other suitable insulating liquid, as does the bushing 51, and communicates with said bushing through the passage 55 so that fluid-actuating means, as the piston 56, is effective to cause flow of oil from the insulating structure 52 into the bushing 51.

Referring to Fig. 4 which illustrates in detail the coacting pairs of contacts arranged in series in the circuit, each pair of relatively movable contacts comprises, as in the previous instance, a tubular or hollow contact 57 and a contact 58 across and along which the oil is forced during separation of the contacts radially to traverse the arcing surfaces and flow into and through the hollow contact 57. In the present arrangement the hollow contact of each pair is stationary, it of course being apparent that the relative movement of the contacts is the same as in the previous case. The contact 58 is conical in form at its contact surface thereby facilitating flow of oil past the same, and in the closed circuit position as illustrated in Fig. 4 seats upon the flared edge of the contact 57, which is mounted upon and resiliently biased by the spring 57', into firm seating engagement with the contact 58. The passage through the contact 57 is preferably diverging in the direction of fluid flow for increasing the velocity of oil across the arcing surfaces of the contacts.

For the purpose of simultaneously operating the movable contacts 58, a pair of operating rods 59 (Fig. 5) extending longitudinally of the bushing 51 on each side thereof are operatively connected as by an insulating yoke 58' to the contacts 58, corresponding pairs of contacts 58 being electrically connected by conducting rods 60 as illustrated in Fig. 4 and the contacts 57 being connected in pairs by suitable means as the flexible means 61 so that the pairs of relatively movable contacts 57 and 58 are in series. The mounting structure for the pairs of contacts comprises a tubular insulating member 62 and an insulating partition or diaphragm 62' extending centrally and longitudinally of the insulating bushing 51. The diaphragm 62' separates the bushing 51 into upper and lower chambers or sections for a purpose hereinafter stated, the bushing likewise being provided with vertical partitions 63 spaced at intervals with respect to the insulating tube 62 and mounted transversely of and within the bushing 51. The partitions 63 accordingly divide the insulating tube 62 into separate compartments for individually housing the respective pairs of contacts. The partitions 63 and insulating tube 62 are provided with openings for permitting flow of oil under pressure from the lower to the upper section of the bushing only by way of the separated compartments in the tube 62. The flow of oil from the lower chamber is therefore directed by the diaphragms 62' into each compartment and transversely across the arcing surfaces of the contacts 57 and 58, into the hollow contact 57 to exhaust again into the upper or low pressure chamber formed between the diaphragm 62' and the bushing 51. The flow of oil is restricted to the path through the hollow contact 57 by reason of an insulating disc 64 providing mounting structure for the contact 57. Accordingly when the oil within the insulating structure 52 is under pressure it flows into an individual contact compartment through an opening 65, into and through the hollow contact 57, assuming of course that the contacts are separated, into the exhaust chamber through the opening 66 to the outer upper space in the insulating bushing. The partitions 63 are likewise provided with openings 68 for permitting continuous flow of oil through the insulating bushing to and from the respective contact compartments. The above arrangement accordingly insures a positive unidirectional flow of oil at predetermined velocity transversely across the arcing surfaces of each pair of contacts so that the arc products are removed through the hollow contact from the arcing surfaces of the contacts and the dielectric strength of each gap is simultaneously increased effectively to interrupt the circuit and extinguish the individual arcs. The gases generated during interruption of the circuit exhaust to the exterior of the breaker by way of the usual vent chamber 51' centrally located with respect to the bushing.

It shall, of course, be understood that any suitable arrangement may be provided for equally dividing the voltage between the respective pairs of contacts; for example a high resistance may be connected in shunt with the breaker across its terminals 50*a* and 50*b* and taps from the resistance may connect with the respective pairs of contacts so that the voltage impressed across each break is substantially the same. The remaining current flowing through the high resistance after opening of the breaker will be of such small value that it may be readily interrupted, as by a disconnecting switch in series therewith.

For the purpose of simultaneously and concurrently operating the movable contacts 58 and for producing fluid pressure to cause flow of oil across the contact surfaces there is provided an operating rod 67 connected to the piston 56 and to the operating mechanism 54. The operating end of the rod 67 has a cam member 168 adapted to engage and actuate the contact operating rods 59. The operating rods 59 are resiliently biased, as by the springs 68', towards the camming surfaces of the members 168 so that the contacts are opened either by positive actuation of the cam or by the action of their biasing means. In the position illustrated in Fig. 3 the contacts are closed and the operating rod 67 is in its lower position. When the compression spring 69 is released to project the piston 56 and operating rod 67 upwardly, the cam member 168 causes one set of operating rods 59, namely, those at the right side of the casing to move towards the open circuit position, and causes the springs on the opposite set of operating rods likewise concurrently to open the contacts associated therewith. The release of the compression spring 69 is caused by deenergization of the tripping magnet 70, releasing the armature 71 which in turn releases the floating pivot 72 of the lever 73, permitting it to rotate clockwise under the influence of the compression spring. The switch closing and spring charging operation is effected simply by resetting the armature 71 when the conditions in the circuit are normal and rotating the lever 73 about the pivot 72 in counterclockwise direction by the operation mechanism.

The circuit interrupter illustrated in Fig. 3, as has been previously described, is mounted for the purposes of simplicity in construction and economy in space within an insulating bushing of the conventional type used for bringing the

lead-in conductors into the steel tank or housing of a high tension oil circuit breaker. With a plurality of breaks in series as illustrated and described, it is possible to construct a circuit interrupter embodying my invention having practically the same rating as the aforesaid oil circuit breakers, within a single insulating bushing of the type used in connection with such breakers. In other words, the multiple break circuit interrupter illustrated in Fig. 3 may be considered as a switch housed within its own insulating bushing. The considerable saving in space effected by this type of circuit interrupter is obviously of great advantage, particularly in its application to electric locomotives which are not well adapted to house and carry bulky oil circuit breakers of the usual type.

It shall be understood that the fluid pressure means, as the piston 56, may comprise any suitable source of pressure adapted to force oil or other insulating liquid in a positive unidirectional flow across the contact surface in the manner above described in response to opening movement of the contacts.

It shall be also understood that my invention is not limited to specific details of construction and arrangement thereof herein illustrated, and that changes and modifications may occur to one skilled in the art without departing from the spirit of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A circuit interrupter comprising relatively movable coating contacts, one of said contacts comprising a tubular member, means for separating said contacts to form a short gap, a piston for producing a unidirectional flow of insulating liquid toward said tubular contact member, means correlating the operation of said piston and said contacts so that said piston is actuated substantially concurrently with separation of said contacts, and means confining said insulating liquid within the said gap and directing the same radially across the arc gap and into said tubular contact member so that the arc is entrapped and the arc products forced by said liquid into said tubular contact member at high velocity.

2. A circuit interrupter comprising a contact, a relatively movable tubular contact coacting therewith, means for separating said contacts to form a short gap, a piston actuated concurrently with opening of said contacts producing a unidirectional flow of insulating liquid towards said movable tubular contact, means correlating the operation of said tubular contact and piston, and means confining within said gap and directing said insulating liquid radially across the arcing surface of said first-named contact and into said tubular contact whereby the arc is entrapped and the arc products forced by said liquid into said tubular contact at high velocity.

3. A circuit interrupter of the impulse type comprising an insulating casing containing an insulating liquid, a fixed contact and a coacting movable tubular contact provided with pressure relief openings, a partition within said casing forming two chambers and substantially preventing flow of said insulating liquid from one chamber to the other in the closed circuit position, and a piston actuated by a predetermined driving force concurrently with the opening movement of the tubular contact producing a positive unidirectional flow of said insulating liquid at a predetermined velocity from one of said chambers radially across the arcing surface of said stationary contact and into said tubular contact to entrap the arc, said insulating liquid exhausting through said pressure relief openings in the open circuit position into the other chamber.

4. A circuit interrupter of the impulse type comprising a pair of hollow insulating members forming a casing, relatively movable contacts disposed within said casing, one of said contacts comprising a hollow movable rod and the other being mounted on a spider of conducting material clamped between said insulating members, said spider comprising one of the terminals of said breaker, a piston within said casing on one side of said spider for forcing insulating liquid under pressure across the arcing surface of said contacts and into said hollow rod contact substantially concurrently with the opening thereof, and means forming a pair of chambers on the other side of said spider within said casing restraining flow of said insulating liquid through said hollow rod contact so as to constrict and entrap the arc and to remove the arc gases formed between said contacts from one chamber to the other.

5. A circuit breaker of the impulse type including a casing containing an insulating liquid, coacting contacts disposed within said casing, fluid pressure means including a piston for introducing oil under impulse across the arcing surfaces of said contacts during separation thereof, and operating mechanism insuring substantially simultaneous actuation of the movable contact and piston common thereto comprising a latching structure, an electroresponsive tripping means for controlling said structure and a spring for actuating said piston and movable contact in response to actuation of the tripping means.

6. A high tension circuit interrupter comprising an insulating bushing, a plurality of pairs of relatively movable contacts arranged in series disposed within said bushing, said bushing containing an insulating liquid, spring means effecting separation of the respective contacts for simultaneously opening the circuit at a plurality of points and producing fluid pressure in said bushing, and means confining flow of said insulating liquid in separate paths radially across the arcing surfaces of said contacts to entrap and extenguish the arcs.

7. A high tension circuit interrupter of the fluid-break type comprising an elongated insulating casing, a plurality of pairs of contacts connected in series disposed longitudinally of and within said casing, each pair of contacts comprising a tubular contact and a contact coacting therewith, means confining flow of fluid to separate paths through said tubular contacts, and fluid actuating means adapted to force oil across the arcing surfaces into the tubular contact of each pair of contacts concurrently with the simultaneous opening of said contacts.

8. A high tension circuit interrupter comprising an insulating casing, a plurality of pairs of contacts arranged in series disposed within said casing, an insulating structure forming individual compartments for each pair of contacts, each compartment being divided by an insulating partition into two chambers, and fluid pressure means subjecting oil within said casing to pressure concurrently with the simultaneous opening of said contacts, each pair of contacts comprising a tubular contact mounted in and extending through a corresponding insulating partition, said partition confining flow of oil from one chamber into another to a path across the arcing surfaces of each pair of contacts.

9. A high tension circuit interrupter comprising a casing containing insulating liquid, a plurality of pairs of coacting contacts connected in series immersed in said liquid, a partition within said casing forming chambers, said chambers communicating through openings in said partition, and means creating fluid pressure in one of said chambers driving insulating liquid through said openings and extinguishing arcing at said contacts.

10. In a circuit interrupter of the fluid-break type, the method of interruption which comprises applying a predetermined force driving insulating liquid into and through the arc gap so as to break the continuity of the gas bubble with respect to the contacts of the circuit interrupter at a rate corresponding to the rate of increase of the recovery voltage.

11. In a circuit interrupter including contacts separable within an insulating liquid, the method of interruption which comprises driving insulating liquid into and through the arc gap so as to break the continuity of the gas bubble with respect to the contacts of the circuit interrupter at a predetermined minimum rate which is related to the rate of increase of the recovery voltage across the terminals of the circuit interrupter.

12. In a circuit interrupter of the fluid-break type, the method of interruption which comprises determining the rate of increase of the recovery voltage in that part of the circuit to be interrupted, and driving insulating liquid into and through the arc gap so as to break the continuity of the gas bubble with respect to the contacts of the circuit interrupter at a predetermined rate at least corresponding to said rate of increase of recovery voltage.

13. In a circuit interrupter of the fluid-break type including means driving oil through the arc gap so as to break the continuity of the gas bubble with respect to the contacts of the circuit interrupter, the method of interruption which comprises determining the rate of increase of the recovery voltage at the circuit interrupter terminals and regulating the velocity of said oil so that it is equal to or greater than a value directly proportional to the rate of increase of the recovery voltage.

DAVID C. PRINCE.

CERTIFICATE OF CORRECTION.

Patent No. 1,922,862. August 15, 1933.

DAVID C. PRINCE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, line 124, for "energizes" read "energized"; page 6, line 34, claim 1, for "coating" read "coacting"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 26th day of September, A. D. 1933.

(Seal)

F. M. Hopkins
Acting Commissioner of Patents.