

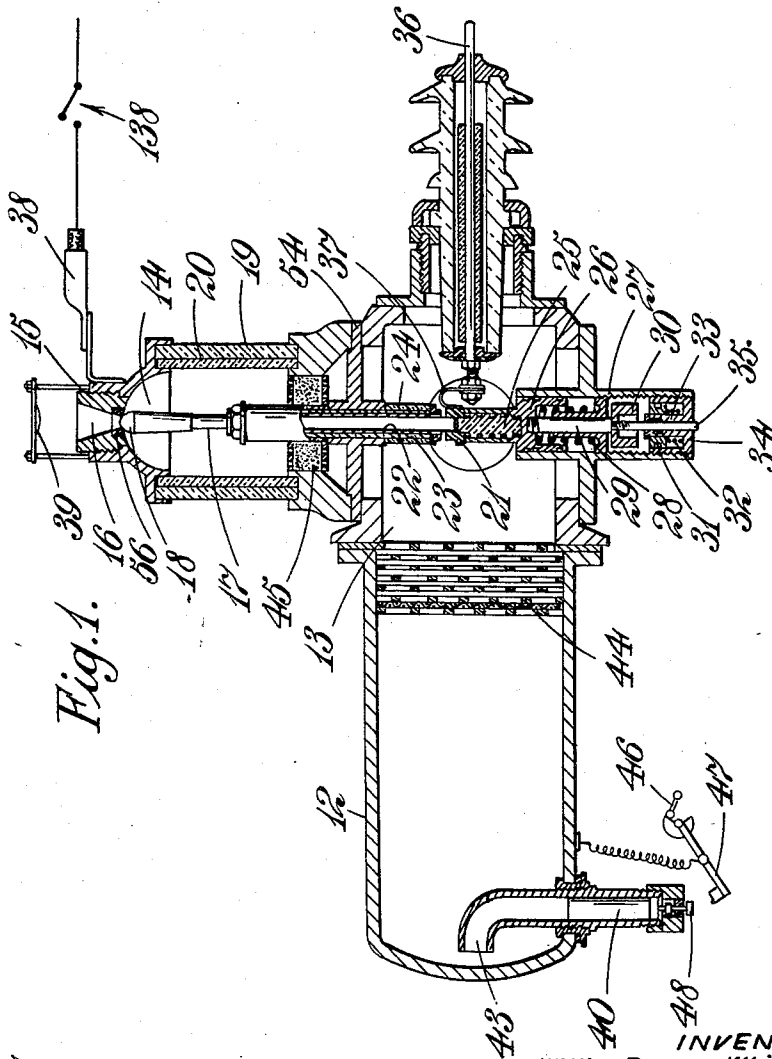
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ELECTRIC CIRCUIT BREAKER

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2 Sheets-Sheet 1



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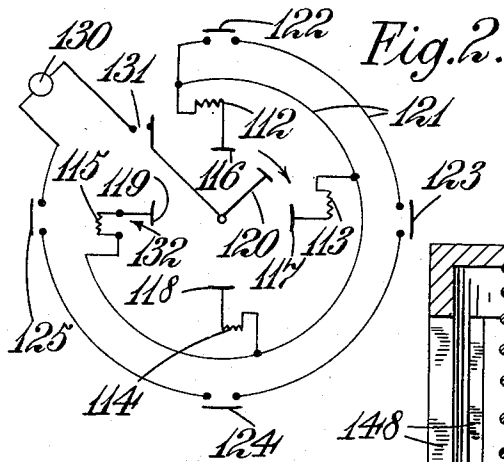
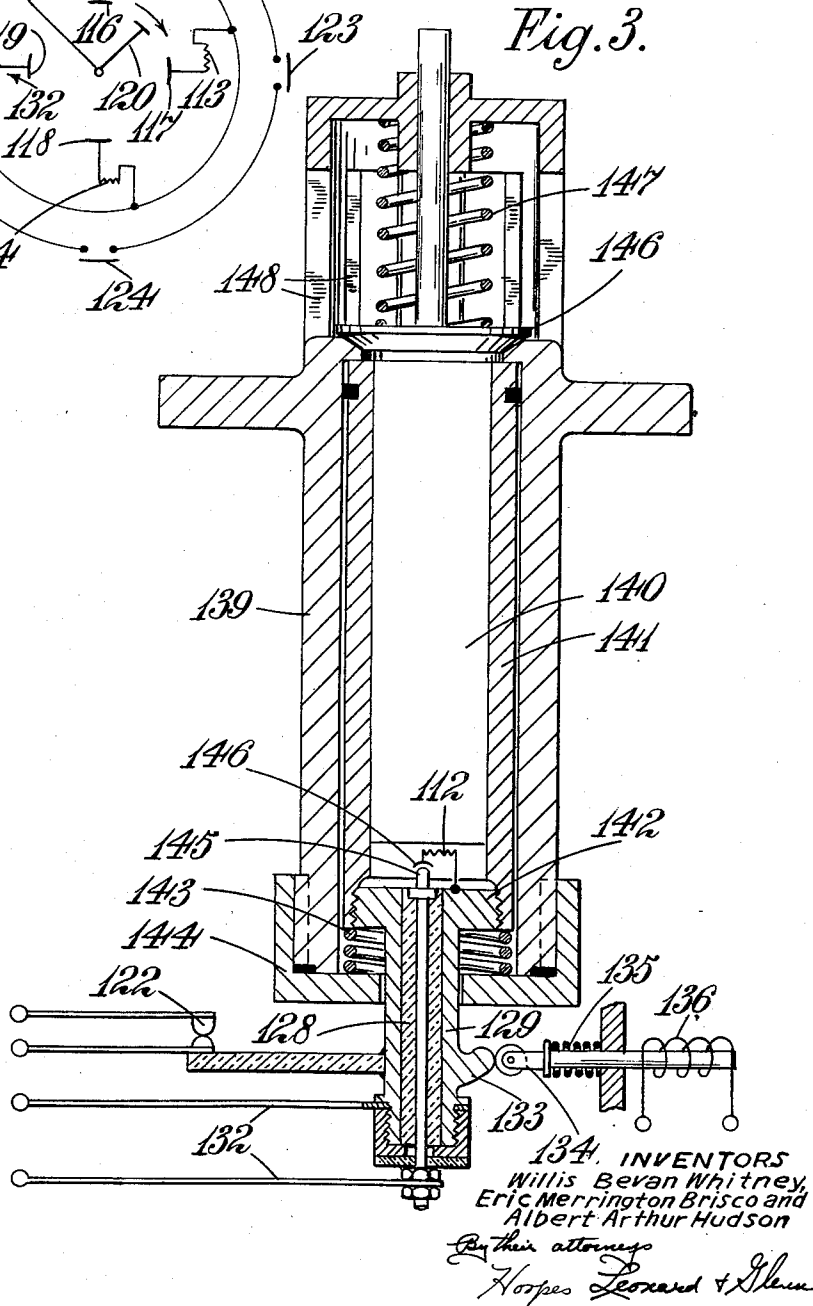
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UNITED STATES PATENT OFFICE

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ELECTRIC CIRCUIT BREAKER

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This invention relates to improvements in gas-blast electric circuit-breakers which utilize gas released from cartridges to provide the gaseous pressure for the blast.

The expression "cartridge" in this specification includes not only cartridges yielding gas under pressure, generated by chemical action, but also cartridges which store gas or readily vaporised liquid under high pressure provided that gas (e. g. air) can be released therefrom by electric or mechanical action. Further the expression "fired" relates not only to initiation of chemical action but also to other release of the gas under pressure.

It has been proposed for example in British patent specification No. 26,694/1901 to generate pressure for a gas-blast circuit-breaker by means of smokeless gun powder, and it has also been proposed to use explosive cartridges for the same purpose but such proposals did not lead to any success mainly because the electrodes in the vicinity of the arc-root and arc-path were actually supplied with hot gases whose dielectric strength was far too low to ensure extinction of the arc or to prevent re-striking of the arc on the appearance of recovery voltage.

The invention is applied to electric circuit-breakers for use in alternating high-tension power circuits of any fluid-blast type in which a portion of the arc-stream associated with any one break between two electrodes lies within a narrow passageway through which a high-velocity blast of gas or vapour escapes from a container to extinguish the arc, and in which the pressure in the container is produced by the discharge into it of gases released from a cartridge. One construction of circuit-breaker to which the invention may be applied is described in the specification of U. S. Patent No. 1,928,470 in which one electrode forms a passage (or a portion thereof) leading out of a container, and the other electrode consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage, or to open the switch and allow air or other gaseous dielectric under high pressure to escape between the electrodes and through the passage so as to quench the arc by the rapid removal of ionized gas from the vicinity of the arc. Such circuit-breakers are known as the axial blast type, but the invention can be applied to any kind of circuit breaker, single or divided-blast, axial or cross-blast or multi-break, and it will be understood that if the hot gases generated by a chemical action in a cartridge passed directly or easily

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to the arc-gap, grave difficulties would arise, firstly because such gases might contain quite a considerable proportion of minute incandescent solid particles which would tend to reduce the dielectric strength of the blast-gas, secondly because the gases emitted from the cartridge might be so hot as to be readily ionized, and thirdly because these gases might in fact be in an ionized condition.

This invention accordingly comprises an electric circuit-breaker of the type described, in which the gases emitted from the cartridge, and the air or vapour in the container, are constrained to reach the arc-gap in such de-ionized condition as to be suitable for arc-extinction by gas blast.

According to another feature of the invention an electric circuit-breaker of the type in which one electrode forms a passage (or a portion thereof) leading out of a container, the other electrode consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage, or to open the switch and allow air or other gaseous dielectric under high pressure to escape between the plug and the mouth of the passage and through the passage so as to quench the arc, and the pressure in the container is produced by the discharge of gases from a cartridge, is characterised by the fact that the gases emitted from the cartridge and the air in the container are in such a condition as to provide a suitable medium for arc-extinction by gas-blast.

This invention consists of an electric circuit-breaker of the type described having a container of which the principal outlet is formed by one or more throats or narrow passageways in which a portion of the arc-stream associated with any one break between two electrodes lies within such throat, said container being equipped with means for subjecting the arc or arcs in said throat or throats, during at least the first cycle of arcing, to a blast of un-ionized fluid and means for bringing about a sudden expulsion of fluid medium from one or more cartridges to increase the pressure in the container and to maintain the blast (suitable for arc extinction) through said throat or throats until the circuit is broken.

It will be understood that if in a cartridge-operated, gas-blast circuit-breaker one cartridge fails (e. g. fails to fire or fails to provide adequate gaseous pressure for extinction of the arc) it is essential that another cartridge shall be fired immediately; and one object of this inven-

tion is to satisfy such a requirement in an efficient, reliable and simple manner.

In the case where the cartridge pressure is generated by chemical action, the gases delivered from the cartridge are so directed and so treated as to bring their temperature and dielectric strength to such a state as to ensure complete electric isolation of the live electrodes of the circuit-breaker from one another for so long as the circuit-breaker remains open.

Preferably the gases delivered from the cartridge are so directed and so treated as to bring their temperature and dielectric strength to such a state as to maintain complete electric isolation of the live electrodes or associated conductive parts from one another during the period from the appearance of recovery voltage across the circuit-breaker till the reclosing of the circuit-breaker.

According to another feature of the invention the emission of gas from the cartridge is caused to displace the relatively cool (and clean) air in the container across the arc-gap to quench the arc, and an isolating switch in series with one of the electrodes is automatically opened after extinction of the arc, prior to the possible arrival at the arc-gap of hot or ionized gases from the cartridge.

In order to remove particles of carbon or any other solid suspensoids from the cartridge gases, the gases emitted from the cartridge may pass through a foraminous filter.

The filter may comprise heat-absorbing and conducting elements which substantially reduce the temperature of the gases passing there-through, or the cooling may be effected separately from the removal of suspensoids.

It is desirable that the gases generated in the cartridge should be so directed as not to impinge directly on an insulating surface relied on to insulate one electrode of the circuit-breaker from the other.

In order to reduce the kinetic energy of any solid suspensoids in the cartridge gases the gases emitted from the cartridge may be directed against a wall of the chamber in a direction opposite to that leading to the filter.

In one practical embodiment of this invention the gas-chamber comprises three parts viz. a tank having the breech to receive the cartridge, an intermediate chest containing the conducting connection between the movable electrode and its associated H. T. lead, and a switch-chamber containing the actual electrodes.

Further, there may be one foraminous, heat-absorbing filter between the tank and the intermediate chest and a second filter between the intermediate chest and the switch-chamber.

This invention includes an electric circuit-breaker of the cartridge-operated gas-blast type in which a series of electrically fired cartridges held in fixed breeches and adapted to deliver gas under high pressure to the circuit-breaker container, are electrically connected respectively to the bars of a distributor having a rotatable contact arm in circuit with (a) a source of firing current, (b) a relay (closed when a fault occurs in the power circuit to be protected) and (c) a common return conductor having for each electric igniter a switch normally closed but opened immediately the corresponding cartridge is successfully fired, so that if on the occurrence of a fault, a cartridge is successfully fired, the said igniter circuit is broken and no further firing takes place until the circuit-breaker has acted

and been reset, but if one cartridge fails, the next in order is fired.

In one arrangement each cartridge or cartridge cage containing the same, is associated with a hydraulic relay (e. g. a fixed cylinder with spring-controlled cartridge cage and axial extension) adapted on the successful firing of the associated cartridge to open the corresponding switch in the common return of the firing circuit and to keep it open as long as the fault persists.

Thus the spring-loaded cage may be directly subjected to the pressure of the cartridge when fired and the axial extension has a lock which holds the extension and keeps the corresponding switch in the open position as long as the fault persists. Thus the cartridge may be held in a cage which can slide freely (through a limited distance) in the fixed breech and the cage (by reaction) applies a thrust to the axial extension when the gases are rapidly expelled from the cartridge.

The nature of this invention and the manner in which it is performed will be appreciated from the following description, reference being made to the accompanying drawings in which—

Figure 1 is a central sectional elevation of one phase of a three-phase circuit-breaker.

Figure 2 is a circuit diagram for the arrangement in which a series of electrically fired cartridges is used, and

Figure 3 is a diagrammatic view indicating the action of the electrically controlled pneumatic lock.

Referring to Figure 1 a gas-chamber has three parts namely a cartridge-tank 12, an intermediate chest 13 and a switch-chamber 14. At the top of the switch-chamber one electrode 15 has a central passage 16 of which the mouth has an annular insert 56 of highly refractory metal such as a sintered tungsten-copper mixture. The plug electrode 17 of aluminum has a tip 18 of the same highly refractory metal. The outer wall 19 of the switch-chamber 14 is of insulating material such as resin-bonded paper and this wall may have a lining 20 of quartz. The plug electrode 17 is movable in the direction of its own axis through a limited distance (e. g. 1 to 2.5 cm.).

The aluminium rod 17 is continued down into an annular steel collar 21 and above said collar it is guided and supported in a tripple sleeve having an inner steel layer 22, an intermediate layer 23 of resin-bonded paper and an outer layer 24 of quartz. This assembly is held in a spider 54. The rod 17 is coupled by collar 21 to a solid extension 25 of insulating material which in turn is connected to an operating piston 26 working in a cylinder 27 fixed in the lower wall of the intermediate chamber 13 (which is conveniently of steel or iron). The piston and the plug electrode 17 are normally urged axially upward by the helical spring 28 but they are forced downwards when the pressure in chamber 13 overcomes the thrust of the spring 28. To limit the downward movement, the piston rod 29 carries a striking collar 30 which can engage the plunger 31 of a dash pot 32 having a helical compression spring 33 under the plunger and between it and the bottom 34 of the cylinder.

The steel collar 21 is electrically coupled to the H. T. lead 35 by a flexible conductor 37. The other H. T. lead 38 is coupled to the hollow electrode 15. If on lowering the plug electrode 17, the arc is struck from the tip 18 to the hollow

electrode 15, the upper end of the arc may travel up to the probe tip 39 which may be of highly refractory metal.

At the end of the tank 12 furthest from the intermediate chamber 13 is the breech for the cartridge 40, which breech forms no part of our invention. The gases are released from it through an outlet nozzle 43 which directs the gases from the cartridge 40 on to the end wall of the tank 12 in a direction opposite to that leading to the intermediate chamber, so as to reduce the kinetic energy of minute solid particles in the gases.

For the purpose of filtering the gases, and cooling them and thereby reducing or removing ionization, the gases pass through a main filter 44 composed of expanded metal or perforated plates and copper gauze which effects cooling and cleansing of the gases without causing objectionable loss of pressure in their passage through it.

A second foraminous metal filter 45 is preferably arranged between the intermediate chest 13 and the switch-chamber 14, and one effect of this filter is to prevent the direct impinging of the gases on the quartz lining 20 of the switch chamber. In practice, the first action of the high-pressure gases passing through the filter 45 is to push the cold air in the chamber 14 upwards through the gap between the electrodes 17 and 15 and through the passage 16, but it will be understood that at an operation of the circuit-breaker, the metal parts including the filters 44 and 45 will be at normal temperature; these filters have the effect of reducing very substantially the temperature of the cartridge gases which may reach the arc-gap.

The cooling of the cartridge-gases may be enhanced, if necessary, by providing for the cooling of the tank 12, as by cooling water, or by fins for air-cooling. It may also or alternatively be of massive construction to provide a large thermal capacity for absorption of heat from the gases.

The discharge of the cartridge may be effected in various ways. Thus an electric relay in the high-tension power-circuit may actuate a trip 46 for a spring-controlled hammer 47 which co-operates with the striking pin 48 for the percussion-cap of the cartridge 40. Alternatively the ignition of the cartridge may be effected electrically or mechanically.

The insertion of a fresh cartridge may be effected manually, but preferably an automatic cartridge-feed is used to ensure that a cartridge will be immediately available for use after a normal operation, or if a cartridge is defective, or preferably the arrangement described with reference to Figures 2 and 3 is used.

Still referring to Figure 1 an isolating switch 138 is provided in the H. T. lead 38 and is arranged to be opened automatically, as soon as the arc has been extinguished, and before the arrival at the arc-gap of cartridge-gases (if any) which are of such reduced dielectric strength as to render them unsuitable for arc-extinction, or prevention.

The operation of the device is as follows: When a fault occurs in the high-tension power circuit, the striker 48 ignites the cartridge 40 and the gases emitted from the cartridge pass to the outlet nozzle 43 of the breech so that they strike the end wall of the tank 12; then the gases pass through the metallic filter 44 into the intermediate chest 13, and ultimately upwardly

through the filter 45 into the switch chamber 14. The high pressure in the chest 13 forces down the piston 26 which carries with it the insulating extension 25, the collar 21 and the movable electrode 17 the tip 18 of which is thus pulled away from the mouth of the passage 16 in the fixed electrode 15. At this stage the cool air in the switch chamber 14 and, it may be, the cooled and cleaned cartridge gases are forced very rapidly through the gap between the tip 18 and the hollow electrode 15 causing a blast through the passage 56 so that the arc is extinguished.

It is important that the downward movement of the movable electrode 17 should be strictly limited to suit the requirements of the circuit (say to a distance of 1 to 2.5 cm.). For this purpose the piston 26 carries down with it the piston rod 29 and striking collar 30, which collar engages the plunger 31 of the dash pot 32 and arrests the downward movement. As soon as the pressure in the chest 13 has fallen sufficiently, the helical spring 28 forces the piston 26 upwards, unrestricted by the dash-pot, to restore the switch to its closed position, but in the meantime (as is well known in electric circuit-breakers) the isolating switch 138 in the main circuit will have been automatically opened.

In the case of a three-phase circuit-breaker, a single gas-chamber operating with a single cartridge may effect the opening of all three phases, by subjecting three pistons 26 to the operating pressure of the gases generated from a cartridge, such pressure, of course, also being available for extinction of the three arcs.

In a typical test, using a 1" diameter copper-tungsten throat and a break-gap limited to 1.8 cms., a circuit-breaker as shown in the accompanying drawing cleared a highly-inductive circuit carrying the highest kva. available for the test, viz. approximately 3 kiloamperes at 10 kv. in one half cycle of arcing, with a maximum switch-chamber pressure of about 35 lbs. per square inch above atmosphere.

Referring to Figures 2 and 3 it will be understood that the circuit-breaker has a container into which the gases under pressure from each cartridge can pass and the tank or tanks containing the fixed breeches for the cartridges may be directly coupled (say through a filter and cooler) with said container. The cartridges belong to the electrically ignited type. Referring to Figure 2 the firing fuses 112, 113, 114, 115 of the cartridges are respectively connected electrically with the bars 116, 117, 118, 119 of a commutator having a radial contact arm 120 which is continuously driven. The axis of the contact arm 120 is connected in circuit with (a) a source of firing current 130, (b) an overload relay 131 normally open but closed when a fault occurs, and (c) common return conductor 121 having for each igniter or firing fuse 112, 113, 114, 115 a corresponding switch 122, 123, 124, 125 normally closed but opened immediately the corresponding cartridge 140 is successfully fired.

Referring to Figure 3, the cartridge 140 is held in a cage 141 closed at the bottom by disc 142 which has screw-engagement with cage 141. The cage 141 can slide freely in the fixed breech 139. A helical spring 143 urges the cage 141 upwardly and is held in position by a cap 144 which engages the breech 139 with a bayonet joint. The disc 142 has an axial downward extension 129 having an upturned protuberance or horn 133. A tappet 134 controlled by helical spring 135 is arranged to lock the extension 129 in its lower

position when the cartridge 140 is successfully fired, and solenoid 136 is actuated when the switch 131 is again opened, so that tappet 134 is withdrawn into the position shown in Figure 3 allowing the cage 141, 142 to rise again to its normal position as shown.

It will be seen that the downward movement of the cage 141, 142 (when the cartridge 140 is successfully fired) opens the corresponding switch 122.

The firing fuse or filament 112 is electrically connected at one end with conducting disc 142 and thus earthed. The other end has a terminal 146 which makes contact with a conducting probe 145 and the probe 145 is electrically connected to one of the corresponding terminals 132. The probe 145 is insulated from extension 129 by sleeve 128.

Above the cage 141 and cartridge 140, is a one way valve 146 controlled by a light spring 147 within the spider or lantern 148 so that gases from the cartridge 140 can freely pass outwards through valve 146 and lantern 148, but extraneous gases (such as those from another cartridge) cannot pass into the cage 141 or breech 139 when the valve 146 is closed.

The method of inserting a new cartridge is simple: The cap 144 is removed from the breech 139; the cage 141 is removed from the breech; the disc 142 is unscrewed from the cage 141; the fired cartridge 140 is removed from the cage and replaced by a fresh cartridge; the disc 142 is screwed back in place and the cage 141 is replaced in the breech 139, the cap 144 being also replaced.

It has been stated above that the rotating arm is continuously driven. Alternatively the arm 120 may be rotated by clockwork which can be wound up after the circuit-breaker has operated and the clockwork may be set in motion when the relay 131 is closed.

We claim:

1. An electric circuit-breaker having a container of which the principal outlet is formed by a throat in which a portion of the arc-stream associated with any one break between two electrodes lies within such throat, said container being equipped with means for subjecting the arc in said throat, during at least the first cycle of arcing, to a blast of gas, means for bringing about a sudden expulsion of gaseous medium from a cartridge to increase the pressure in the container and to provide and maintain the blast through said throat until the circuit is broken and de-ionizing means interposed between said cartridge and said electrodes ensuring that the whole of the gas reaching the arc-gap is in such de-ionized condition as to be suitable for arc-extinction by gas-blast.

2. An electric circuit-breaker of the type in which one electrode forms a passage leading out of a container, the other electrode consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage, or to open the switch and allow gaseous dielectric under high pressure to escape between the plug and the mouth of the passage and through the passage so as to quench the arc, and the pressure in the container is produced by the discharge of gases from a cartridge, and in which de-ionizing means interposed between said cartridge and said electrodes ensure that the gases delivered from the cartridge and the air in the container are wholly in such a condition on reaching the electrodes as to pro-

vide a suitable medium for arc-extinction by gas-blast.

3. An electric circuit-breaker as claimed in claim 1 in which when one cartridge fails to fire or to provide adequate gaseous pressure for extinction of the arc, action is automatically transferred immediately to another cartridge arranged to discharge into the container.

4. An electric circuit breaker of the type in which one electrode forms a passage leading out of a container, the other electrode consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage or to open the switch and allow gaseous dielectric under high pressure to escape between the plug and the mouth of the passage and through the passage so as to quench the arc, and in which the pressure in the container is produced by the discharge of gas from cartridge means, the discharged gas and the air in the container being in such a condition as to provide a suitable medium for arc extinction by gas-blast, said circuit-breaker comprising in combination a series of electrically fired cartridges held in fixed breeches and adapted to deliver gas under high pressure to the circuit-breaker container and electrically connected respectively to the bars of a distributor having a rotatable contact arm in circuit with (a) a source of firing current, (b) a relay (closed when a fault occurs in the power circuit to be protected), and (c) a common return conductor having for each electric igniter a switch normally closed but opened immediately the corresponding cartridge is successfully fired, so that if on the occurrence of a fault, a cartridge is successfully fired, the said igniter circuit is broken and no further firing takes place until the circuit-breaker has acted and been re-set, but if one cartridge fails, the next in order is fired.

5. An electric circuit-breaker as claimed in claim 4 in which each cartridge is associated with a hydraulic relay adapted on the successful firing of the associated cartridge to open the corresponding switch in the common return of the firing circuit and to keep it open as long as the fault persists.

6. An electric circuit breaker as claimed in claim 4 in which each cartridge is contained within a cartridge cage associated with a hydraulic relay comprising a fixed cylinder embracing a spring controlled cartridge cage having an axial extension adapted on the successful firing of the associated cartridge to open the switch in the common return of the firing circuit and to keep it open as long as the fault persists.

7. An electric circuit-breaker as claimed in claim 6 in which the spring-loaded cage is directly subjected to the pressure of the cartridge when fired and the axial extension has a lock which holds the extension and keeps the corresponding switch in the open position as long as the fault persists.

8. An electric circuit-breaker for use in high-tension power circuits with alternating current of the type in which one electrode forms a passage leading out of a gas-tight container and the other electrodes consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage or to open the switch and allow dielectric gas under high pressure to escape between the plug and the mouth of the passage and through the passage so as to quench the arc by the rapid removal of ionized gas from the

vicinity of the arc root, said circuit-breaker comprising in combination with the container, a cartridge tank, a cartridge mounted in said tank, means for firing the cartridge and means for cooling and filtering the gas discharged from said cartridge so that the said gas and the air in the container when they reach the said escape passage are in such a state of temperature and dielectric strength as to ensure complete electric isolation of the live electrodes of the circuit-breaker from one another for so long as the circuit-breaker remains open.

9. An electric circuit-breaker for use in high-tension power circuits with alternating current of the type in which one electrode forms a passage out of a gas-tight container and the other electrode consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage or to open the switch and allow dielectric gas under high pressure to escape between the plug and the mouth of the passage and through the passage so as to quench the arc by the rapid removal of ionized gas from the vicinity of the arc root, said circuit-breaker comprising in combination with the container, a cartridge tank, a cartridge mounted in said tank, means for firing the cartridge and means for cooling and filtering the gas discharged from said cartridge so that the said gas and the air in the container when they reach the said escape passage are in such a state of temperature and dielectric strength as to maintain complete electric isolation of the live electrodes or associated conductive parts from one another during the period from the appearance of recovery voltage across the circuit-breaker till the reclosing of the circuit-breaker.

10. An electric circuit-breaker as claimed in claim 8 in which in order to remove particles of carbon or any other solid suspensoids from the cartridge gases, the gases emitted from the cartridge pass through a foraminous filter comprising heat-absorbing or conducting elements which substantially reduce the temperature of the gases passing therethrough.

11. An electric circuit-breaker for use in high-tension power circuits with alternating current of the type in which one electrode forms a passage leading out of a gas-tight container and the other electrode consists of a metallic plug axially movable through a limited distance to close the switch and to close the mouth of said passage or to open the switch and allow dielectric gas under high pressure to escape between the plug and the mouth of the passage and through the passage so as to quench the arc by the rapid removal of ionized gas from the vicinity of the arc root, said circuit-breaker comprising in combination with the container, a cartridge tank, a cartridge mounted in said tank, means for firing the cartridge and means for cooling and filtering the gas discharged from said cartridge so that the said gas and the air in the container when they reach the said escape passage are in such a state of temperature and dielectric strength as to ensure complete electric isolation of the live electrodes of the circuit-breaker from one another for so long as the circuit-breaker remains open, the circuit-breaker gas chamber comprising three parts, namely a tank having a breech to receive the cartridge, an intermediate chest containing the conducting connection between the movable electrode and its associated H. T. lead, and a switch chamber containing the actual electrodes.

12. An electric circuit-breaker having a container of which the principal outlet is formed by a throat in which a portion of the arc-stream associated with any one break between two electrodes lies within such throat, said container being equipped with means for subjecting the arc in said throat, during at least the first cycle of arcing to a blast of fluid and means for bringing about a sudden expulsion of fluid medium from a cartridge to increase the pressure in the container and to maintain the blast (suitable for arc extinction) through said throat until the circuit is broken, in which when one cartridge fails to fire or to provide adequate gaseous pressure for extinction of the arc, action is automatically transferred immediately to another cartridge arranged to discharge into the container.

13. An electric circuit-breaker having a container of which the principal outlet is formed by a throat in which a portion of the arc-stream associated with any one break between two electrodes lies within such throat, said container being equipped with means for subjecting the arc in said throat, during at least the first cycle of arcing to a blast of fluid and means for bringing about a sudden expulsion of fluid medium from a cartridge to increase the pressure in the container and to maintain the blast (suitable for arc extinction) through said throat until the circuit is broken, said circuit-breaker comprising in combination a series of electrically fired cartridges held in fixed breeches and adapted to deliver gas under high pressure to the circuit-breaker container and electrically connected respectively to the bars of a distributor having a rotatable contact arm in circuit with (a) a source of firing current, (b) a relay (closed when a fault occurs in the power circuit to be protected) and (c) a common return conductor having for each electric igniter a switch normally closed but opened immediately the corresponding cartridge is successfully fired, so that if on the occurrence of a fault, a cartridge is successfully fired, the said igniter circuit is broken and no further firing takes place until the circuit-breaker has acted and been re-set, but if one cartridge fails, the next in order is fired.

14. An electric circuit-breaker as claimed in claim 13 in which each cartridge is associated with a hydraulic relay adapted on the successful firing of the associated cartridge to open the corresponding switch in the common return of the firing circuit and to keep it open as long as the fault persists.

15. An electric circuit breaker as claimed in claim 13 in which each cartridge is contained with a cartridge cage associated with a hydraulic relay comprising a fixed cylinder embracing a spring controlled cartridge cage having an axial extension adapted on the successful firing of the associated cartridge to open the switch in the common return of the firing circuit and to keep it open as long as the fault persists.

16. An electric circuit-breaker as claimed in claim 13 in which the spring-loaded cage is directly subjected to the pressure of the cartridge when fired and the axial extension has a lock which holds the extension and keeps the corresponding switch in the open position as long as the fault persists.

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