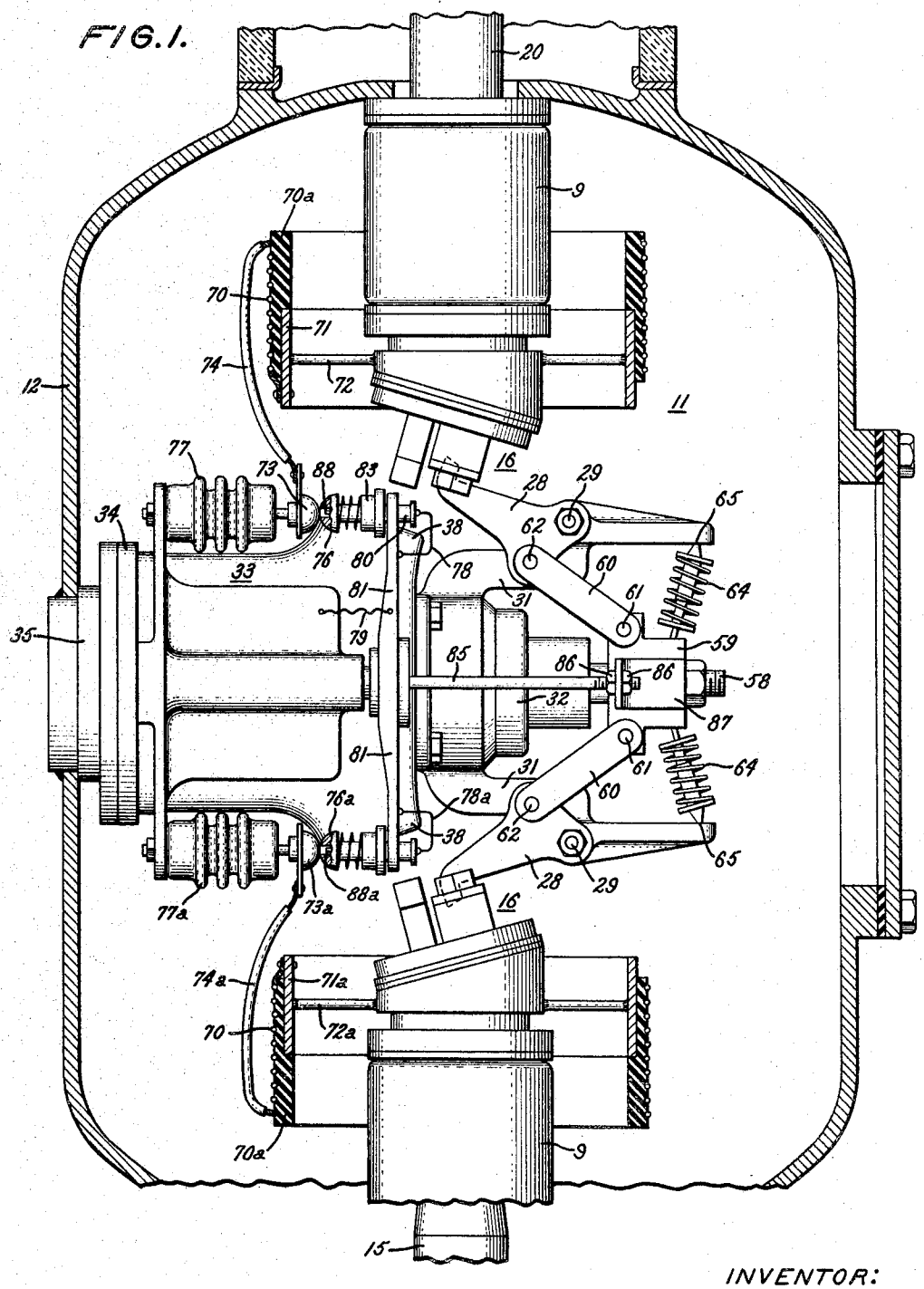
Aug. 16, 1966 W. R. WILSON 3,267,241

MULTIPLE BREAK HIGH VOLTAGE CIRCUIT BREAKER WITH VARIABLE LENGTH GAP CONTROL MEANS

Filed Oct. 5, 1964 2 Sheets-Sheet 1

FIG. 1.



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FIG. 2.

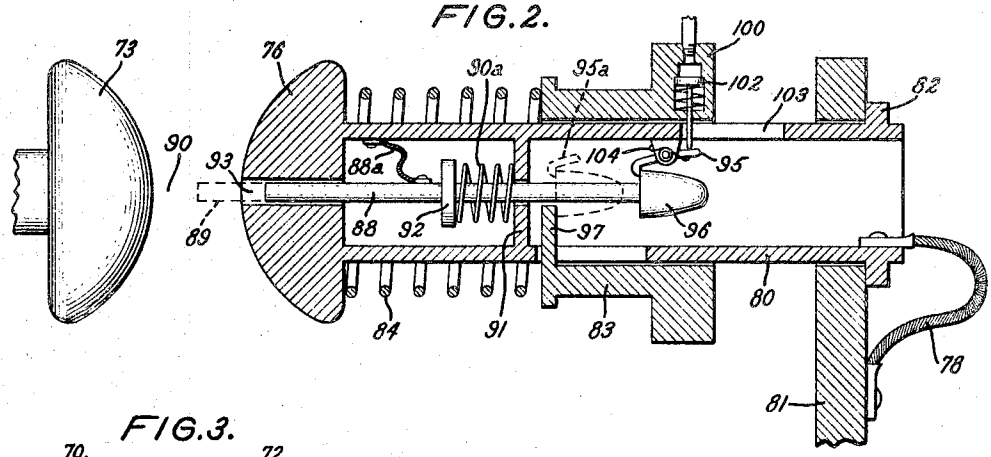


FIG. 3.

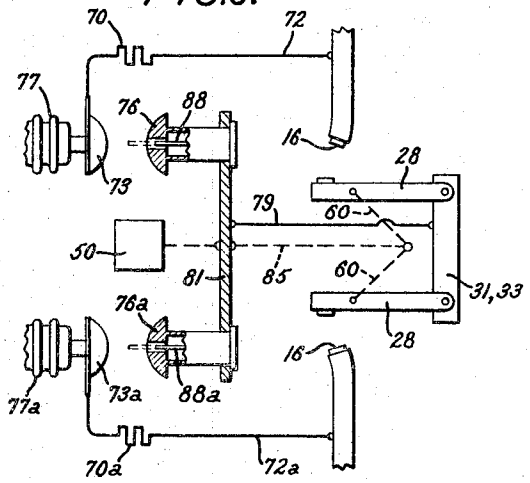


FIG. 1a.

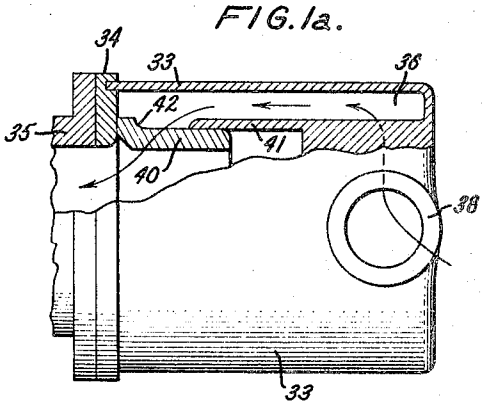


FIG. 4.

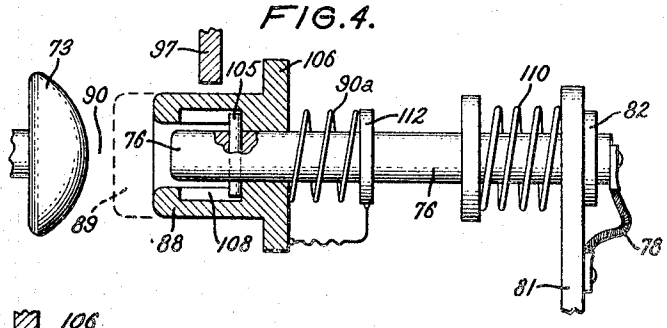
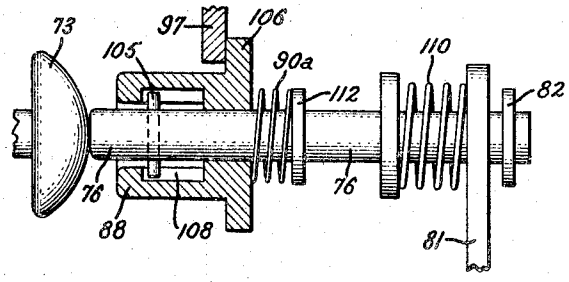


FIG. 5.



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3,267,241

MULTIPLE BREAK HIGH VOLTAGE CIRCUIT BREAKER WITH VARIABLE LENGTH GAP CONTROL MEANS

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Filed Oct. 5, 1964, Ser. No. 401,628
15 Claims. (Cl. 200—146)

This invention relates to a high voltage circuit breaker of the type that has a plurality of breaks electrically connected in series. The invention is particularly concerned with means for protecting the insulation of such a circuit breaker from being damaged by certain overvoltages that can arise during a closing operation.

In closing a multiple-break circuit breaker of the above type, an effort is usually made to close all of the series-connected breaks substantially simultaneously. For various reasons, however, it may not be feasible to control the closing operation so precisely that all the breaks reach closed position at exactly the same instant. If the breaks are not closed precisely simultaneously, the available voltage across the last break to close will approach in magnitude the value of the entire voltage then prevailing across the multiple break circuit breaker.

If the gap at the last break is relatively long at the instant that this entire voltage becomes available thereacross, it may not break down in response to the application of this voltage, and this can subject any insulation paralleling the break to this voltage. This can produce a damaging flashover across the paralleling insulation, particularly if the voltage involved is very high.

An object of the present invention is to prevent such a flashover from occurring across the insulation paralleling the last break to close.

Another object is to perform this protective function without causing current to flow through the circuit breaker prior to effective closing of the first break to close.

In carrying out my invention in one form, I provide a high voltage circuit breaker that comprises a plurality of breaks electrically connected in series and means for closing said breaks approximately simultaneously. Connected across at least one of the breaks, I provide means defining a variable length gap. The variable length gap is maintained in a fully open position when the circuit breaker is fully open. Gap control means is provided for shortening said variable length gap during a circuit breaker closing operation to a predetermined length wherein the gap upon reaching said predetermined length has a lower breakdown voltage than is normally then present across any of the insulation paralleling said gap. Means is provided for causing said gap control means to shorten said gap to said predetermined length before any of the other breaks is sufficiently closed to initiate a flashover across said one break and before said one break has a breakdown voltage as low as said gap. In a preferred form of the invention, the predetermined gap length is sufficiently high to prevent the gap from breaking down before any one of said breaks effectively closes during a circuit breaker closing operation.

For a better understanding of the present invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a cross-sectional view of an electric circuit breaker embodying one form of the present invention, the circuit breaker being shown in closed position.

FIG. 1*a* is a simplied view, partly in section, of a portion of the circuit breaker of FIG. 1.

FIG. 2 is an enlarged sectional view of one of the breaks of the resistor switch that constitutes a part of

the circuit breaker of FIG. 1. This break is shown in its open position.

FIG. 3 is a schematic illustration of the circuit breaker of FIG. 1 showing the circuit breaker in open position.

FIG. 4 is a sectional view of a modified form of the invention showing the parts in the position occupied when the circuit breaker is fully open.

FIG. 5 shows the modification of FIG. 4 in its closed position.

Referring now to FIG. 1, the circuit breaker shown therein is of the general type disclosed and claimed in Patent No. 2,911,546, Oppel, and in Patent No. 2,783,-338, Beatty, both assigned to the assignee of the present invention. This circuit breaker comprises an enclosed interrupting chamber **11** defined, in part, by a metallic casing **12** which is filled with pressurized arc-extingishing gas.

A pair of elongated conductive studs **15** and **20** project into the casing **12** from diametrically-opposed points, and each of these studs carries a suitable stationary contact assembly **16** at its radially inner end. Insulators **9** support these studs and electrically isolate them from the casing **12** when the circuit breaker is open. Cooperating with each stationary contact assembly is a movable contact **28** pivotally mounted upon a stationary pivot **29**. These pivots **29** are supported upon stationary brackets **31** which are integral with one end of a stationary operating cylinder **32**. Suitable means (not shown) are provided for transferring current between the movable contacts **28** and the brackets **31**, so that the brackets **31** together with the cylinder **32** form a conductive path electrically interconnecting the two movable contacts **28**.

The cylinder **32**, at its left hand end, is suitably supported from a generally cylindrical housing **33**, which, in turn, is suitably secured at its left hand end to the metallic casing **12**. The mechanical connection between the housing **33** and the casing **12** is best shown in FIG. 1*a*, where the housing **33** is shown provided with a flange **34** that is suitably joined to a flange **35** secured to the casing **12**.

For producing a gas-blast action for extinguishing the arcs which are established by separation of the contacts **16** and **28**, the housing **33** is provided with a normally-closed annular exhaust passage **36** which leads from the interrupting chamber **11** to the surrounding atmosphere. This will be more readily apparent from FIG. 1*a*. The housing **33** at its right hand end is formed with a pair of generally diametrically-opposed nozzle-type electrodes **38** defining inlets to the exhaust passage **36**. For controlling the flow of arc-extinguishing gas through the nozzle electrodes **38** and through the exhaust passage **36**, there is provided at the outer end of the exhaust passage **36** a cylindrically-shaped reciprocable blast valve member **40** which slides smoothly in a surrounding tubular valve housing **41** integrally formed in the housing **33**. In FIG. 1*a*, the valve member **40** is shown in its closed position wherein an annular flange **42** formed at its left end sealingly abuts against the stationary flange **34**, which serves as a valve seat. The valve member **40** is normally maintained in this closed position of FIG. 1*a* by the action of a suitable spring (not shown) and by the action of the pressurized gas within the passageway **36** acting upon flange **42**.

Since the chamber **11** is normally filled with pressurized gas, it will be apparent that when the valve member **40** is opened by movement to the right (by means not shown), gas in the chamber **11** will flow at high speed through the nozzles **38** and out the passage **36** past valve member **40** to atmosphere, as is indicated by the arrows shown in FIG. 1*a*. This rapid flow of gas through the nozzles **38** creates an axial arc-enveloping blast which acts rapidly to extinguish the arcs which are drawn adja-

cent the nozzles **38** by movement of the movable contacts **28** away from their stationary contact assemblies **16**.

For operating the blast valve **40** and the movable contacts **28**, a combined operating mechanism preferably of the fluid-actuated type shown in the aforementioned Beatty patent is provided within the cylinders **32** and **33**. This operating mechanism is shown in block form at **50** in the schematic illustration of FIG. 3. The details of this operating mechanism **50** form no part of the present invention and, hence, such details are not shown in the present application. An adequate understanding of the present invention may be had if it is understood that the operating mechanism acts during an opening operation to drive a piston rod shown at **58** in FIG. 1 to the right and also acts to open the blast valve **40**. The piston rod **58** is coupled to the contacts **28** (by means soon to be described) and, hence, such movement of the piston-rod serves to drive the contacts open. At a predetermined instant after the contacts **28** have been opened, the then-open blast valve **40** is driven closed by the operating mechanism, as it is described in detail in the Beatty patent. This prevents further loss of gas from interrupting chamber **11**.

The means for coupling the piston rod **58** to the main contacts comprises a cross head **59** and two sets of connecting links **60**. The cross head **59** is rigidly secured to the piston rod **58** by suitable clamping means, whereas the connecting links **60** are pivotally connected at **61** and **62** to the cross head and movable contacts, respectively.

In the position of FIG. 1, the movable contacts **28** are biased into closed position by means of overcenter compression springs **64**. Each of these springs **64** has one end pivotally supported at **65** on a projecting portion of one of the brackets **31**. At their inner ends, the springs **64** are pivotally supported on the cross head **59**. These overcenter springs **64** tend to urge the contacts closed while the cross head **59** is to the left of a reference line connecting the pivots **65**. But when the cross head is moved to the right beyond this reference line (as occurs during a contact-opening operation), the overcenter springs thereupon tend to urge the contacts in a contact-opening direction. This action coupled with that of the operating mechanism acts to hold the contacts **28** in a fully-open position until the operating mechanism is subsequently operated to close the contacts **28**.

Shunting the upper pair of main contacts **16, 28** is an impedance element **70**, preferably in the form of a resistor wound about an insulating core **70*a*** carried by a conductive tube **71**. The conductive tube **71** is supported from the conductive stud **20** by means of conductive webs **72** electrically interconnecting the tube **71** and the stationary contact assembly **16**. The lower terminal of the resistor **70** is connected to the tube **71**, whereas the upper terminal is locally insulated from the tube **71** and is connected by means of a conductor **74** to a stationary contact **73** of an auxiliary or resistor switch **75**.

The resistor switch **75** comprises, in addition to the stationary contact **73**, a second contact **76** that is movable with respect to the stationary contact **73**. The movable contact **76** is shown in FIG. 1 in a position of engagement with the stationary contact **73**, but it is movable to the right out of engagement with the contact **73** to form an interrupting break between the two contacts. The stationary contact **73** is shown supported on the central housing **33** by an insulator **77** which is capable of isolating the contact **73** from the housing **33** when the resistor switch is open. The movable contact **76** is also supported on the housing **33** but is electrically connected to the housing through a conductive cross bar **81** and a suitable conductive braid **78** connected through the cross bar **81** and the movable contact **76**. An electrical connection between the cross bar **81** and the housing **33** is schematically shown at **79**.

When the circuit breaker is in the closed position of FIG. 1, it will be apparent that the resistor **70** is connected in shunt with the upper contact **16, 28** by means of a circuit which extends through the parts **72, 71, 70, 74, 73, 76, 78, 81** and **79**. It should also be apparent from FIG. 1 that the lower main contacts **16, 28** are shunted by a similar circuit. Since the parts forming this lower shunting circuit are substantially identical to those forming the upper circuit, corresponding lower parts have been assigned corresponding reference numerals. The schematic illustration of FIG. 3 provides a simplified showing of the electrical relationships between the parts. For simplicity I have depicted only a single interrupting assembly, but it is to be understood that additional interrupting assemblies (not shown) may be connected in series with the single illustrated assembly. In such circuit breakers suitable means (not shown) is provided for operating the assemblies concurrently.

For controlling the operation of cross-bar **81**, an operating rod **85** is coupled at one end to the cross-bar **81** and at its opposite end to the cross head **59**. Thus, when the cross head **59** is driven to the right from its position of FIG. 1 during a circuit breaker opening operation, the cross-bar **81** is also moved to the right to effect opening of the resistor switch. Similarly, when the cross head **59** is driven to the left from its open position during a circuit breaker closing operation, the cross-bar **81** is driven to the left from its position of FIG. 3 to effect closing of the resistor switch. To simplify the present description, the details of the coupling between the operating rod **85** and the cross-bar **81** have not been shown, but it is to be understood that they can be as described in the aforesaid Oppel Patent 2,911,456. It is to be understood that on circuit-breaker opening this coupling will provide for a time delay between opening of the main contacts **16** and opening of the resistor switch contacts, thus permitting the resistor switch contacts to open at an appropriate instant after opening of the main contacts.

Referring now to FIG. 2, which is an enlarged sectional view of one of the breaks of the resistor switch **75** in its open position, it will be noted that the movable contact **76** comprises a tubular rod portion **80**. The tubular rod portion **80** is slidably mounted in an opening in the conductive cross-head **81** and is also slidably mounted in a stationary bearing **83** which is carried by the central housing **33**. At the outer end of the tubular rod portion **80** there is a shoulder **82** that bears against the outer side of the cross head **81** when the switch is open. A compression spring **84**, bearing at its rear end on the stationary bearing **83** and at its forward end on the movable contact **76**, urges the movable contact **76** toward closed position but is prevented from moving the contact **76** out of its open position of FIG. 2 so long as the cross head **81** is maintained in its open position shown. When the cross head **81** is moved to the left toward closed position, the compression spring **84** drives the movable electrode **76** into engagement with the stationary electrode **73** to close the resistor switch **75**.

Closing of the circuit breaker described hereinabove is effected by causing the operating mechanism **50** to drive the two main contacts **26** and the two resistor switch contacts **76** into engagement with their respective stationary contacts to reestablish the power circuit through the circuit breaker. The resistor switch contacts **76** and **76*a*** can be arranged to engage their respective stationary contacts **73** and **73*a*** either after or before the main contacts **28** reach their closed position. But in the preferred embodiment of the invention described hereinafter, the resistor switch contacts **76, 76*a*** are assumed to reach closed position prior to the instant that the main contacts **28** reach closed position. Thus, during closing, the power circuit is initially established through the resistor switch contacts.

In accordance with conventional practice, an effort is made to cause the two movable contacts **76** and **76*a*** of the resistor switch to reach closed position at substantially the same instant. For various reasons, however, it may not be feasible to cause the movable contacts **76*a*** and **76** to reach their closed position at precisely the same instant. Attain-

ing this simultaneous closing of series connected breaks is particularly difficult when there are additional assemblies (corresponding to the assembly of FIG. 3) connected in series with the assembly of FIG. 3 and suitably arranged to be operated approximately simultaneously therewith. The more of these assemblies that are present, the more difficult it is to operate all of the assemblies in precise synchronism.

If one of the movable contacts **76** or **76***a* has not reached closed position when the other contact has, then a voltage approaching in magnitude the entire voltage then prevailing across the circuit breaker will become available across the last break to close. This is likewise true if there are additional assemblies closing approximately simultaneously. If the gap at the last break is then relatively long, it will not immediately break down in response to the application of this high voltage thereto. This results in this high voltage being applied for a significant interval across any insulation paralleling the last gap to close, e.g., the insulator **77** or the insulator **9** of FIG. 1. If this voltage is high enough, then it can produce a possibly damaging flashover along this paralleling insulation. A primary object of the present invention is to prevent any such flashover of the insulation parallelling the last break to close.

I achieve this objective by providing each of the breaks of the resistor switch **75** with a variable length gap that is connected thereacross during the crucial portion of a closing operation. During the closing operation, each of these gaps is controlled in a manner (soon to be described) that prevents a damaging breakdown of the above-described nature from occurring.

For serving as one electrode of the protective gap paralleling each resistor switch break, I provide an auxiliary electrode **88** of rod form. Referring to FIG. 2, this auxiliary electrode **88** is disposed within the tubular portion **80** of one of the movable contacts **76** of the resistor switch **75** and is electrically connected to the movable contact **76** by a suitable flexible braid **88***a* that permits relative movement between the auxiliary electrode **88** and the movable contact **76**. The auxiliary electrode **88** cooperates with the stationary contact **73** of the resistor switch to form the above-described protective gap therebetween.

When the circuit breaker is open as shown in FIG. 2, the protective gap between the auxiliary electrode **88** and the stationary electrode **73** is relatively long. But as soon as circuit breaker closing is initiated, the auxiliary electrode **88** is quickly projected into its dotted line position **89** to shorten the protective gap (indicated at **90**). The protective gap **90** is so designed that when the auxiliary electrode **88** enters its dotted line position **89**, the breakdown voltage across the gap **90** is lower than the breakdown voltage across any solid or gaseous insulation paralleling the gap **90**. Accordingly, if the resistor switch break shown in FIG. 2 happens to be the last break of the resistor switch **75** to close and the entire voltage thus becomes available to appear across this break, this voltage will not cause a breakdown across the paralleling insulation. If the gap **90** is the shortest gap at this instant, then any breakdown that occurs upon application of this high voltage will occur across the gap **90** rather than along across the parallel insulation. Of course, it the gap between the contacts **76** and **73** is then shorter than the gap **90**, then any breakdown that occurs will be between the contacts **76** and **73**. But, at any rate, the breakdown will not be adjacent or through any solid insulation. A breakdown across gap **90** or across the switch break between contacts **73** and **76** will not be damaging to the insulation of the circuit breaker since the arc resulting from such a breakdown will be remote from the circuit breaker's solid insulation and will be quickly extinguished by complete closing of the resistor switch.

Additional features of the protective gap will be pointed

out in connection with the following detailed description of the gap and its control means. Referring now to FIG. 2, it will be noted that the auxiliary electrode **88** is biased toward its dotted line position **89** by means of a compression spring **90***a* which bears at its rear end on an internal shoulder **91** in the tubular rod portion **80** and bears at its forward end against the shoulder **92** of the auxiliary electrode **88**. The movable electrode **76** has a central opening **93** in which the forward end of the auxiliary electrode **88** is slidably mounted so that it can move into its dotted line position **89** shown.

When the resistor switch is open, as shown in FIG. 2, the auxiliary electrode **88** is latched in its retracted position of FIG. 2 by means of a latch **95** carried by the tubular portion **80** of the movable electrode **76**. This latch **95** cooperates with a latching head **96** on the auxiliary electrode **88** to latch the auxiliary electrode in its retracted position. But when the latch **95** is released, the spring **90***a* quickly projects the auxiliary electrode **88** into its dotted line position **89**. The shoulder on the forward surface of latching head **96** is engaged by a stationary stop **97** to establish the minimum length of the gap **90**.

For controlling the instant at which the auxiliary electrode **88** is released for movement into its dotted line position, a suitably controlled pneumatic operator **100** is provided. This operator **100** comprises a small plunger **102** which can be moved downwardly to pivot the latch **95** clockwise against its reset spring **104**. The latch **95** is so released at the start of the closing operation to permit the auxiliary electrode **88** to begin moving into its dotted line position **89** immediately upon commencement of the closing operation. Because the auxiliary electrode **88** is a very light weight part, it is able to reach its dotted line position well ahead of the relatively massive resistor switch electrode **76**. More specifically, the auxiliary electrode **88** of each protective gap is moved into its dotted line position at **89** before any one of the movable contacts **76** or **76***a* can engage its corresponding stationary contact. Thus, assurance is had that each of the protective gaps **90** is short enough to protect the paralleling insulating should a high voltage appear across one of the resistor switch breaks as a result of its being the last of the breaks to close.

As mentioned hereinabove, the invention is applicable to circuit breakers that comprise additional assemblies such as shown in FIG. 3 connected in series with the assembly of FIG. 3 and approximately simultaneously operable therewith. In such circuit breakers, the auxiliary electrode **88** associated with each resistor switch break is projected into its dotted line position **89** before a sufficient number of the resistor switch breaks have closed to initate a flashover across any remaining series-connected breaks that are still open. In a prefered form of the invention, the auxiliary electrode **88** associated with each resistor switch break is projected into its dotted line position before any one of the resistor switch contacts **76** or **76***a* engages its stationary contact during the closing operation.

The length of each gap **90** when the associated electrode **88** is in its position **89** of minimum gap length should be sufficiently high to prevent any of the gaps **90** from breaking down before the first of the resistor switch breaks closes during a breaker-closing operation. Thus, the presence of the auxiliary electrodes **88** does not result in any advancement of the current-initiating point ahead of the point in which at least one resistor switch break is closed.

When the resistor switch is operated into its open position of FIG. 2, by moving the cross head **81** to the right from its closed position of FIG. 1 to its open position of FIG. 2, the electrode **88** is carried with movable contact **76** and is thus restored to its open position of FIG. 2. Opening forces are transmitted to the electrode **88** during this opening operation through the latch **95**. This latch

95, since it is mounted on the portion 80 of the movable contact 76, was carried by a prior closing operation into the dotted line position 95*a* of FIG. 2 wherein its latching surface reset behind the latching head 96. Such resetting rendered the latch 95 capable of transmitting opening motion to the electrode 88 from the movable contact 76. A slot 103 in the tubular portion 80 of the movable contact 76 permitted the movable contact to move into its closed position without interference from the plunger 102.

It is to be noted that the resistor (70 or 70*a*) that is associated with each of the resistor switch breaks is connected in series with the auxiliary electrode 88. This is advantageous inasmuch as the resistor can effectively limit the amount of current that will flow through the electrode 88 should a breakdown take place across the gap 90. By effectively limiting this current, I can appreciably reduce the amount of arc erosion that the electrode 88 will be subjected to as a result of such a breakdown. Reduced arc erosion prolongs the life of the gap device and also makes it possible to maintain its breakdown voltage substantially unchanged despite prior breakdowns.

It is to be noted that the illustrated arrangement is well suited for a close-open operation of the circuit breaker inasmuch as the air blast that accompanies an opening operation passes adjacent the resistor switch contacts and thus scavenges this region of any ionized gases that might have been developed by a breakdown of the immediately preceding closing. In the illustrated arrangement, the air that passes adjacent the resistor switch break also flows through the main orifice 38. I can, however, provide a separate orifice through the resistor switch and controlled by the blast valve 40 for controlling the air blast through the region of the resistor switch.

Another arrangement for establishing a protective gap of the above described length at an early stage in the closing operation is illustrated in FIGS. 4 and 5. Here the resistor switch comprises a stationary contact 73 and a movable contact 76, which are electrically connected in circuit through the breaker in the same manner as the correspondingly designated contacts of the resistor switch of FIGS. 1–3. The movable contact 76 is carried by a conductive cross head 81 that is conductively connected to the movable contact 76 by flexible braid 78. A wipe spring 110 between the cross head 81 and the movable contact 76 urges the movable contact 76 toward its closed position, but a shoulder 82 on the movable contact 76 abuts against cross head 81 to hold the movable contact in the position of FIG. 4 when the cross head 81 is in its open position.

Surrounding the forward end of the movable contact 76 and slidably mounted thereon is an electrode 88 that is urged toward the dotted line position 89 of FIG. 4 by a compression spring 90*a*. This compression spring 90*a* bears at its rear end on a shoulder 112 fixed to the movable contact 76 and bears at its forward end against the rear of electrode 88. When the resistor switch is open, the electrode 88 is prevented from moving into its position 89 by means of pin 105 that is carried by the movable contact 76. But when the cross head 81 is driven toward closed position during a switch closing operation, as was described in connection with FIGS. 1–3, the movable contact 76 and the electrode 88 move together toward the stationary contact 73. When the electrode 88 has reached its dotted line position 89, a stationary stop 97 engages a shoulder 106 on the electrode 88 and thus prevents further movement of electrode 88 toward stationary contact 73.

The movable contact 76, however, continues moving toward its closed position after the electrode 88 has been engaged by stop 97. In this connection, an axially extending groove 108 is provided in the bore of the electrode 88 for receiving the pin 105. The pin 105 thus slides in this groove 108 while the movable contact 76 continues its travel toward closed position. Finally, the movable contact 76 engages the stationary contact 73, after which the cross head 81 moves slightly further through a short wipe distance compressing the wipe spring 100. The cross head 81 is then suitably latched in its closed position by means (not shown). The parts of the switch then occupy the position of FIG. 5.

Switch opening is effected by driving the cross head 81 to the right from its position of FIG. 5. After a short initial movement the cross head 81 engages the shoulder 82 on the movable contact 76, carrying the movable contact 76 back into its open position of FIG. 4. At an intermediate point of the opening stroke, the pin 105 on the movable contact engages the top end of the groove 108 and then carries the electrode 88 into its open position of FIG. 4 along with the movable contact 76.

When the electrode 88 entered the position 89 during the above described closing operation, a protective gap 90 was formed between the electrode 88 and the stationary contact 73 that corresponds to the protective gap 90 of FIGS. 1–3. As is the case with the gap 90 of FIGS. 1–3, the gap 90 of FIG. 4, upon entry of the electrode into position 89, has a breakdown voltage that is lower than the breakdown voltage then present across any insulation paralleling the gap and its associated break. Accordingly, any breakdown occurring as a result of an abnormally high voltage applied between the contacts 76 and 73 during the time when the forward end of the contact 76 is still within the electrode 88 will be across the gap 90 rather than across any insulation paralleling the gap 90. As is also the case with the gap 90 of FIGS. 1–3, the gap 90 of FIGS. 4 and 5 is made sufficiently long to prevent its breakdown before the first of the resistor switch breaks closes during a circuit breaker closing operation.

It will be apparent that in the modification of FIGS. 4 and 5, the gap is established at an early stage of a closing operation and is thus available to serve its protective function should any of the other resistor switch breaks connected in series therewith reach closed position prior to emergence of the forward end of the movable contact 76 from the electrode 88. The modification of FIGS. 4–5 differs from that of FIGS. 1–3 primarily in the fact that the electrode 88 of FIGS. 4–5 is moved into its position 89 by actual closing motion of the resistor switch rather than by stored energy means 90*a* which is released by a latch 95 as was the case in FIGS. 1–3.

It should be apparent from the above description that the presence of the auxiliary electrode 88 in the two embodiments does not significantly interfere with opening of the circuit breaker since the auxiliary electrode is withdrawn along with the movable electrode 76 during an opening operation. This withdrawal of the auxiliary electrode also insures that sufficient breakdown voltage will be present across the auxiliary gap when the breaker is open to preclude any significant reduction of the dielectric strength across the breaker. In FIG. 4, the presence of the auxiliary electrode 88 does tend to slightly shorten the fully open position gap at the resistor switch, but this shortening can be compensated for, if necessary, by making the resistor switch opening stroke slightly longer.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. A high voltage circuit breaker comprising:

(a) a plurality of breaks electrically connected in series,

(b) means for holding said breaks in an open position when said circuit breaker is open,

(c) means for closing said breaks approximately simultaneously during a circuit breaker closing operation, said breaks being so controlled that the initial current path through said circuit breaker during a normal circuit breaker closing operation is through said breaks,

(d) means defining a plurality of variable length gaps respectively connected across said breaks,

(e) means for maintaining said gaps in an open position when said circuit breaker is open,

(f) insulation paralleling each of said breaks and its associated gap,

(g) gap control means for shortening each of said variable length gaps during a closing operation to a predetermined length wherein the gap upon reaching said predetermined length has a lower breakdown voltage than is normally then present across any insulation paralleling said gap and its associated break,

(h) and means for causing said gap control means to shorten said gap to said predetermined length before any of said breaks is completely closed and before the break paralleled by a given gap has a breakdown voltage as low as that of said gap.

2. The circuit breaker of claim 1 in which said predetermined gap length is sufficiently high to prevent any of said gaps from breaking down before the first of said breaks closes during a circuit breaker closing operation.

3. A high voltage circuit breaker comprising:

(a) a plurality of breaks electrically connected in series,

(b) means for holding said breaks in an open position when said circuit breaker is open,

(c) means for closing said breaks approximately simultaneously during a circuit breaker closing operation, said breaks being so controlled that the initial current path through said circuit breaker during a normal circuit breaker closing operation is through said breaks,

(d) means defining a plurality of variable length gaps respectively connected across said breaks,

(e) means for maintaining said gaps in an open position when said circuit breaker is open,

(f) insulation paralleling each of said breaks and its associated gap,

(g) gap control means for shortening each of said variable length gaps during a closing operation to a predetermined length wherein the gap upon reaching said predetermined length has a lower breakdown voltage than is normally then present across any insulation paralleling said gap,

(h) and means for causing said gap control means to shorten said gaps to said predetermined length before a sufficient number of said breaks are closed to initiate a flashover across the remaining breaks and before the break paralleled by a given gap has a breakdown voltage as low as that of said gap.

4. The circuit breaker of claim 3 in which said predetermined gap length is sufficiently high to prevent any of said gaps from breaking down before the first of said breaks closes during a circuit breaker closing operation.

5. The high voltage circuit breaker of claim 3 in combination with a resistor connected in series with said breaks for limiting the current flowing through any of said gaps that breaks down during a closing operation.

6. A high voltage circuit breaker comprising:

(a) a plurality of main breaks electrically connected in series,

(b) a plurality of resistor switch breaks respectively connected in parallel with said main breaks,

(c) resistors respectively connected in parallel with said main breaks and in series with said resistor switch breaks,

(d) means for holding all of said breaks in an open position when said circuit breaker is open,

(e) means for closing said main breaks approximately simultaneously during a circuit breaker closing and for closing said resistor switch breaks approximately simultaneously during a circuit breaker closing,

(f) means defining a plurality of variable length gaps respectively connected across said resistor switch breaks,

(g) means for maintaining said gaps in an open position when said circuit breaker is open,

(h) insulation paralleling each of said breaks and its associated gap,

(i) gap control means for shortening each of said variable length gaps during a closing operation to a predetermined length wherein the gap upon reaching said predetermined length has a lower breakdown voltage than is normally then present across any insulation paralleling said gap,

(j) means for causing said gap control means to shorten said gap to said predetermined length before any of said breaks is completely closed and before the break paralleled by a given gap has a breakdown voltage as low as that of said gap.

7. The circuit breaker of claim 6 in which said predetermined gap length is sufficiently high to prevent any of said gaps from breaking down before the first of said resistor switch breaks closes during a circuit breaker closing operation.

8. The high voltage circuit breaker of claim 6 in which said resistor switch breaks are effectively closed prior to effective closing of said main breaks.

9. The circuit breaker of claim 3 in which

(a) one of said breaks comprises a pair of relatively movable contacts, and

(b) said gap is defined by a movable auxiliary electrode and a first one of said contacts.

10. The circuit breaker of claim 3 in which

(a) one of said breaks comprises a pair of relatively movable contacts,

(b) said gap is defined by a movable auxiliary electrode and a first one of said contacts,

(c) the means for maintaining said gaps in open position comprises restraining means for holding said auxiliary electrode in an open position,

(d) and said gap control means comprises:

(i) means for disabling said restraining means at the start of a closing operation,

(ii) and means for driving said auxiliary electrode into a position wherein said gap has said predetermined length at an early stage of a circuit breaker closing operation.

11. The circuit breaker of claim 3 in which

(a) one of said breaks comprises a pair of relatively movable contacts,

(b) said gap is defined by a movable auxiliary electrode and a first one of said contacts,

(c) said gap control means comprises:

(i) means for causing said auxiliary electrode to move toward said first contact with the second of said contacts as said second contact approaches the first contact during a closing operation,

(ii) means for blocking continued movement of said auxiliary electrode toward said first contact when said gap of predetermined length is present between said auxiliary electrode and said first contact,

(iii) and means for permitting said second contact to continue into engagement with said first contact after movement of said auxiliary electrode is blocked.

12. In a high voltage circuit breaker comprising a plurality of breaks electrically connected in series and means for closing said breaks approximately simultaneously:

(a) means defining a variable length gap connected across one of said breaks,

(b) means for maintaining said gap in a fully open position when said circuit breaker is fully open,

(c) insulation paralleling said one break and said gap,

(d) gap control means for shortening said variable length gap during a circuit breaker closing operation to a predetermined length wherein the gap upon reaching said predetermined length has a lower breakdown voltage than is normally then present across any insulation paralleling said gap,

(e) means for causing said gap control means to shorten said gap to said predetermined length before any of the other breaks are sufficiently closed to initiate a flashover across said one break and before said one break has a breakdown voltage as low as said gap,

(f) said predetermined gap length being sufficiently high to prevent said gap from breaking down before any of said breaks closes during a circuit breaker closing operation.

13. The circuit breaker of claim **12** in which:

(a) said break comprises a pair of relatively movable contacts, one of which is movable,

(b) said gap comprises a pair of relatively movable electrodes, one of which is movable,

(c) said gap control means comprises:

(i) means for causing said movable electrode to move toward the other of said electrodes with the movable contact as said movable contact approaches the other contact during a closing operation,

(ii) means for blocking continued movement of said movable electrode toward the other electrode when said gap of predetermined length is present between said electrodes,

(iii) and means for permitting said movable contact to continue into engagement with the other contact after movement of said movable electrode is blocked.

14. The circuit breaker of claim **12** in combination with means for returning said movable electrode to its open position of substantially maximum gap length in response to opening of said one break.

15. In a high voltage circuit breaker comprising a plurality of breaks electrically connected in series and means for closing said breaks approximately simultaneously:

(a) means defining a variable breakdown voltage gap connected across one of said breaks,

(b) means for maintaining said gap in a maximum breakdown voltage condition when said circuit breaker is fully open,

(c) insulation paralleling said one break and said gap,

(d) gap control means for reducing the breakdown voltage of said gap during a circuit breaker closing operation to a predetermined value wherein the gap upon said reduction in breakdown voltage has a lower breakdown voltage than is normally then present across any insulation paralleling said gap.

(e) means for causing said gap control means to reduce the gap breakdown voltage to said predetermined value before any of the other breaks are sufficiently closed to initiate a flashover across said one break and before said one break has a breakdown voltage as low as said gap,

(f) said predetermined breakdown voltage being sufficiently high to prevent said gap from breaking down before any of said breaks closes during a circuit breaker closing operation.

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