Jan. 7, 1958 W. F. SKEATS 2,819,429

ELECTRIC PROTECTIVE EQUIPMENT

Filed May 24, 1954

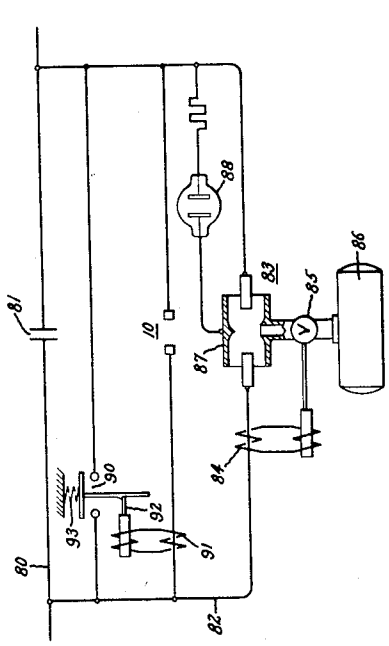

Fig. 3.

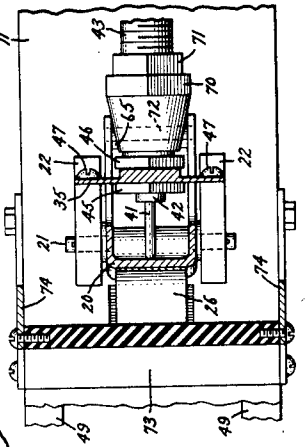

Fig. 2.

Fig. 1.

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United States Patent Office 2,819,429 Patented Jan. 7, 1958

2,819,429

ELECTRIC PROTECTIVE EQUIPMENT

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Application May 24, 1954, Serial No. 431,828

15 Claims. (Cl. 317—12)

This invention relates to equipment for protecting electrical apparatus against overvoltages and, more particularly, to a spark gap device for safely by-passing excessive currents around the protected apparatus.

To provide overvoltage protection for the insulation of a wide variety of types of electrical apparatus, it is common to provide the apparatus with a by-pass circuit containing a spark gap device. The spark gap device is set to arc over at a safe voltage thereby to safely by-pass any excessive currents around the apparatus. To insure reliable operation of such a gap device, it is important that the breakdown voltage, or dielectric strength, of the gap remain substantially constant. For many applications, the only significant factor tending to vary this dielectric strength is a varying ambient temperature.

Accordingly, it is a primary object of the present invention to provide a new and improved spark gap device which includes a gap having a dielectric strength which remains substantially constant in spite of variations in ambient temperature.

The arcing which occurs in a spark gap device generates an appreciable volume of hot gases which are capable of subjecting the parts of the device to very high temperatures and forces which, unless properly controlled, may seriously damage these parts. This problem is especially critical when the parts of the gap device include relatively movable elements, such as are present in a temperature-compensating mechanism.

Accordingly, it is a further object of my invention to provide, in a spark gap device having temperature-compensating mechanism for rendering the device insensitive to ambient temperature variations, means which protect the mechanism from the high temperatures and forces which are present during arcing.

In accordance with one form of my invention, there is provided in a protective device, the combination of a pair of relatively-movable electrodes biased into spaced-apart relationship to define a spark gap therebetween, compensating means responsive to variations in ambient temperature for effecting movement of one of said electrodes in a direction to vary the length of said gap as a direct function of said temperature variations and by an amount sufficient to maintain a substantially constant dielectric strength of said gap, and current responsive means operative to move said electrodes together in response to current flow between said electrodes in excess of a predetermined value, whereby to relieve the compensating means of the stresses produced by the arcing which accompanies said current flow.

For a better understanding of my invention, reference may be had to the accompanying drawing wherein Fig. 1 is an elevational view partially in section of a spark gap device constructed in accordance with my invention; Fig. 2 is a cross-sectional view taken along the line 2—2 of Fig. 1, and Fig. 3 schematically illustrates the spark gap device of my invention as being utilized in protective equipment for a series capacitor.

Referring now to Fig. 1, there is shown a spark gap

device **10** comprising an insulating base **11** upon which are mounted a pair of spaced electrodes **12** and **13**, preferably formed of graphite. The electrode **12** is a stationary electrode adjustably mounted on a threaded conductive stud **14** which, in turn, is carried by an adapter **15** having a first terminal **16** secured thereto. The adapter **15** and the stationary electrode **12** are supported from the base **11** by means of a suitable insulator, such as a porcelain column **17**.

The other electrode **13** is mounted for movement with respect to the stationary electrode **12** by means of a pivotally-mounted, L-shaped bracket **20**. This L-shaped bracket is mounted on a pivot pin **21** which extends transversely between a pair of spaced-apart stationary side walls **22**. For mounting the electrode **13** at the upper end of the bracket **20**, there is provided a suitable clamping screw **25** which is arranged to clamp a conductive strip **26** in electrically-connected relationship to the electrode **13**. For reasons which will soon appear more clearly, this conductive strip **26** is wound into a flattened multi-turn coil **28** extending around spaced-apart mounting pins **27** and is suitably connected at the inner end of the coil to a second terminal structure **30**. The turns of the coil **28** are insulated from each other by a suitable coating of insulation covering the strip **26**.

The relatively-movable electrodes **12** and **13** are urged apart by biasing means including a compression spring **32** acting through a connecting rod **33**. This connecting rod **33** is pivotally joined by a pin **34** to the electrode-supporting bracket **20** and extends loosely through an opening formed in a stationary abutment plate **35**. The compression spring **32**, which has one end bearing against abutment plate **35**, bears at its other end against a tension adjusting unit **36** suitably threaded on connecting rod **33**.

In order to insure reliable operation of a spark gap device, it is important that the arc-over voltage, or dielectric strength, of the gap between the electrodes of the device remain substantially constant. Should this dielectric strength be appreciably diminished from its preset value, then false operation of the device is likely to occur, whereas if the dielectric strength is appreciably increased from its preset value, then the protected apparatus may be damaged by overvoltage before the gap arcs over. In many applications, the only significant factors tending to vary this dielectric strength are variations in ambient temperature. To insure that the dielectric strength of the gap between electrodes **12** and **13** of my device will remain constant in spite of such temperature variations, I have provided, in accordance with my invention, temperature compensating mechanism **40**. This mechanism **40** comprises an elongated actuating rod **41** formed of a material having a low thermal expansion coefficient, e. g., stainless steel. At its outer end this rod **41** is adjustably attached to a tube **42** formed of material having a relatively high thermal expansion coefficient, e. g., an aluminum alloy. This expansible tube **42** surrounds the actuating rod **41** in generally concentric relationship and contains suitable annular guides **9** slidably receiving the rod **41** so as to insure rectilinear motion of the rod within the tube **42**. The tube **42** is rigidly connected at its inner axial end to the base **11** by means of an outer shielding tube **43** which is rigidly supported from the base **11** and is rigidly attached at **44** to the expansible tube **42**. The supporting means for the outer shielding tube **43** comprises a pair of opposed nuts **45** and **46** threaded on the inner axial end of the shielding tube **43** and firmly clamping the stationary abutment plate **35** therebetween. The abutment plate **35** is suitably secured to the stationary side walls **22**, as by screws **47**. The shielding tube **43** is supported intermediate its length by means of a supporting plate **48** having an apertured portion snugly receiving the shielding tube **43**. This supporting plate **48** is, in

turn, suitably secured to a rigid sub-base **49**. At its outer end, the shielding tube **43** is provided with a closure member **50** slidably receiving the expansible tube **42**. Secured to the outer end of expansible tube **42** is a socket **51** having a threaded bore which receives the threaded outer end of the elongated actuating rod **41**. A suitable lock nut **52** maintains the rod **41** and socket **51** in a predetermined position of adjustment.

From this detailed description of the structure of temperature compensating mechanism **40**, it will be apparent that expansion and contraction of the temperature sensitive tube **42** in response to ambient temperature variations will axially shift the central actuating rod **41** thereby varying the position of the inner end of the rod **41** in accordance with these temperature variations. Since this inner end of rod **41** forms a stop against which the movable electrode-supporting bracket **20** is biased by means of compression spring **32**, it will be apparent that the position of movable electrode **13** will be varied in accordance with such temperature variations. Since, as seen in Fig. 1, the movable electrode **13** will be shifted to the left in response to temperature decreases and to the right in response to temperature increases, it will be apparent that the length of the gap between electrodes **12** and **13** will be varied as a direct function of the temperature variations. The length of the expansible tube **42** and the moment arm between pivot pin **24** and the force-transmitting rod **41** are selected in such a manner that this variation of the gap length will be of such a value as to maintain the dielectric strength of the gap substantially constant in spite of said temperature variations.

Now when the gap between electrodes **12** and **13** breaks down to permit current to flow through the gap, the resulting arc will generate an appreciable volume of hot exhaust gases. These exhaust gases are capable of subjecting the parts of the gap device to very high temperatures and forces which, unless properly controlled, may seriously damage these parts. This problem is especially acute where, as in the present device, the parts include a relatively sensitive mechanism such as my temperature compensating mechanism **40**. For example, the hot exhaust gases generated by arcing, in addition to creating high temperature conditions, also tend to force the electrodes **12**, **13** apart with a relatively high force which, if uncontrolled, might seriously impair the operation of temperature-compensating mechanism **40**.

To protect the adjacent parts and, especially, the temperature-compensating mechanism **40**, against the harmful effects of the hot gases generated by arcing, I utilize the multi-turn coil **28** to force the electrodes together as soon as arcing between the electrodes is initiated. More particularly, the coil **28** is of a flattened configuration, shaped in such a manner that it has two physically opposed sides **60** and **61** disposed in close proximity to each other. As a result of this proximity, the two sides **60** and **61**, when energized by current flowing through the coil, have a strong mutual repulsion. The lower side **61** of the coil is backed up by an insulated channel-shaped metal support **62** so as to be held firmly in place, but the upper side **60** is free to move upwardly in response to the repulsive force between the sides. For transmitting this upward movement to the movable electrode **13**, there is provided a convex shoe **63**, which rests on the concave upper surface of the coil and carries a force-transmitting pin **64** extending upwardly through a guide opening in the base **11** into a position adjacent the L-shaped, electrode-supporting bracket **20**. A suitable compression spring **66** encircling the pin **64** tends to urge the coil into the configuration of Fig. 1. Thus, when the upper side **60** of the coil moves upwardly against the bias of spring **66** in response to current flow through the coil, this upward movement is transmitted through pin **64** to a transversely-extending portion **65** of L-shaped bracket **20**, whereby to effect rotation of the bracket **20** counterclockwise about its pivot pin **21**. This, of course, forces the movable electrode **13** toward the fixed electrode **12**.

In order to prevent the electrodes from being damaged by impact resulting from the movement of electrode **13** into engagement with the other electrode **12**, there is provided a stop **70** which is arranged to prevent the electrode **13** from moving beyond a limit point immediately adjacent to but spaced from the fixed electrode **12**. This stop **70** takes the form of a conical nut adjustably threaded on the shielding tube **43**. By properly positioning the conical nut **70** on this tube, the minimum separation of the electrodes can be adjusted to any desired value. A jam nut **71** is utilized to prevent accidental loosening of the stop nut **70** from its preselected position of adjustment. This conical nut **70** is arranged to engage a crossbar **72** carried by the bracket **20** so that the travel of bracket **20**, as it moves counterclockwise under the influence of coil **28**, will be halted just prior to the point at which electrodes **12** and **13** would engage.

To further protect the temperature-compensating mechanism **40** against the hot exhaust gases produced by arcing, I have provided a barrier **73** constructed of a suitable insulating material. This barrier **73** is supported between spaced-apart side plates **74** and physically isolates the arcing gap between the electrodes **12** and **13** from the temperature-compensating mechanism **40**. Because the barrier is generally disposed in a plane which is at an acute angle to a vertical plane, the hot arcing products will be deflected upwardly and away from the temperature compensating mechanism **40**. The movable electrode **13** extends through a suitable opening **75** formed in the barrier **73**.

To illustrate an application of my invention, I have, in Fig. 3, schematically shown the device as utilized in series capacitor protective equipment. More particularly, there is shown connected in power line **80** a bank of series capacitors represented schematically by the reference character **81**. In shunting relationship to the series capacitor bank **81** is a by-pass circuit **82** containing a self-clearing main spark gap **83**. This main spark gap **83** is preferably constructed as described and claimed in application Serial No. 274,694, now Patent No. 2,760,121 filed by A. W. Roth and assigned to the assignee of this invention. As more fully described in this Roth application, when this main gap **83** arcs over in response to overvoltage across the series capacitor **81**, the resulting current flowing through the by-pass circuit **82** immediately induces in current transformer **84** a current which is effective to cause a blast valve **85** to open. Opening of this blast valve **85** permits a blast of high pressure fluid to flow from a fluid pressure source **86** into the main spark gap device **83** thereby to extinguish the arc which had been established therein. In accordance with the aforesaid Roth application, the arc-over voltage of the main gap **83** has been rendered insensitive to ambient temperature variations by means of a trigger electrode **87** controlled by a hermetically-sealed pilot gap **88**. The pilot gap, being hermetically-sealed, has a dielectric strength which remains constant in spite of ambient temperature variations. When the pilot gap arcs over at its preset voltage, it immediately triggers, or ignites, the main spark gap **83**, so that as a result, the main spark gap will almost always arc over at the voltage for which the pilot gap is preset.

Now, if for some unusual reason, the opening of the blast valve **85** should result in an excessive arc extinguishing effort in the main gap **83**, it will be apparent that the main gap will not be effective to by-pass current around the series capacitor bank **81** in the desired manner. To protect the capacitor bank under such unusual circumstances, I have utilized the temperature-compensated gap device of my invention to function as a so-called "back-up" gap. This back-up gap, which is schematically shown at **10** in Fig. 3, is connected in shunt to the capacitor bank **81** and in shunt with the main spark gap **83**. The back-up gap is preset to arc over at a slightly higher volt-

age than the main gap **83**. Thus, if for some unusual reason the main gap should fail to arc-over at its preset value of voltage, then the back-up gap **10** immediately becomes effective to relieve the capacitor bank **81** of overvoltage. It will be apparent that optimum coordination between the operation of the back-up gap and operation of the main spark gap will be obtained if the preset difference between the arc-over voltages of these respective gaps remain constant in spite of variations in ambient temperature. More specifically, if this difference remains constant under all temperature conditions, then the back-up gap may be set to arc over at any desired voltage larger than the arc over voltage of the main gap without the hazard of the back-up gap incorrectly arcing over first if the temperature should increase or without the hazard of the back-up gap arcing over at too high a voltage should the temperature decrease. This preset difference is maintained constant in my protective arrangement by reason of the fact that both of these gaps are insensitive to ambient temperature variations—the main spark gap **83** by virtue of its pilot-controlled trigger electrode **87** and the back-up gap **10** by virtue of temperature-compensating mechanism **40**, described hereinabove. Thus, by utilizing the back-up gap of my invention in combination with a main spark gap such as **83**, I am able to obtain between these gaps, an optimum degree of coordination, which coordination remains unchanged in spite of ambient temperature variations.

When the back-up gap **10** does arc over, the resulting arc is extinguished after a predetermined number of cycles by a shorting switch such as schematically shown at **90** in Fig. 3. More particularly, a current transformer **91**, which is arranged to be energized by current flow through gap **10**, is utilized to operate a latch **92** which, in turn, is released to permit the switch **90** to close under the influence of spring **93**, thereby to completely short out the capacitor bank **81** as well as each of the gaps **10** and **83**.

Although I have shown my temperature-compensated gap device utilized as a back-up gap in series capacitor protective equipment, it is to be understood that it is not limited to such uses and may be used as a protective device for any suitable electrical apparatus, even without requiring the main spark gap device **83**.

While I have shown and described a particular embodiment 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, aim 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 protective device comprising a pair of relatively-movable electrodes spaced-apart in an unsealed atmosphere to define a spark gap therebetween, and compensating means operable in response to ambient temperature variations to vary the length of said gap directly in accordance with said temperature variations and by an amount sufficient to maintain a substantially constant dielectric strength of said gap in spite of said temperature variations.

2. A protectective device comprising a pair of relatively-movable electrodes spaced-apart in an unsealed atmosphere to define a spark gap therebetween, compensating means operable to response to ambient temperature variations to vary the length of said gap directly in accordance with said temperature variations and by an amount sufficient to maintain a substantially constant dielectric strength of said gap in spite of said temperature variations, and current responsive means operative to move one of said electrodes toward the other in response to current flow between said electrodes, whereby to relieve said temperature-compensating means of the stresses produced by the arcing which accompanies said current flow.

3. A protective device comprising a pair of relatively-movable electrodes spaced-apart in an unsealed atmosphere to define a spark gap therebetween, compensating means operable in response to ambient temperature variations to vary the length of said gap directly in accordance with said temperature variations and by an amount sufficient to maintain a substantially constant dielectric strength of said gap in spite of said temperature variations, current responsive means operative to move said electrodes relatively toward each other in response to current flow between said electrodes, whereby to relieve said temperature-compensating means of the stresses produced by the arcing which accompanies said current flow, and stop means for limiting the relative movement of said electrodes toward each other to a position wherein the electrodes are slightly spaced apart.

4. A protective device comprising a pair of relatively-movable electrodes spaced-apart in an unsealed atmosphere to define a spark gap therebetween, compensating means operable in response to ambient temperature variations to vary the length of said gap directly in accordance with said temperature variations and by an amount sufficient to maintain a substantially constant dielectric strength of said gap in spite of said temperature variations, and an insulating barrier disposed between said spark gap and said compensating means whereby to shield said mechanism from the hot gases produced by arc-over of said gap.

5. A temperature-compensated spark gap device comprising a first electrode, a second electrode mounted for movement with respect to the first electrode, said electrodes being located in an unsealed atmosphere, means for biasing said second electrode into a position spaced from said first electrode whereby to provide a gap between said electrodes, compensating means opposing said biasing means and operable in response to ambient temperature variations to effect movement of said second electrode into positions wherein the dielectric strength of said gap remains substantially constant in spite of said temperature variations, and current responsive means for moving said second electrodes toward said first electrode in response to current flow between said electrodes in excess of a predetermined value.

6. A temperature-compensated spark gap device comprising a first electrode, a second electrode mounted for movement with respect to the first electrode, said electrodes being located in an unsealed atmosphere, means for biasing said second electrode into a position spaced from said first electrode whereby to provide a gap between said electrodes, compensating means opposing said biasing means and operable in response to ambient temperature variations to effect movement of said second electrode into positions wherein the dielectric strength of said gap remains substantially constant in spite of said temperature variations.

7. A temperature-compensated spark gap device comprising a first electrode, a second electrode mounted for movement with respect to the first electrode, said electrodes being located in an unsealed atmosphere, means for biasing said second electrode into a position spaced from said first electrode whereby to provide a gap between electrodes, compensating means opposing said biasing means and operable in response to ambient temperature variations to effect movement of said second electrode into positions wherein the dielectric strength of said gap remains substantially constant in spite of said temperature variations, current responsive means for moving said second electrode toward said first electrode in response to current flow between said electrodes in excess of a predetermined value, and stop means for limiting the movement of said second electrode toward said first electrode to a position wherein the electrodes are slightly spaced apart.

8. A temperature-compensated spark gap device comprising a first electrode, a second electrode mounted for movement with respect to the first electrode, said electrodes being located in an unsealed atmosphere, means for

biasing said second electrode into a position spaced from said first electrode whereby to provide a gap between said electrodes, compensating means opposing said biasing means and operable in response to ambient temperature variations to effect movement of said second electrode into positions wherein the dielectric strength of said gap remains substantially constant in spite of said temperature variations, a current responsive coil having a generally-flattened configuration and connected in series circuit relationship with said gap, said coil having a pair of closely-spaced sides one of which is movable in response to the mutual repulsion produced between said sides by energization of said coil, and means operable in response to movement of said one side for forcing said second electrode toward said first electrode.

9. A protective device comprising a pair of relatively-movable electrodes spaced-apart in an unealed atmosphere to define a spark gap therebetween, compensating means operable in response to ambient temperature variations to vary the length of said gap directly in accordance with said temperature variations and by an amount sufficient to maintain a substantially constant dielectric strength of said gap in spite of said temperature variations, a current responsive coil having a generally-flattened configuration and connected in series circuit relationship with said spark gap, said coil having a pair of closely-spaced sides one of which is movable in response to the mutual repulsion which occurs between said sides when the coil is energized by currents through said gap in excess of a predetermined value, and means operable in response to movement of said one side for forcing one of said electrodes toward the other.

10. A temperature-compensated spark gap device comprising first and second electrodes located in an unsealed atmosphere, electrode-supporting structure mounting said second electrode for movement with respect to said first electrode, means for biasing said electrodes into spaced-apart relationship whereby to provide a gap therebetween, an actuating member having a portion bearing against said electrode-supporting structure to provide a stop for limiting the length of said gap, and compensating means responsive to ambient temperature variations for adjusting the position of said stop portion in a direction to vary the length of said gap directly in accordance with said temperature variations and by an amount sufficient to maintain a substantial constant dielectric strength for said gap in spite of said temperature variations.

11. The device of claim 10 in combination with current responsive means operable to move said second electrode toward said first electrode in response to current flow between said electrodes.

12. The device of claim 10 in combination with a current responsive coil having a generally-flattened configuration and connected in series circuit relationship with said spark gap, said coil having a pair of closely-spaced sides one of which is movable in response to the mutual repulsion which occurs between said sides when the coil is energized by currents through said gap, and means operable in response to movement of said one side for forcing said second electrode toward said first electrode.

13. In a by-pass circuit for protecting electrical apparatus from overvoltages, a main spark gap device having a gap which is set to arc-over in response to overvoltage across said apparatus equaling at least a predetermined first value, fluid blast means associated with said main gap device for extinguishing said arc, temperature-compensating means for maintaining the arc-over voltage of said main gap device substantially constant in spite of variations in ambient temperature, said fluid blast means being occasionally subject to the type of operation that acts to increase the arc-over voltage of said gap to a value considerably in excess of said first value, a back-up gap device connected in shunt relationship to said main gap device and having a gap located in an unsealed atmosphere, said gap being set to arc-over at a predetermined second value of overvoltage which is of a greater magnitude than said first value but of low enough magnitude to protect said apparatus, temperature-compensating means for maintaining the arc-over voltage of said back-up gap substantially constant in spite of variations in ambient temperature, and means for establishing a short circuit about said back-up gap in response to arc-over thereof.

14. In a by-pass circuit for protecting electrical apparatus from overvoltages, a main spark gap device having a gap which is set to arc-over in response to overvoltage across said apparatus exceeding a predetermined first value, means associated with said main gap device for extinguishing said arc, temperature-compensating means for maintaining the arc-over voltage of said main gap device subsantially constant in spite of variations in ambient temperature, a back-up gap device connected in shunt relationship to said main gap device, said back-up gap device comprising a pair of relatively-movable electrodes spaced-apart in an unsealed atmosphere to define therebetween a spark gap which is set to arc-over at a predetermined second value of overvoltage, said second value being of a greater magnitude than said first value, and compensating means operable in response to ambeint temperature variations to vary the length of said spark gap directly in accordance with said temperature variations and by an amount sufficient to maintain the arc-over voltage of said spark gap substantially constant at said second value in spite of temperature variations.

15. The gap device of claim 10 in which said compensating means comprises an expansible member having a positive thermal expansion coefficient, means for fixedly supporting one end of said expansible member adjacent said electrode-supporting structure with the other end thereof located remote from said structure, and means for coupling said other end of the expansible member to said actuating member.

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