May 20, 1958 J. H. NICHOLAS 2,835,725

HIGH VOLTAGE ELECTRIC TERMINATOR

Filed Feb. 1, 1954

Fig. 1

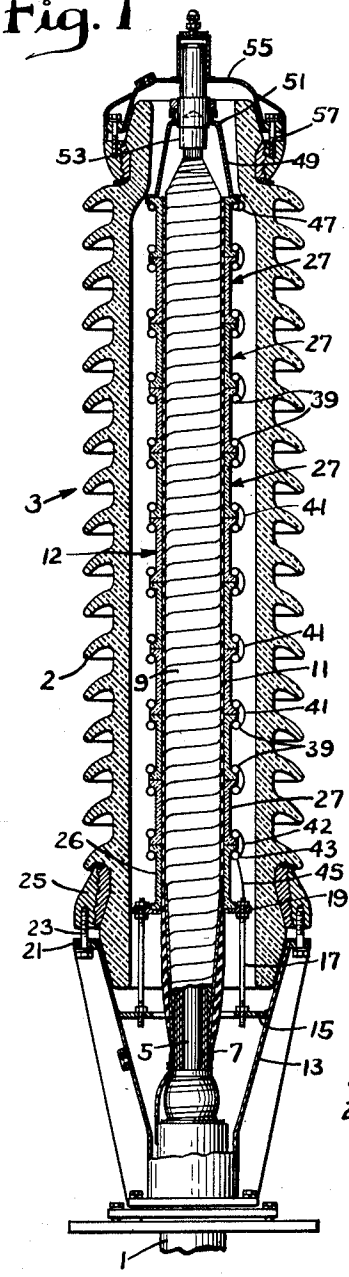


Fig. 4

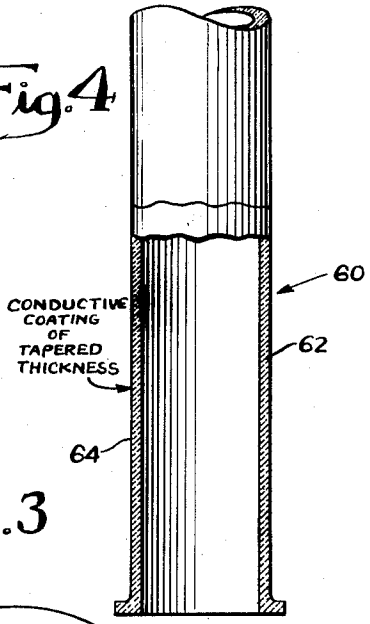
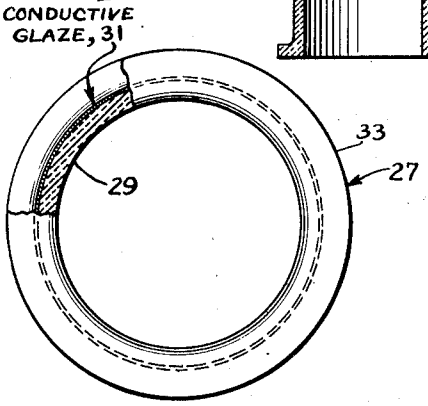


Fig. 3



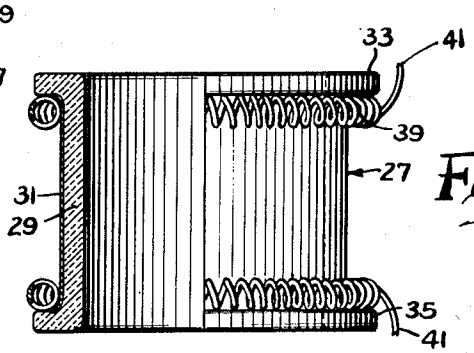


Fig. 2

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HIGH VOLTAGE ELECTRIC TERMINATOR

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Application February 1, 1954, Serial No. 407,255

6 Claims. (Cl. 174—142)

This invention relates to high voltage electrical potheads such as are used for terminating the end of an insulating conductor, particularly a cable conductor, or for terminating a conductor constituting one terminal of a high voltage transformer or circuit breaker. The present invention is particularly useful in connection with potheads or cable terminations at voltages above the 160 kv. class.

It is one of the objects of the present invention to provide means for controlling the potential gradient in the outer insulator of a pothead or terminator structure to maintain as far as possible a uniform axial potential gradient in the transition from the radial electric field to the axial or longitudinal field.

The use, on extra high voltages, of potential gradient control means such as have heretofore been employed in potheads up to 160 kv. would generally result in an extremely large porcelain tube or tubes, which would be very costly and inefficient. A considerably greater length and larger bore diameter would generally be required. Therefore, the ability of the porcelain tube to withstand the high internal hydraulic or gas pressures employed on pipe type cable systems would be reduced. The rupture stresses might be so great as to make the design infeasible.

It is one of the objects of the present invention to provide means for controlling the external surface potential gradients in such a manner as to keep them at a more uniform value for the entire overall length of the porcelain of the pothead, thus using all of the surface with an equal and therefore high efficiency. In accordance with the principles of the present invention there is employed a ceramic tube of fairly rugged wall section and of material having an extremely high dielectric constant, that is, a specific inductive capacity of 100 to 200. By properly applying a conducting media on the external surface of such a tube or cylinder a very effective radial stress control tube can be obtained. This is so because the radial voltage division between two coaxial electrodes insulated by two or more dielectric materials is not only a function of the various radii of the electrodes but also of the dielectric constant or specific inductive capacity (S. I. C.), and the thickness of the various dielectric materials. The higher the S. I. C. of one material used compared to the S. I. C. of the other material the less voltage the higher S. I. C. material has developed across it. Therefore, if the ratio of the S. I. C. of the two materials is made quite high, say 50 or 100 to one, then the high S. I. C. material will have a very small potential drop across it.

Thus, even though the outside surface of the high S. I. C. stress control tube is metallized, the effect of the voltage division is such that the electrode potential would appear to exist at the inner surface of the tube because the S. I. C. of the cable and built-up dielectric is roughly 3, compared to 100 to 200 of the new control tube.

The proximity shielding effect is, therefore, not limited by manufacturing difficulties and fragile construction but is dependent only on how close radially the stress cone

shielding braid can be brought to the inner wall (bore) of the high S. I. C. material.

One method of obtaining uniform surface voltage division on alternating current equipment is by resistance division. By employing several resistor units in series, and controlling the resistance of each unit to a certain ratio of the total, a definite voltage division can be obtained across each resistor. Ideally, ten resistors of identical value connected in series would each have 10% of the total voltage applied across each unit. This would then be a perfectly uniform voltage division. However, the resistance division, as applied to potheads and bushing, is complicated by the fact that a capacitance exists between each unit resistor and the insulated conductor which passes within the unit resistor. The resistor units near the grounded end of the structure would be required to carry more capacitance current than those near the conductor or line potential end. This increased current passing through the units nearer the grounded end would produce a greater potential drop across these units than across the unit near the line end. Therefore, the uniform potential gradient would not be obtained.

It is an object of the present invention to use resistor units of diminishing values connected in series between the grounded end and the live end and properly graded so that a uniform voltage division is obtained.

For simplicity in manufacture and production dielectric testing, it is desirable that individual resistor sections be employed. However, a one-piece construction which results in an electrically equivalent resistance could be used.

It is a still further object of the present invention to provide a resistance assembly for controlling the potential gradient in the outer insulator of a high voltage terminator, which assembly is of an annular shape so that it can be slipped over the end of the high voltage conductor in assembling the terminator.

It is a still further object of the present invention to provide a combination of resistor units for controlling the stress distribution throughout the body of the outer insulator and a radial stress control unit adjacent the grounded end of the terminator, so arranged as to afford the necessary controls wherever the dielectric stress would otherwise become excessive.

While the high voltage potential gradient control apparatus of the present invention is primarily intended for use on cable systems which depend upon high internal hydraulic or gas pressures for their satisfactory operation, the principles of the present invention are also applicable to potheads for low pressure systems.

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

In the drawings:

Fig. 1 is a longitudinal sectional view of a terminator embodying the present invention;

Fig. 2 is a half elevational view and a half longitudinal sectional view of a resistance unit of the present invention;

Fig. 3 is a plan view of the resistance unit in partial section; and

Fig. 4 is a view similar to Fig. 2 but showing an alternate resistance grading tube.

Reference may now be had more particularly to the drawings wherein like reference numerals designate like parts throughout.

In the high voltage cable terminator of Fig. 1 a cable 1 is mechanically connected to an outer porcelain insulator 2 of a pothead or terminator 3 in the same manner as shown and more fully described in my pending application Serial No. 219,294, filed April 4, 1951, now

Patent No. 2,748,184, to which reference may be had. Means for sealing the end of a cable that enters the pothead may be the same as that shown and described in my application above referred to.

The cable conductor is indicated at **5** and it extends longitudinally through the outer porcelain insulator **2**. The cable conductor **5** within the insulator **2** is surrounded by conventional wrapped paper insulation **7** and a stress cone insulator **9** is formed around the wrapped paper insulation **7**. The stress cone may consist of an impregnated wrapped paper tube tightened on the cable insulation **7** during installation. Surrounding the stress cone insulator **9** is a wrapping of cover insulation **11**. The covering insulation **11** is preferably a wrapping that can be pressed considerably without permanently distorting the same. One suitable material is a spongy crepe paper. Surrounding the covering insulation is an assembly **12** of resistance potential gradient control units which equalizes the axial potential gradient of the insulator body **2** in the manner to be described.

A grounded stainless steel conical body **13** is secured at its lower end to the terminator mounting plate and is suitably gasketed to provide a liquid-tight seal. A metal ring **15** is welded within the body **13** for supporting the stress control assembly **12**. The ring **15** has a series of supporting bolts **17** threaded thereinto which are secured in place by lock nuts. The supporting bolts **17** are uniformly spaced from one another, there being any suitable number of such bolts, six, eight, or more. The supporting bolts **17** are of metal and support at their upper ends a base or seating ring **19** of metal, on which seating ring the resistance grading equipment **12** rests. The body **13** has a metal ring **21** welded to the top thereof to facilitate securing the outer porcelain insulator **2** in place as by bolts **23** threaded into a ring **25** cemented to the bottom of the outer porcelain insulator **2**.

The resistance grading equipment **12** of the present invention includes a radial stress unit **26** that rests on the seating ring **19** and in turn supports a series, in this instance ten, of resistance potential gradient control units **27**. The radial stress unit **26** is a hollow circular tube or sleeve of fairly rugged wall section, having lower and upper surrounding flanges. The unit **26** closely surrounds the covering insulation **11**. The material of which the tube is made is preferably ceramic, and of an extremely high dielectric constant (specific inductive capacity between 100 and 200). One suitable material, by way of example, is titanium dioxide. A conductive glaze or coating is formed on the outer cylindrical portion of the unit **26**, covering substantially the entire cylindrical surface of the inner sides of the peripheral flanges where the metallic glaze terminates. The top and bottom of the unit are formed as perfectly flat surfaces parallel to one another and at right angles to the longitudinal axis of the unit.

The flanges of the unit **26** merge with the body of the unit along smooth curves, free of sharp edges, so that the metal glaze on the outside of the unit is also free of sharp edges where it extends from the cylindrical portion to the flanged portion of the unit.

The resistance control units **27** are similar to radial stress unit **26** and closely surround the wrapping or covering insulation **11**. Each of the potential gradient control units **27** includes a hollow circular tube or sleeve **29** made of the same material as the body of radial stress unit **26**. A high resistance coating or glaze **31** is formed on the outer cylindrical portion of each potential gradient control unit **27** and extends between upper and lower axially spaced flanges **33** and **35** formed in the ceramic tube **29**. The high resistance coating **31** covers substantially the entire cylindrical surface of each ceramic tube **29** and extends part way along the inner sides of the peripheral flanges **33** and **35** where the glaze terminates. The top and bottom of each gradient control unit **27** are formed as perfectly flat surfaces parallel to one another and at right angles to the longitudinal axis of the unit.

The high resistance glaze **31** may be made of any suitable well known resistance conductive glaze materials.

The high resistance coatings on each of the gradient stress control units are connected in series with the coating on the units above and below it. The outermost units are connected respectively between conductor and ground potential. The means by which this is accomplished will be explained further on in the specification.

In considering the flow of current through the connected resistance elements of the grading tubes there are a number of factors that must be borne in mind. One is the usual current flow through the resistances that are connected in series from the line potential to the ground potential as determined by what might be called the axial resistance of the respective units. The other is the radial capacitance current through the resistances due to the capacity existing between each conductive glaze **31** and the conductor **5**. It is apparent that all of the units are required to carry the resistance current resulting from the axial series resistance and that the units **27** near the grounded end of the structure would be required to carry more of the radial capacitance current than is required of those units that are near the conductor or line potential. This increased current passing through the lower units would normally tend to produce a greater potential drop across the lower units than the potential drop across the units near to the top of the pothead. Therefore, a uniform potential gradient would not be obtained if the respective grading tubes **27** having the same axial length would have the same resistance values. By providing the resistor elements with high resistance coatings which are graded in value such that the resistances of the resistance units **27** decrease progressively from the high potential to the grounded end thereof, a substantially uniform voltage division between the respective grading tubes may be obtained. For mechanical simplicity all of the resistance grading units **27** may be of a similar overall size and construction. However, as pointed out previously, there is an electrical advantage in making these control units of different resistances reaching from a minimum resistance value at the lowermost unit and gradually increasing in value to the uppermost unit. The variation in resistance is obtained by any suitable means, as for example, by grading the thickness of the high resistance coating on each ceramic tube **29**. Assuming that the conductive coatings are each made of identical material, then the grading is obtained by varying the thickness in an amount inversely proportional to the desired resistance values.

The specific inductive capacity of the insulating tubes **29** of each gradient control element **27** is of a much higher value than the specific inductive capacity of the covering insulation **11**, the stress control cone **9**, and of the cable insulation **8**, which, for example, may be in the neighborhood of four. In such case, substantially all of the voltage drop between the cable conductor **5** and the coating **31** at any point appears across the insulation between the tubes **29** and the cable conductor **5**. In such case, the potential on the inner surface of the respective ceramic grading tubes **29** is only a fraction of one per cent different from the voltage on the outside of the tubes which carries the high resistance coatings **31**, so that within the pothead insulator the potential on the outer surface of the wrapped insulation around the cable conductor is, at each point of the axial length thereof, at a value substantially equal to that of the adjacent outer conductive coating **31**. The resistance grading tubes **27** are arranged to provide a uniform step voltage stress distribution of the line voltage at the top of the pothead to ground voltage at the bottom thereof and, therefore, substantially the same voltage distribution is ob-

tained along the outer surface of the cable conductor covering insulation.

The respective gradient potential control units **27** make a snug fit around the covering insulation **11** which, due to its compressible character, provides a suitable medium to take care of any radical expansion due to heating of the cable proper. Each axial resistance unit **27** is conected electrically in series with its adjacent units. This is accomplished by respective helically coiled metal garter springs **39** which embrace the high resistance coatings **31** at the flanged ends of each of the potential gradient control units. The resistance of each unit is determined by the net resistance of the conductive coatings extending between the metal springs **39**. Each spring is stretched and therefore tensioned by the cylindrical body of the resistance grading tube, so that each spring remains in place and in electrical contact with the end portions of the resistance coatings thereon. The connection between adjacent resistor units is formed by short braided copper bronze jumper leads **41** each of which is soldered or otherwise electrically secured at its opposite ends to the springs on adjacent resistance grading tubes, as may be seen from Fig. 1. The lowermost grading tube is connected at its bottom half by a jumper lead **42** to a spring **43**, identical with the spring **39**, that surrounds and is tensioned around the conductive coating **31** on the stress unit **26**, said spring being also connected by a similar jumper lead **45** to one of the grounded bolts **17**. The uppermost spring of the series of resistance grading tubes is connected by a jumper lead **47** to a metal yoke **49** that rests upon the upper flange of the uppermost grading control unit **27**. The jumper lead is electrically connected to the cable conductor at the other end. It is thus apparent that the resistance grading tubes are connected in series between ground potential at their lower end and the conductor potential at their upper end. The bight portion **51** of the yoke **49** has a centrally located hole therethrough through which a metal connector stud **53** extends that is mechanically and electrically secured to the end of the cable conductor **5**. The yoke **49** may be pressed downwardly by a suitable coil spring that bears on the top of the yoke. The yoke **49** thus presses against the top of the uppermost potential grading tube **27** and maintains all of the grading tubes in engagement with each other and the lowermost tube in engagement with the seating ring **19** of the pothead assembly.

The upper portion of the pothead may be sealed in any conventional manner, for instance, as shown in my pending application Serial No. 219,294 above referred to, to which reference may be had. The seal is generally effected by means of the hood **55** which is secured in sealing engagement with the top of the outer ceramic insulator **2** with the aid of bolts **57** and a gasket which extends between the hood **55** and the upper neck of the insulator **2**.

It is desirable that individual grading tube sections be employed because this simplifies manufacturing problems and permits testing of the respective units and rejecting those units which do not have the desired resistance grading without affecting the usefulness of the other elements. However, a one-piece construction of two or any number, up to all, of the units **27** may be provided. This is illustrated in a fragmentary manner in Fig. 4 wherein the unit **60** comprises all of the separate units shown in the previously described embodiment. Thus a single cylindrical ceramic tube **62** is provided which has a resistance coating **64** on the outer cylindrical surface thereof the thickness of which is graded from one end of the tube to the other so that the resistance of the tube gradually decreases from the high potential end thereof to the grounded end thereof. In the unit of Fig. 4 the resistance may be varied in steps rather than as a continuous gradation. This may be done by coating various adjacent circumferentially extending areas with different resistivity glazes and allowing them to blend at the junction between two adjacent circumferentially extending areas or, if desired, two adjacent circumferentially extending bands of different resistivity glazes may be deliberately separated, which separations are shunted by copper jumpers, etc., for instance, such as the jumpers **41** and springs **39**, during test and installation.

The high voltage pothead described above is primarily adapted for use in cable systems which are of the high internal hydraulic or gas pressure type. The principles can, however, be applied to potheads for low pressure systems. In the design of such systems there is much greater leeway as to the outer porcelain bore diameters, since these diameters are not limited by the porcelain rupture stresses involved on the high pressure systems.

In compliance with the requirements of the patent statutes I have here shown and described a preferred embodiment of my invention. It is, however, to be understood that the invention is not limited to the precise construction here shown, the same being merely illustrative of the principles of the invention. What I consider new and desire to secure by Letters Patent is:

1. A high voltage terminator or joint structure having a high voltage conductor extending axially therein, and a plurality of resistance elements spaced axially within the structure and stacked one upon another and electrically connected in series between the conductor and ground, said resistance elements having outer ends which are shaped to abut substantially the entire confronting end faces of the adjacent resistance elements to permit the close stacking of the resistance elements.

2. A high voltage terminator or joint structure comprising an outer hollow body of solid insulation into which a conductor extends, means maintaining one end of the body at ground potential and the opposite end at the potential of the conductor that extends through the body, covering insulation around the conductor within the body, and means for controlling the axial potential gradient of the outer hollow insulating body, said last means comprising resistance means within the outer hollow body of insulation and extending axially along the covering insulation and in circuit between ground and the end of the conductor, said resistance means having axially spaced sections progressively decreasing in value axially from the end connected to the conductor to the opposite grounded end thereof.

3. A joint or terminator structure for a high voltage conductor, comprising an outer insulation into which the conductor extends, means maintaining one end of the outer insulator at ground potential and the opposite end at the potential of the conductor that extends through the outer insulator, means for controlling the axial potential gradient in the outer insulator, said last means comprising axially spaced resistance elements within the hollow insulator and each surrounding and in radial capacity coupling relationship with the conductor, means electrically connecting adjacent resistance elements in series between the high voltage conductor and ground, the respective series connected resistance elements being of progressively different values and of a relationship which is inverse to the relationship of the current flowing through them so that the voltages across the respective resistance elements are the same.

4. A joint or terminator structure for a high voltage conductor, said joint comprising an outer hollow insulating body into which the conductor extends, covering insulation around the conductor within the hollow insulating body, means maintaining one end of the hollow insulating body at ground potential and the opposite end at the potential of the conductor that extends therethrough, and means for controlling the axial potential gradient of the outer insulating body, said last means comprising a sleeve of solid insulation closely surrounding the covering insula-

tion and location within the hollow insulating body, said sleeve having a specific inductive capacity which is many times greater than that of the covering insulation so that the potentials at the opposite inner and outer surfaces of the sleeve are substantially the same, and a layer of high resistance material contiguous to and extending axially along the said insulating sleeve, said layer of high resistance material being electrically connected between ground and the end of the conductor and progressively decreasing in value axially from the end of the sleeve connected to the conductor to the opposite grounded end thereof.

5. A high voltage terminator or joint structure having a hollow outer insulator and a high voltage conductor extending therein, and means maintaining one end of the outer insulator at ground potential and the opposite end at the potential of the conductor extending therethrough, means within the hollow insulator for controlling the voltage gradient of the hollow insulator, comprising a series of high resistance elements surrounding and aligned axially of and being insulated from the conductor, means electrically connecting the adjacent ends of the high resistance elements to form a series circuit of said elements, and means electrically connecting the outer resistance elements respectively to the said conductor and to ground, said high resistance elements each including a separate, hollow cylindrical insulating member having a cylindrical sleeve of a high resistance conductive material coated thereon.

6. In a high voltage terminator of joint structure having a high voltage conductor extending thereinto, first means for controlling the voltage gradient of the structure comprising a series of high resistance elements surrounding and aligned axially of and being insulated from the conductor, second means electrically connecting the adjacent ends of the high resistance elements to form a series circuit of said elements, and third means electrically connecting the outer resistance elements respectively to the said conductor and to ground, said resistance elements each including a separate, hollow cylindrical insulating member having a cylindrical sleeve of a high resistance conductive material coated on a surface thereof, said cylindrical, conductive coated insulating members abutting the adjacent insulating members at the ends thereof, the said conductive coatings thereon terminating short of the ends of the members, and said second means comprising respective conductive resilient rings tensioned about opposite ends of the conductive coatings on the insulating members, and conductive jumpers electrically connecting adjacent resilient rings.

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