

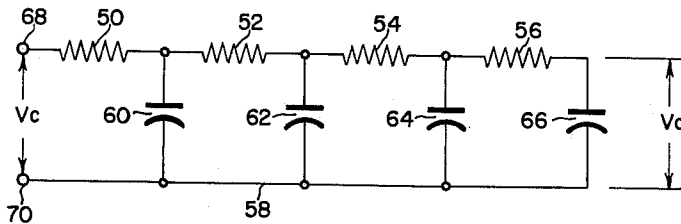
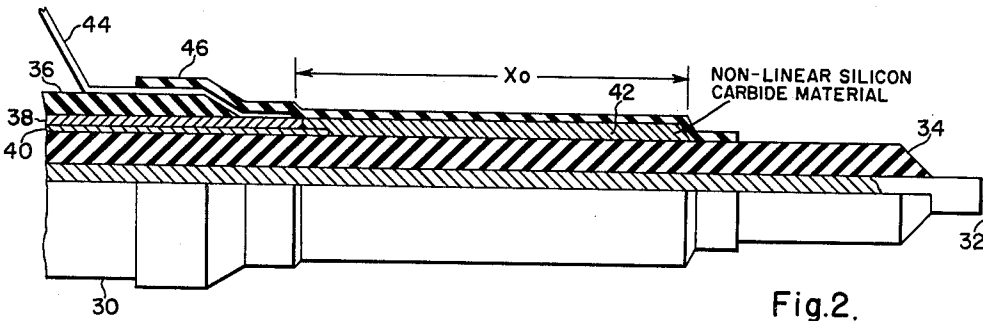
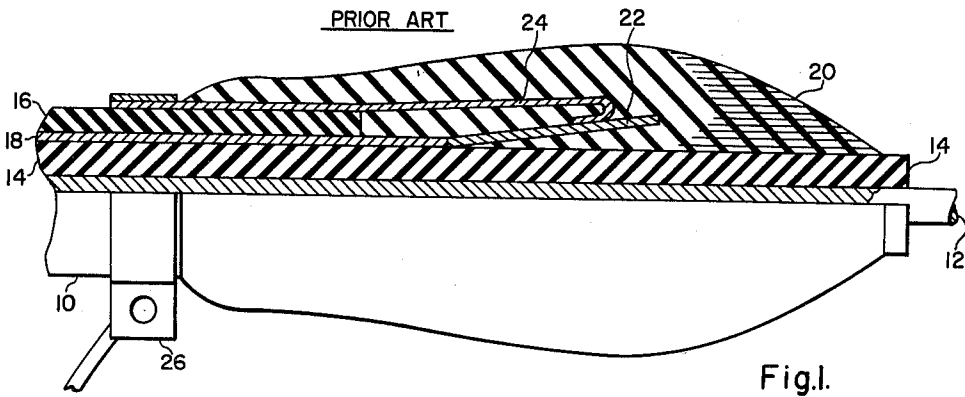
Oct. 5, 1965

R. W. SUELMANN

3,210,460

TERMINATING MEANS FOR SHIELDED ELECTRICAL CONDUCTORS

Filed July 15, 1963



WITNESSES

Theodore F. Wrobel
James F. Young

INVENTOR

Robert W. Suellmann

BY *Donald R. Lackey*
ATTORNEY

1

3,210,460

TERMINATING MEANS FOR SHIELDED ELECTRICAL CONDUCTORS

Robert W. Suelmann, Masury, Ohio, assignor to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Filed July 15, 1963, Ser. No. 295,106

3 Claims. (Cl. 174-73)

This invention relates in general to electrical conductors, and more particularly to terminating means for shielded electrical conductors.

The rapidly increasing usage of shielded underground electrical conductor or cable to replace overhead lines has pointed out the need for more effective terminating means for shielded cable. Throughout the length of shielded cable, the maximum voltage gradient occurs at the surface of the conducting element. However, at the termination of the cable, and hence the termination of the electrically conductive shielding means or grounded shield surrounding the conducting element, the maximum voltage gradient is increased and shifted from the surface of the conducting element to the edge or end of the grounded shield. This change in the electric field also introduces longitudinal electrical stresses on the cable insulation. Thus, the cable termination point is the point of the weakest dielectric strength and most failures of shielded cable occur at this point.

In order to reshape the electrical field and reduce the electrical stresses at the cable termination, the method almost universally used is a hand built stress cone. This method involves building up the cable insulation beyond the ground shield with insulating tape in the form of a cone. Conducting tape is then wound over this insulating tape to form a cone shaped extension to the grounded shield. After connections are made between the grounded shield and the cone shaped conducting tape, additional insulating tape is added. This tape formed insulating cone requires a considerable amount of time to construct, and its effectiveness in reducing electrical stresses at the termination of the shielded cable depends upon the skill of the person forming the stress cone. Further, as is well known, electrical stress is increased by surfaces which are not smooth and by voids or air pockets in insulation. The overlapping tape method of forming the conventional stress cone produces an inherently rough surface which substantially reduces the corona starting voltage, and is very likely to produce a plurality of air pockets between tape layers where the turns of tape overlap. The field stress abruptly increases at an air pocket in inverse ratio to the dielectric constants of the tape or solid insulation and the air. For example, if the dielectric constant of air is one-fourth the dielectric constant of the solid insulation, the electric stress in the air pocket will be four times the electric stress in the solid insulation. These air pockets become sources of ionization or corona discharges in the insulation structure with accompanying radio interference. Although the short time strength of an insulation structure may not be affected by the presence of corona, the life of the insulation may be drastically reduced because of the eroding effects of corona discharges.

Accordingly, it is an object of this invention to provide new and improved terminating means for shielded electrical conductor or cable.

Another object of this invention is to provide new and improved terminating means for shielded cable which will substantially increase the voltage at which corona and radio interference occur.

A further object of this invention is to provide new and improved terminating means for shielded cable which has a smooth surface with no voids or air pockets in the solid insulation.

2

A still further object of this invention is to provide new and improved terminating means for shielding cable which may be quickly and inexpensively formed by unskilled labor.

Briefly, the present invention accomplishes the above-cited objects by utilizing a semiconducting coating or paint to terminate the grounded shield. More specifically, by applying a semiconducting coating, whose conductivity is a function of the voltage across its length, to the end of the conducting shield and for a predetermined extension thereof along the cable insulation, the voltage of the semiconducting coating increases until no potential difference exists between the inner conductor and the semiconducting coating. Thus, the shielded cable has been terminated with a minimum of electric stress, resulting in a corona and radiation free termination.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 shows the prior art method, in partial cross section, for the termination of shielded electric cable;

FIG. 2 shows, in partial cross section, a termination for shielded cable constructed in accordance with the teachings of this invention; and

FIG. 3 is a schematic diagram showing the equivalent electrical circuit of the shielded cable termination shown in FIG. 2.

Referring now to the drawings, and FIG. 1 in particular, there is shown in partial cross section the prior art method of constructing a stress cone to reduce the electric stress at the termination of the conducting shield. More specifically, there is shown in FIG. 1 an electric cable 10 comprising an electrical conductor 12, inner solid insulating means 14, outer solid insulating means 16 and conducting shield 18 which separates said inner and outer solid insulating means 14 and 16, respectively.

Insulating tape 20 is wound over the solid insulation 14 of the cable 10, beyond the end of the ground shield 18, in the form of a cone. After a certain amount of insulating tape has been disposed upon the solid insulation 14, conducting tape 22 is disposed around the insulating tape 20 to form a cone shaped extension to the ground shield 18. A ground strap 24 is then connected to the conducting tape 22 and to a ground clamp 26. Additional tape insulation 20 is then added to form the completed stress cone as shown in FIG. 1. As hereinbefore stated, the effectiveness of the stress cone shown in FIG. 1 depends upon the degree of skill of the person constructing the stress cone, and further, the laminated insulation or tape used to construct the stress cone has considerably less dielectric strength in the longitudinal direction than it does in the radial direction. This inherent weakness of the laminated tape insulation, along with the relatively rough surface of the lapped insulation, which causes the electrical stress concentration, and the small air pockets which may be trapped in the insulation, which may cause corona and radio interference, all cooperate to produce an unpredictable cable termination. Further, the cable termination of FIG. 1 takes a considerable amount of time to construct and is, therefore, expensive.

FIG. 2 shows a cable termination, partially in cross section, constructed according to the teachings of this invention. More specifically, there is shown in FIG. 2 a shielded cable 30, comprising a conducting element 32, formed of copper or any other suitable conductor, inner solid insulating means 34, outer solid insulating means 36 and conducting shield 38, which may be copper mesh or any other suitable conductor, which separates the inner

and outer solid insulating means 34 and 36, respectively. A high resistance tape 40 may be disposed between the inner solid insulation 34 and the conducting or ground shield 38. The outer solid insulation 36, conducting shield 38 and high resistance tape 40 may be prepared substantially as shown in FIG. 2.

A semiconducting coating 42, having the characteristic of a true semiconductor whereby its conductivity is a function of the voltage across its length, is then applied for a predetermined length X_0 along the inner solid insulation 34, starting from and contacting conducting shield 38. The semiconducting coating 42 may also contact the high resistance tape 40. Next, a ground strap 44, formed of copper or any other suitable electrical conductor, is disposed in contact with conducting shield 38, and a heat shrinkable insulating tube 46, or any other suitable insulating means may be disposed to hold the ground strap 44 in place, as well as provide insulation for the semiconducting coating 42. If a heat shrinkable insulating tube or sleeve is used for insulation 46, it has the advantage of providing a smooth insulating surface, as well as providing a tight protective covering in a matter of a few seconds time. Further, by using a heat shrinkable insulating tube, the semiconducting coating may be applied by precoating the inside of the tubing with the semiconductor material, which makes the process of forming the cable termination a simple matter of placing the ground strap 44 in position and locating the insulating tube 46 with the precoated semiconducting material in the proper position. Upon heating the insulating tube with hot air, or any other suitable means, it will shrink into a tight protective covering and locate the semiconducting coating in contact with the conducting shield 38 and for a predetermined distance along inner insulation 34.

The property of the semiconducting coating whereby its conductivity is a function of the voltage across its length enables the shielded cable 30 to be terminated without severe distortion of the electric field, thus preventing concentration of electric stress at the termination of the conducting shield 38 and preventing corona and the resultant degradation of the surrounding insulation. Additional insulating means (not shown) may be disposed around the heat shrinkable tubing if desired, since the potential of the semiconducting coating increases along its length to reduce the potential difference between the semiconducting coating 42 and the electrical conductor 32 to zero.

FIG. 3 shows the equivalent electrical circuit for the cable termination shown in FIG. 2. The resistors 50, 52, 54 and 56 correspond to the semiconducting coating 42 of FIG. 2, the conductor 58 in FIG. 3 corresponds to the electrical conductor 32 of FIG. 2, and the capacitors 60, 62, 64 and 66 illustrate the capacitive effect of the semiconducting coating 42 and the conductor 32 being separated by inner insulation 34. The equivalent circuit shown in FIG. 3 explains why the extension of the semiconducting paint or coating beyond the end of conducting shield 38 reduces the high fringing electric field that is normally experienced at the termination of the conducting shield. This electrical stress grading is accomplished by the gradual reduction of the voltage difference between the semiconducting coating 42 and the electrical conductor 32 with distance along the semiconducting coating, caused by the semiconducting coating supplying capacitive current to the environment. Thus, the potential difference between the terminals 68 and 70 of the circuit shown in FIG. 3 is substantially equal to the voltage V_c of the conductor 58 to ground. The potential difference between the semiconducting coating 42 and conductor 32 gradually reduces along the semiconducting coating 42 until a point is reached where the potential difference is zero, which may be called V_0 . This gradual reduction in potential difference along the semiconducting coating 42 is due to the fact that the coating 42 is a true semiconductor, whose resistivity changes with the strength

of the electric field. In a region of high field, the semiconducting coating is essentially a conductor and in a region of low field it is essentially an insulator. Thus, the semiconducting coating automatically assumes the right or proper resistivity to meet the electrical conditions to which it is subjected. The semiconducting coating 42 thus has one portion conducting in the region of maximum field near resistor 50, and another portion substantially nonconducting in the region of low field, near resistor 56, with a gradual transition between resistors 50 and 56. This gradual transition results in a uniform field and prevents corona.

To illustrate the difference in corona and radio interference between the conventional stress cone shown in FIG. 1 and the termination for a shielded cable constructed according to the teachings of this invention, as shown in FIG. 2, tests were made on both types of terminations, using the same type and size of shielded cable and the same dimensions from the end of the cable to the end of the stress cone. The first test was to measure the corona starting voltage, or the lowest applied voltage that will cause corona discharges, the results of which are tabulated below:

CORONA STARTING VOLTAGE MEASUREMENTS

	Kv.
Shielded cable with no stress cone	4.5
Shielded cable with conventional stress cone	9.0
Shielded cable with termination constructed according to the teachings of this invention	20.0+

The test of the shielded cable termination constructed according to the teachings of this invention was discontinued at 20 kv., and corona had not started.

The radio interference measurements on the conventional stress cone and the stress cone constructed according to the teachings of this invention are tabulated below:

R.I.V. (MICROVOLTS)

Applied voltage (kv.)	Conventional stress cone	Shielded cable termination constructed according to the teachings of this invention
8.0	0	0
9.0	7	0
12.0	7-10	0
14.5	10-12	0
16.0	15-20	0
17.0	40-50	0
18.0	50-100	0
20.0	100-200	0

Since corona had not yet started at 20 kv., the radio interference was zero for each of the voltage settings for the shielded cable termination constructed according to the teachings of this invention.

Any semiconducting coating of the proper resistivity range and having a conductivity which varies with the voltage across its length may be utilized as the electrical stress grading element in this invention. For example, film-forming coating compositions containing particulated non-linear silicon carbide have been found to have advantageous properties as stress grading coatings. The liquid coating or semiconducting paint composition may be described as an admixture of finely divided non-linear silicon carbide and certain thermosetting liquid resinous film-forming materials. The non-linear silicon carbide must contain small amounts of impurities such as aluminum or phosphorus to possess the desired resistive properties. The typical commercial grades of silicon carbide possess such impurities and non-linear resistive properties. Pure silicon carbide is an excellent insulator and because of its high resistivity would not serve as a satisfactory filler in this invention. Silicon carbide of the type used for some electrical purposes, such as lightning arresters,

has a relatively low resistivity and in general is not as desirable as silicon carbide having a higher resistivity, because of the possibility of discharges within the coatings which affect the life of said coatings. It is preferable to utilize high-resistivity silicon carbide of the N-type, such as that utilized in electronic semiconductor devices, and eliminate any possibility of discharges within the coating. Coatings having a content of high resistivity silicon carbide of approximately 25% of the volume of the coating have been found to be excellent, but the percent of volume of the coating may vary considerably on both sides of the 25% figure and still produce a satisfactory coating. For example, if lower resistivity silicon carbide is used, the percent by volume of silicon carbide to the coating may drop as low as 10 to 15%.

The non-linearity of the resistivity of silicon carbide powder may be determined by measuring the voltage at various currents in a cylindrical column having a diameter of 1". The powder is placed in the column between electrodes at a pressure of 400 p.s.i. The current will be proportional to the voltage raised to a power according to the formula: $I = kV^n$. For satisfactory non-linear stress-grading coatings, n should have a value of at least 2. Materials with an n value as high as 7 are available commercially and may be employed. In the formula, k is a constant of dimensionality and is a measure of the conductivity of the silicon carbide powder. In general, k will increase as the average particle size increases.

While particle size will influence the resistivity range to some extent, it is not a critical property. Silicon carbide powders with an average particle size of from about 100 to 1000 mesh may be employed. It is, of course, advantageous to employ particle sizes which will permit a uniform dispersion of the particles in the liquid resinous material and the stress-grading coating.

If certain thermosetting liquid resinous compositions are employed in combination or admixture with particulated non-linear silicon carbide, stress-grading coatings may be produced which do not significantly change from their original resistive properties even after prolonged exposure to heat, humidity and electrical stress. The retention of resistive properties, i.e., the desired conductivity, will permit the electrical stress-grading coatings to continually prevent or diminish the corona damage to electrical insulation in shielded cable terminations.

Liquid resinous film-forming varnish compositions which may be employed in admixture with particulated non-linear silicon carbide to produce suitable coatings which may be utilized in this invention, are epoxy modified urea or melamine-formaldehydes, phenolic-modified alkyls and blends of polyvinylformal and phenol-formaldehyde. Each of these resinous materials has produced stress-grading coatings with superior resistivity retention properties.

The epoxy modified urea-formaldehydes or epoxy modified melamine-formaldehydes are blends of from 50 to 85 parts by weight of a glycidyl polyether of a dihydric phenol having a 1,2-epoxy equivalency greater than 1 and from 50 to 15 parts by weight of at least one thermosetting resin selected from the group consisting of melamine-aldehyde and urea-aldehyde resins.

The resinous glycidyl polyethers employed in the enamel compositions may be prepared by reacting predetermined amounts of at least one polyhydric phenol and at least one epichlorohydrin in the alkaline medium. Phenols which are suitable for use in preparing such resinous polymeric epoxides include those which contain at least two phenolic hydroxy groups per molecule. Polynuclear phenols which have been found to be particularly suitable include those wherein the phenol nuclei are joined by carbon bridges, such for example as 4,4'-dihydroxy-diphenyldimethylmethane (referred to herein-after as bis-phenol "A") and 4,4'-dihydroxy-diphenylmethane. In admixture with the named polynuclear phenols, use also may be made of these polynuclear

phenols wherein the phenol nuclei are joined by sulfur bridges such, for example, as 4,4'-dihydroxyl-diphenyl-sulfone.

While it is preferred to use epichlorohydrin as the epichlorohydrin in the preparation of the resinous polymeric epoxide starting materials, homologues thereof, for example, epibromohydrin and the like also may be used advantageously.

In the preparation of the resinous polymeric epoxides, aqueous alkali may be employed to combine with the halogen of the epichlorohydrin reactant. The amount of alkali employed should be substantially equivalent to the amount of halogen present and preferably should be employed in an amount somewhat in excess thereof. Aqueous mixtures of alkali metal hydroxides, such as potassium hydroxide and lithium hydroxide, may be employed although it is preferred to use sodium hydroxide since it is relatively inexpensive.

The resinous polymeric epoxide, or glycidyl polyether of a dihydric phenol, which may be used, has a 1,2-epoxy equivalency greater than 1.0. By epoxy equivalency reference is made to the average number of 1,2-epoxy groups contained in the average molecule of the glycidyl ether. Owing to the method of preparation of the glycidyl polyethers and the fact that they are ordinarily a mixture of chemical compounds having somewhat different molecular weights and contain some compounds wherein the terminal glycidyl radicals are in hydrated form, the epoxy equivalency of the product is not necessarily the integer 2.0. However, in all cases it is a value greater than 1.0. The 1,2-epoxy equivalency of the polyethers is thus a value between 1.0 and 2.0.

Suitable resinous polymeric epoxides or glycidyl polyethers may be prepared by admixing and reacting from one to two mol proportions of epichlorohydrin, preferably epichlorohydrin, with about one mol proportion of bis-phenol "A" in the presence of at least a stoichiometric excess of alkali based on the amount of halogen.

To prepare the resinous polymeric epoxides, aqueous alkali, bis-phenol "A" and epichlorohydrin are introduced into and admixed in a reaction vessel. The aqueous alkali serves to dissolve the bis-phenol "A" with the formation of the alkali salts thereof. If desired, the aqueous alkali and bis-phenol "A" may be admixed first and then the epichlorohydrin added thereto, or an aqueous solution of alkali and bis-phenol "A" may be added to the epichlorohydrin. In any case, the mixture is heated in the vessel to a temperature within the range of about 80° C. to 110° C. for a period of time varying from about one-half hour to three hours, or more depending upon the quantities of reactants used.

Upon completion of heating, the reaction mixture separates into layers. The upper aqueous layer is withdrawn and discarded, and the lower layer is washed with hot water to remove unreacted alkali and halogen salt, in this case, sodium chloride. If desired, dilute acids, for example, acetic acid or hydrochloric acid, may be employed during the washing procedure to neutralize the excess alkali.

Glycidyl polyethers may be prepared in either solid or liquid form. The commercially available glycidyl polyethers which are solids are less expensive than the liquid grades, thus the use of the solid materials affords a substantial cost savings when used in accordance with this invention. Usually, the liquid polyethers have very few, if any hydroxyl groups. The solid polyethers, on the other hand, have a substantial number of hydroxyl groups per molecule.

A typical urea-aldehyde resin suitable for use with the glycidyl polyether so prepared is the reaction product of one mol of urea with two mols of aldehyde such as formaldehyde. Ordinarily, the reaction is carried out in an alcohol such as butanol, and the reaction product is an alcoholated urea-resin, for instance, butylated urea-

aldehyde resin. The preparation of the urea-aldehyde resins is well known in the art and need not be detailed herein. When preparing the enamel compositions of this invention, the clarified and dehydrated urea-aldehyde in the solvent soluble stage or A-stage is dissolved in a suitable solvent or mixture of solvents and blended with the other enamel components.

The melamine-aldehyde resins which may be used with the glycidyl polyethers may be prepared by reacting from two to six mols of an aldehyde, such as formaldehyde, with one mol of melamine under alkaline conditions. The number of substituted methylol groups occurring in the product is generally dependent upon the mol ratio of the reactants. Thus, it is possible to react formaldehyde or another aldehyde with melamine in mol ratios sufficient to give mono-, di-, tri-, tetra-, penta-, and hexamethylol melamines or mixtures thereof. Any of these derivatives or mixtures thereof are satisfactory in preparing the resins for use in forming semiconducting coatings suitable for use in this invention.

Aldehydes other than formaldehyde may be used in preparing the urea-aldehyde and/or melamine-aldehyde resins. For example, acetaldehyde, propionic aldehyde, butyric aldehyde, benzaldehyde and the like may be used to replace a part or even all of the formaldehyde, with satisfactory results being obtainable. Satisfactory solvents for the blended material are known in the art and include for example, a mixture of toluol and n-butanol. A sufficient amount of solvent should be employed to permit easy application of the resinous materials. The baking or curing temperature may be varied over a wide range depending on the time of the cure. Temperatures above 150° C. are normally employed.

Suitable phenolic-modified alkyds are blends of oil modified phenol-formaldehyde and an alkyd resin. The phenol-formaldehyde may, for example, be a tung oil modified cresylic acid formaldehyde resin. The alkyd may, for example, be a linseed oil modified glycerol phthalate. The usual monomers which are employed in the preparation of alkyd resins are, for example, phthalic anhydride and glycerol. Based on a solids weight basis, the proportion of alkyd to phenol-formaldehyde, respectively may vary from 4:1 to 1:2.

The resins which are least subject to environmental aging and resistivity change, and accordingly the preferred materials for the semiconducting coatings utilized in this invention, are blends of polyvinyl formal and phenol-formaldehyde. The polyvinyl formal resin may be first dissolved in a solvent comprised of equal parts by weight of ethanol and toluol and blended with a phenol-formaldehyde resin in an ethyl Cellosolve-ethanol solvent system. Superior coating compositions may be produced with resin blends containing from about 5 to 40%, by weight, of polyvinyl formal and about 60 to 95%, by weight, of phenol-formaldehyde on a resin solids basis. Further reduction in viscosity, if required for application as a coating film, may be made with a solvent of equal parts by weight of methyl Cellosolve and acetone.

The semiconducting coatings utilized in this invention may comprise the hereinabove described resins admixed with the described particulated silicon carbide. Preliminary tests on coatings produced with the compositions herein described consisted of measuring changes in resistivity during exposure to elevated temperatures. A 20 mil thick film of the subject stress-grading coating is deposited on a 1 by 3 inch microscopic slide and cured. Electrodes are evaporated onto the film coating to leave a one-fourth inch gap between the electrodes and a film width of one-half inch. The samples are exposed to elevated temperatures, as for example 150° C. or higher, and the D.C. resistivity is measured at regular intervals over periods of time as long as 200 days. Coatings which showed no significant change in resistivity after exposure to elevated temperatures for prolonged times were further tested on test bars.

The test bars are comprised of a copper conductor approximately one-half by 3 inches in cross section and 48 inches in length. The conductor is insulated by a plurality of layers of mica tape having a polyester binder and impregnated with co-reactive styrene monomer. A wall thickness of approximately 188 mils is employed. The insulated bar is then coated with the subject electrical stress-grading coating about 10 mils thick. The test bars were then subjected to electrical stress under normal room temperature and humidity conditions. Average relative humidity was about 50%.

Example I

Material:	Proportions, parts by weight
Non-linear silicon carbide (400 grit) -----	6
Epoxy modified urea-formaldehyde resin -----	1
Toluene -----	4

The foregoing composition, with the resin solids comprised of about 65% glycidyl polyether and 35% urea-formaldehyde, by weight, was thoroughly mixed so that the silicon carbide particles were in uniform suspension. It was applied to mica insulated test bars to provide a cured coating film approximately 10 mils thick. After 400 hours at 20 kv. (R.M.S.) in air, these stress-grading coatings exhibited little or no change in color and showed no evidence of corona erosion.

Example II

Material:	Proportions, parts by weight
Non-linear silicon carbide (400 grit) -----	3
Polyvinyl formal and phenol-formaldehyde blend -	1
Toluene -----	4

The foregoing composition, with the resin solids comprised of about 25% polyvinyl formal and 75% phenol-formaldehyde, by weight, was thoroughly mixed so that the silicon carbide particles were in uniform suspension. It was applied to test bars and cured to provide a coating approximately 10 mils thick. After 400 hours at 20 kv. (R.M.S.) in air, these coatings exhibited little or no change in color and showed no evidence of corona erosion.

Example III

Material:	Proportions, parts by weight
Non-linear silicon carbide (400 grit) -----	3
Phenolic modified alkyd resin -----	1
Toluene -----	4

The foregoing composition, with the resin solids comprised of about 50% phenol-formaldehyde and 50% alkyd, by weight, was thoroughly mixed so that the silicon carbide particles were in uniform suspension. It was applied to test bars and cured to provide a coating approximately 10 mils thick. After 400 hours at 20 kv. (R.M.S.) in air, these coatings exhibited little or no change in color and showed no evidence of corona erosion.

It will be apparent from the foregoing examples that the stress-grading coating compositions and coatings produced therefrom substantially maintain their original resistive properties after prolonged exposure to typical environmental conditions. The test samples maintained their original resistive properties and therefore exhibited no evidence of corona erosion.

The proportion of the non-linear silicon carbide to resin solids is not critical and may vary, in weight proportion from about equal parts of non-linear silicon carbide and resin to about 1 part of resin to 6 parts of non-linear silicon carbide. It will be understood, of course, that the non-linear silicon carbide contents will influence the resistivity range of the coating. Since a specific resistivity range may be advantageous in a particular application, a specific non-linear silicon carbide to resin solids ratio may be selected within the above range. The resistivity range of a particular composition may be easily determined by those skilled in the art. Although 400 grit silicon carbide

particles were employed in the examples, there appears to be no criticality attached to the respective particle sizes. It is, of course, advantageous to employ particle sizes which will permit a uniform dispersion of the particles in the liquid coating composition and the film coating. To further improve the aging properties of the semiconducting coatings, from about 0.5 to about 3%, by weight, of finely divided carbon may be added to the coating composition.

In selecting the proper silicon carbide stress grading coating for use in eliminating or reducing corona in a shielded cable termination, a coating of the proper resistivity must be chosen. If a coating has too low a resistivity, it will not reduce the potential difference between the coating and the conductor sufficiently, causing corona at the edge of the coating extension. In other words, the coating would have to be so long in order for the potential difference to be reduced to zero that it would not be practical. If shorter coatings than required are utilized, the potential difference will not be reduced to zero, and corona may result at the end of the coating.

If a semiconducting coating has too high a resistivity, the semiconducting coating will act like an insulator and there will be a high electric field at the end of the conducting shield, causing corona at this point. In other words, if the resistivity of the semiconductive coating is too high, it acts substantially like a cable termination without any stress cone at all.

Further, in order to insure that there will be no corona in air, the maximum field along the semiconductive coating must be less than the corona starting field in air. The field in a silicon carbide coating necessary to cause corona in the silicon carbide coating—air interface is in the order of 40 kv. per inch.

The actual semiconducting coating that is utilized for a particular shielded cable termination must be decided by the particular circumstances in each case, dictated by the capacitance between the semiconductive coating and electrical conductor, the voltage to be applied to the electrical conductor, and a compromise between too high a resistivity which would produce corona due to too high a voltage gradient along the surface of the semiconductive coating and at the junction of the conducting shield and the semiconductive coating, and too low a resistivity which would require too great a length of the semiconductive coating to reduce the potential difference between the semiconductive coating and the electrical conductor to zero.

The termination for shielded cable disclosed herein has many advantages over the conventional stress cone in addition to the substantial reduction in corona and radio interference. For example, the disclosed termination may be easily and quickly assembled with unskilled labor. Further, the disclosed termination provides a more uniform insulation structure which is less subject to faults of workmanship.

It will, therefore, be apparent that there has been disclosed new and improved terminating means for shielded electric cable which is not only inexpensive to construct, but substantially increases the voltage at which corona and radio interference occur.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative, and not in a limiting sense.

I claim as my invention:

1. Electric cable terminating means for suppressing corona, comprising an electrical conductor adapted for connection to a source of electrical potential, first insulating means, said first insulating means being disposed around and in contact with said electrical conductor,

shielding means formed of electrically conductive material, said shielding means being disposed around and in contact with a predetermined length of said first insulating means, semiconductor coating means containing particulated non-linear silicon carbide disposed around and in contact with said first insulating means, said semiconductor coating means having a first end starting at and electrically contacting said shielding means and extending along and in continuous contact with said first insulating means for a predetermined length to a second end, said semiconductor coating means having a resistivity dependent upon the magnitude of the electric field produced when the source of electrical potential is applied to said electrical conductor, the predetermined length of said semiconductor coating means being selected to reduce the potential difference between said electrical conductor and the second end of said semiconductor coating means to substantially zero when the source of electrical potential is connected to said electrical conductor, second insulating means comprising a tubular insulating member having a wall portion that is continuous in at least its longitudinal direction, said second insulating means being disposed around and in contact with said semiconductor coating means.

2. Electric cable terminating means for suppressing corona, comprising an electrical conductor adapted for connection to a source of electrical potential, first insulating means, said first insulating means being disposed around and in contact with said electrical conductor, shielding means formed of electrically conductive material, said shielding means being disposed around and in contact with a predetermined length of said first insulating means, semiconductor coating means containing non-linear silicon carbide particles disposed around and in contact with said first insulating means and having one end starting at and electrically contacting the end of said shielding means and extending along said first insulating means for a predetermined length to a second end, said semiconductor coating means having a resistivity dependent upon the magnitude of the electric field produced when the source of electrical potential is applied to said electrical conductor, the predetermined length of said semiconductor coating means being selected to reduce the potential difference between said electrical conductor and said semiconductive coating means to substantially zero when said source of electrical potential is applied to said electrical conductor, second insulating means comprising a heat shrinkable tubing, said second insulating means being disposed around and in contact with said semiconductor coating means.

3. Electric cable terminating means for suppressing corona, comprising an electrical conductor adapted for connection to a source of electrical potential, first insulating means, said first insulating means being disposed around and in contact with said electrical conductor, shielding means formed of electrically conductive material, said shielding means being disposed within said first insulating means and dividing said first insulating means into inner and outer layers, the outer layer of said first insulating means and said shielding means being removed for predetermined lengths from the end of said electrical conductor allowing a predetermined length of said shielding means to extend past the outer layer of said first insulating means, semiconductor coating means comprising non-linear silicon carbide particles suspended in a resinous binder, said semiconductor coating means having a resistivity which is a function of the voltage across its length, said semiconductor coating means being disposed around and in contact with the inner layer of said first insulating means starting at and electrically contacting the end of said shielding means and extending along and in continuous contact with said first insulating means for a length sufficient to reduce the potential difference between said electrical conductor and said semi-

11

conductor coating means to substantially zero, grounding means electrically contacting the extended portion of said shielding means, second insulating means comprising insulating tubing means having a wall portion that is continuous in at least its longitudinal direction, said second insulating means being disposed around and in contact with said semiconductor coating means and a portion of the outer layer of said first insulating means.

12

References Cited by the Examiner

UNITED STATES PATENTS

2,209,894	7/40	Scott et al.	174—73 X
3,066,180	11/62	Virsberg et al.	174—73 X

JOHN F. BURNS, *Primary Examiner*.DARRELL L. CLAY, *Examiner*.