Aug. 3, 1948. T. F. PETERSON 2,446,387

SHIELDED CABLE

Filed May 19, 1943

Fig. 1.

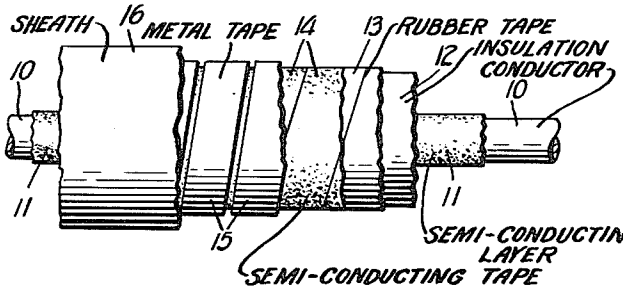


Fig. 2.

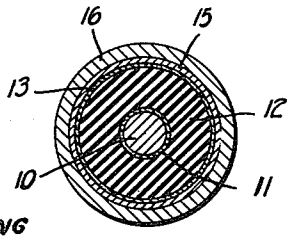


Fig. 3.

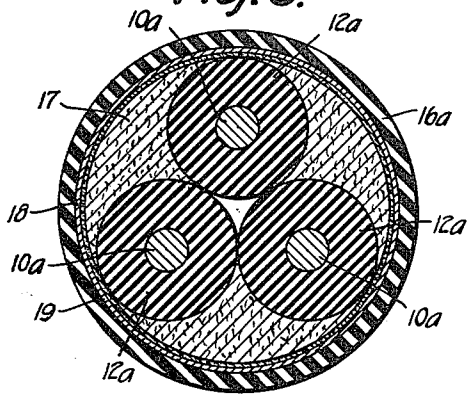
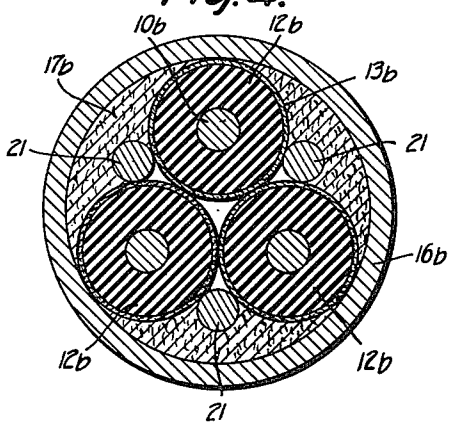


Fig. 4.



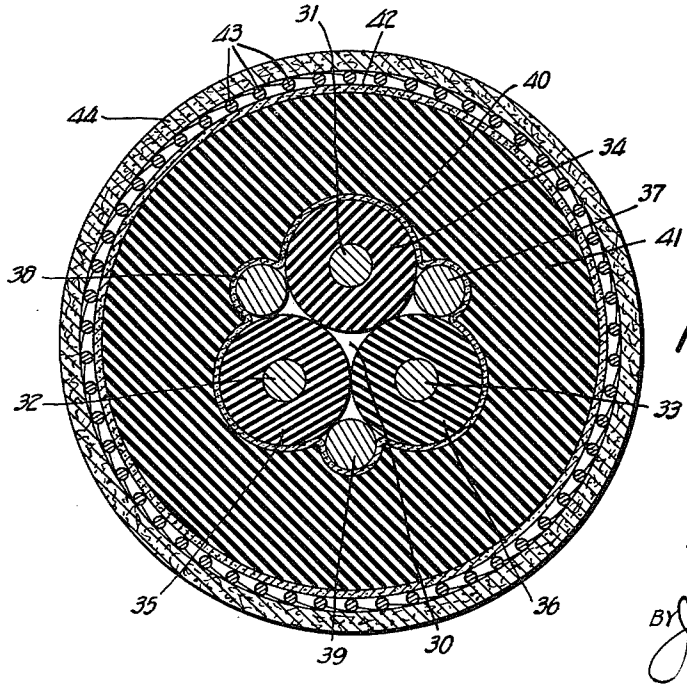


Fig. 5.

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SHIELDED CABLE

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10 Claims. (Cl. 174—105)

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This invention relates to the shielding of electric cables for confining electrical stresses or eliminating interference by the cable with external circuits or interference from sources external to the cable. In a copending application Serial No. 373,181 filed June 24, 1929, that has since become Patent No. 2,322,702, June 22, 1943, there is described a cable structure embodying a semi-conducting layer in intimate contact with a surface of the conductor insulation for dissipating or conducting away charges that may otherwise build up a potential difference at the surface under the applied electrical stress, which potential difference may cause ionization with consequent breakdown of the insulation. In general the layer is described therein as one given semi-conducting properties by conductive carbon or metal particles embedded in, sprayed on, or included in a coating medium, such as a paint or lacquer, directly on the conductor insulation itself or on the surface of a base material that is normally insulating such as rubber, paper, varnished cambric or fabric tapes and in intimate contact with the conductor insulation. The present application is a continuation-in-part directed to the coating or the paint and lacquer type of semi-conducting layer.

Coating media that form adherent continuous films or layers upon deposition and drying cover a wide range of known materials; they are applied as relatively thin solutions for spraying or brushing or as pastes which can be frictioned or rubbed on. Solutions, dispersions, or pastes, made with spirit (alcohol) or other volatilizable solvents or vehicles to leave solid continuous films upon solvent removal after application, are known as and herein intended by the term lacquers; liquids or solutions that in themselves solidify after application into continuous films, either through oxidation or polymerization or both, are known as and herein intended by the term paints. The lacquer type depends upon film-forming solutes or phases (either the continuous or the disperse phases) and these comprise natural and synthetic resins, cellulose esters, polymerized and copolymerized compounds, natural and synthetic rubber, etc. Paints generally depend for film-forming upon oils which are drying, i. e. air-oxidizing, or heat-polymerizing, such as tung, oiticica, linseed, soya bean, etc., and the oils are normally extended with compatible natural or synthetic resins, or the like, to give body and durability. Both lacquers and paints are insulating electrically, form tough elastic films and can be utilized as media

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or carriers for conductive particles, such as conductive carbon (of which acetylene black is an example), graphite, metallic powders, etc.; but for most installations requiring resistance to oxidation or other properties, lacquers are preferred.

While cellulose ester (cellulose nitrate and acetate) lacquers have found extensive use in the cable art so as to be regarded as synonymous with "lacquers" and are useful as media for conductive particles to form semi-conducting coatings or layers, they are open to such objections as insufficient resistance to heat and oils. It has been found that improvements in these respects are obtained when elastomers, i. e. inherently flexible or elastic compounds or compounds made so by plasticizers, are utilized as the film-forming constituents in lacquers; known elastomers that are suitable for the purpose include organic polymers, natural and synthetic rubbers and plasticized or oil-modified synthetic resins, such as

Thiokol—organic polysulfide
Neoprene—chloroprene polymer
Vinylite—plasticized vinyl chloride - acetate copolymers
Koroseal—vinyl chloride polymer
Vistanex—isobutylene polymer (butyl rubber)
Buna S—butadiene-styrene copolymer
Buna N—butadiene-acrylonitrile copolymer
Alkyd resins—fatty acid-modified polyhydric alcohol-dibasic acid esters
Phenolic resins—oil-modified phenolic aldehyde condensation products.

Among these, neoprene and the alkyd resins have been found particularly effective when the cable insulation is wrapped paper filled with viscous petroleum compounds.

The lacquers need not be true solutions; they can be colloidal dispersions or suspensions so long as the non-volatile phase becomes a continuous solid and adherent film upon deposition and removal of the volatile component. A distinguishing characteristic of the compositions is that the lacquers or paints forming the media for the conductive particles are in themselves essential constituents of the coatings or films and have their modifying effect on the electrical properties, such as conductivity.

The preparation of the semi-conductive compositions requires no particular procedure. Normally, however, conductive particles are premixed with a lacquer or paint to form a solution or paste. For lacquers including elastomers and some resinous media, a kneading or rolling action

may be required to secure a uniform distribution of the conductive particles in the lacquers.

Without any intent of limiting the physical formation or the electrical behavior of the semi-conducting films or layers to any particular theory or explanation, it appears that the conductive particles are present in the electrically-insulating matrices in varying degrees of contact; even in the case of "high resistivity" films, there are undoubtedly paths of continuous contact between the particles. Such contacts between individual particles, however, are evidently at points forming but small portions of the surface areas of the average particles and through the carrier separating the particles to impart semi-conductivity, for the particles are in and are coated by the insulating matrix; the conductivity so manifested is what is known as "non-metallic" conductivity, since it is of the nature of an insulating material that allows but slight current leakage through or along its surface. By an increase of the particle contact areas, as by an increase of the number of particles in the matrix or increase of the average relative contact area to particle surface area, the film resistivity (which, as hereinafter stated, can be varied from a few ohms to many megohms) is found to be correspondingly reduced; for instance, burnishing of the films reduces the resistivity. The surface resistivity may be millions of times that of metal foil or inlay or sprayed or otherwise deposited metal film that in continuous metal-to-metal contact has resistivities in the order of .001 ohm/cm. square; the resistivity of such a metal film, however, can become infinite upon a crack or break developing in the film. Since typical non-metallic films containing conductive carbon particles are produced with particles having an average size approximating 12 microns, it is practically impossible to determine the relative spacings and nature of the conducting paths or leakages which contribute to the film conductivity. The non-metallic semi-conducting film, moreover, has a negative temperature coefficient, i. e., the resistance decreases with increase in temperature, whereas the resistance of a continuous metal foil or film increases with increase in temperature.

Insulation on electrical conductors can be wrappings of paper or varnished cambric, preformed synthetic resin films, etc.; strips of rubber, etc., applied longitudinally of a conductor; or a homogeneous wall structure such as is obtained by the extrusion of rubber, thermoplastic resins, and the like about the conductor; and any of these insulation structures can have overall "filled-fabric" or other tapes, such as rubber-filled cotton fabric tapes. A semi-conducting coating can be formed directly on a surface of such insulation, as by the conventional dipping, spraying or frictioning methods on an outside surface or by a transfer of a film to an inside surface accomplished for instance by applying a coating to the copper conductor and leaving the coating in a condition, when the insulation is placed about the conductor, to unite or adhere intimately to the insulation. When the semi-conducting film-forming compositions are coated on or made into base materials as on tapes, fabrics, etc., or preformed into films before application to the insulation, the compositions can have adhesive backings of rubber or the like, and in this form they can be wound either about the insulation or directly on the conductor to contact the inner surface of the cable insulation. For coating tapes or other base materials, calendering or knife-coating machines can be used for pastes or viscous solutions; thin liquid solutions are conveniently incorporated by passing the base materials through a bath of the solution and then drying to permit further handling. Preformed films of coating materials can be made by pouring a solution on a plate, drying and then stripping; the stripped films can be sliced into tapes, made adhesive on the backs with solvent or with other suitable medium and wrapped intimately about the insulation, since they are flexible and elastic, to give the equivalent of a coating applied in liquid form and dried or polymerized in place on the insulation.

After the application of the semi-conductive composition, either to the cable insulation or to a separate tape or other base for winding about or in place on or under the insulation, it is customary to heat in order to hasten the drying or volatilization of solvent. Heating is required when a high boiling solvent is used or when the film-forming constituent is one that sets or is cured to an insoluble or a higher-melting form by heat; tape coatings are usually heated before their application to the cable insulation. Since heating, however, is necessary to vulcanize rubber insulation, that has been extruded on the cable conductor in its unvulcanized form and customarily has a cable tape wound about it to retain it in place and keep it from swelling, the cable assemblage including the tape can be submitted to heat to simultaneously vulcanize the rubber insulation and to set the semi-conducting compound on the surface or embedded in the interstices of the tape.

When the paints and lacquers as herein described are coated on cable insulation, they function as shielding layers in the manner explained in the parent application; they need have but little material thickness, since it is the surface resistivity that is of moment, and they usually vary from .0001 up to .010 inch, the latter including a base material or tape. For this purpose the relative proportion of conductive particles can be varied to give any degree of surface resistance along the cable from a few ohms to many megohms; 100 megohms per centimeter per centimeter (or per inch per inch) of surface is found highly satisfactory for high tension (e. g. 3,000 volts or more) cables having frequent splices and terminals, since the conductivity longitudinally of the cable is sufficient to dissipate destructive charges and the splicing and terminal constructions are greatly simplified. Resistance grading of shielding at terminals can be accomplished by coating the insulation with progressively higher resistivity lacquers as the bared end of the cable is approached, or by successively fewer coats of a given lacquer applied along insulation from the edge of shielding to the end of cable.

Lacquers and paints deposited on the insulation as coatings, and particularly as coatings on or in tapes, have a most practical advantage over layers made integral with the conductor insulation of being removable, where desired as at splices and terminals, as by the stripping of the tapes and applying solvents to clean the insulation surface; since the tapes are separately applied, their adhesion to the insulation in general is not such as to prevent their removal. Lacquers and paints are also distinguished by the ease of application to cable insulations without interfering with or requiring modification in the manufacture of the cable. In addition they combine stability with any desired range of conductivity

while the bond is intimate and amply sufficient to accomplish the electrical effects.

By choice of types and relative loading with carbon, graphite or metal, varying resistivities and physical properties are attainable to meet specific requirements.

Some specific forms of semi-conductive compositions are hereinafter described as illustrations of the invention.

Example 1.—A cable tape for wrapping about the rubber insulation, consisting of a cotton cloth fabric containing unvulcanized rubber in its interstices and being adhesive, had brushed on one surface a lacquer made from conductive carbon particles dispersed in a thin solution of unvulcanized rubber in benzene; about 15 to 20 per cent of carbon based on the weight of rubber was used. The tape resistivity per inch per inch along the coated surface was reduced from 15,000 megohms to less than 100,000 ohms, along the opposite uncoated surface from 14,300 megohms to 104 megohms (showing penetration into the tape interstices), and perpendicularly through the tape from 27,100 megohms to 16 megohms.

Example 2.—A lacquer of a flexible oil-extended phenol-aldehyde resin in volatile solvent had metal powder dispersed in it in amount to give, when coated on a fabric, a surface conductivity per inch per inch of 10,000 ohms to 1 meghom.

Example 3.—Paints having a linseed oil base were made semi-conducting by incorporating litharge and "Aquadag" which is a colloidal water-dispersion of conductive carbon. When coated on a cotton cloth tape, these showed reductions in surface resistivities of the same range as Example 1.

Example 4.—The following synthetic resin composition, in an acetone solvent for painting or spraying, yielded when coated on paper, Cellophane, or the like, films having surface resistivities between 2,000 to 100,000 ohms per inch per inch:

	Parts
Vinyl chloride (85–88%)-acetate copolymer resin	100
Plasticizer (triglycol di-2-ethylhexoate)	5
Tricresyl phosphate	50
White lead	3
Zinc oxide	10
Lead stearate	2
Spindle oil	1
Acetylene black	75

Example 5.—For paper cable, i. e. cable in which the insulation is made of layers of paper and the spaces filled with Vaseline or a viscous petroleum fraction, a semi-conducting tape was made by coating fabric or conventional paper insulating tape with a composition of

	Parts
Neoprene G (chloroprene polymer)	40
Magnesium oxide	4
Acetylene black	32
Cottonseed oil	10

and minor amounts of stearic acid, barium sulfate and pine tar. The tape so coated was wrapped about the paper insulation and also on the conductor to contact the inner surface of insulation. Surface resistivities between 5,000 and 100,000 ohms per inch per inch were maintained even after long periods of immersion in and contact with hot insulating oils.

Example 6.—Thiokol (an organic polysulphide) was similarly compounded as in Example 5 and carried in suitable solution. Films were formed with electrical and chemical characteristics similar to those of Example 5.

Example 7.—A cellulose nitrate cable lacquer was compounded with other ingredients in the following proportions:

	Grams
Colloidal graphite dispersion	20
Butyl acetate	5
Acetone	5
Lacquer	20

When this was further thinned with a conventional thinner, such as acetone, and sprayed on a base fabric or sheet material, films after drying were obtained with resistivities of approximately 50,000 ohms to one megohm per inch per inch.

Example 8.—A solution in toluol of an element-convertible alkyd ester resin, prepared by the reaction of an aliphatic dibasic acid, castor oil and glycerol and having dispersed therein colloidal graphite, was sprayed on paper and Cellophane strips, dried and cured at 350° F. for one hour, to develop resistivities from 10,000 ohms to 50,000 ohms per inch per inch. The films have been found very durable, and they retain their conductivity after prolonged immersion in hot oil.

In the usual cable structure there is armor, rubber, braid, or other protective sheath over the insulation. Such a sheath when of metal provides a conductor for return currents at ground potential and thus confines the electrical stress to the insulation. A metal sheath also serves to drain charging current from the semi-conducting layer on the exterior surface of the insulation by contact at intervals along the length of the cable with the semi-conducting layer on the outer surface of the insulation; calculations show that in a cable operating at 13,000 volts with a semi-conducting layer having a surface resistance as high as 100 megohms per centimeter per centimeter, such contact intervals can be about one-third of an inch apart without the building up of harmful charges, which is a distance much greater than exists or is likely to occur in a metallic-sheathed cable during use. When the sheath or covering is of rubber or other insulating material, a longitudinally extending external wire or metal tape is placed about or in longitudinal contact with the semi-conducting layer; for example, in a three-conductor cable a wire can be placed in the center or a valley of the cable to contact each of the layers on the insulation of the conductors, or a wire or metal tape can be helically wrapped about the semi-conducting layer on each conductor of the cable for this purpose. The semi-conducting layer can be interposed between the conductor of the cable and the insulation about it to serve in this position as a preventative for corona discharges, and the conductor itself then serves to drain charging currents from the layer and to prevent development of destructive potential differences at the layer; in this construction the coating is applied to the conductor, the insulation, if rubber, is extruded about it into intimate contact, and the coating upon vulcanization intimately adheres to the insulation. In the case of wrapped insulation, the first tape (next to conductor) whether rubber, paper, cloth, etc., can be coated with the semi-conducting film-forming paint or lacquer.

In the accompanying drawing there are illustrated some typical cable structures in which

Fig. 1 is an elevation of a single conductor cable;

Fig. 2 is a radial cross-section of Fig. 1;

Fig. 3 is a radial cross-section of a three-conductor cable;

Fig. 4 is a radial cross-section of another form of three-conductor cable; and

Fig. 5 is a radial cross-section of a multiple conductor cable designed for X-ray voltages and supplying filament current.

In the single conductor cable, illustrated in Figs. 1 and 2, there is provided a central conductor 10; this can be either solid or stranded. About the conductor is shown a semi-conducting coating 11 of either lacquer or paint carrying conductive carbon or metal particles; for many types of cable structures the coating 11 is not necessary and can be omitted. Over the coating is the cable insulation 12 of rubber, paper, varnished cambric or the like; and about the insulation there can be a wrapping of rubber-filled or other cable tape 13. Applied to the insulation 12 or to the wrapping 13 is a continuous semi-conducting coating 14 (shown as a tape in Fig. 1) similar to the coating 11. In contact with the coating 14 is a conductor 15, shown as a metal tape, but the conductor can be wire braid, helically wrapped wire, etc., and it serves as a ground connection to drain charges which may build up on the coating 14 and to carry any return currents. A protective covering 16, such as a saturated braid, an abrasive-resistant rubber sheath, a lead sheath or a metal armor, encloses the cable parts; when the sheath is metallic or conducting and grounded, the tape 15 is not required.

A cable, such as is shown in Figs. 1 and 2, can be made, for example, by running the conductor through a solution of lacquer containing conducting particles. The coated conductor is then passed through a wiping die to form a thin uniform film on the surface, and then through a drying oven to remove solvent and to leave a tacky coating on the conductor. Unvulcanized rubber insulation can then be extruded on, following the known practice, and tape can be wrapped about the rubber. The tape is coated by passing through a solution of the lacquer, and the assembly passed through an oven to vulcanize the insulation and to set the semi-conducting coatings in intimate and adhering contact with the insulation. The metallic tape or other conductor and outside covering are then applied to the cable.

The multiple conductor cable, shown in cross-section in Fig. 3 comprises conductors 10^a, each provided with insulation 12^a. The conductors are helically twisted about each other, and the valleys thus formed are filled out with jute 17. A tape 18 is wrapped about the insulated conductors and jute filling, and the tape is provided with a semi-conducting coating on its outer surface. Over the tape is a conductive metal tape or braid or wire 19 and an insulating covering or sheath 16^a protects the metal tape.

A modified three-conductor cable is shown in cross-section in Fig. 4. In this form each of the conductor insulations 12^b has an exterior semi-conductive coating 13^b. In the valleys formed by the insulated conductors extend wires 21 in longitudinal contact with the coatings 13^b. The valleys are filled out with jute 17^b, and a sheath 16^b encloses the cable parts.

The X-ray cable of Fig. 5 has a core 30. As shown the core includes conductors 31, 32, 33 for carrying filament-heating currents (the voltage drop for this purpose is only about 6 volts), and the conductors have insulations 34, 35, 36 respectively; (in the figure, these insulations are shown disproportionately large for clearness). Twisted with the insulated conductors, and extending the length of the conductors, are wires 37, 38, 39 to serve as drain wires for any charging currents, and wrapped or formed about the conductors and wires is a jacket 40 which can be of tape or other base material having a semi-conducting coating on its surface in contact with the drain wires. The jacketed assembly constitutes the core.

For X-ray use the core is maintained at a high potential of from 50,000 to 100,000 volts; a heavy body of insulation 41 about the core is therefore required. As shown, the insulation 41 is rubber extruded about the core and therefore intimately contacting the semi-conductive jacket 40. On the exterior of the insulation is provided a semi-conductive tape or coating 42, a grounded wire braid 43 over the tape or coating, and a woven cotton braid covering or sheath 44.

With this construction the semi-conducting jacket 40 is external to the conductor insulations 34, 35, 36 but internal to the main body of insulation 41. Conductors 31, 32, 33 are at potentials approximately equal (within 100 volts) to the high potential of jacket 40 and the potential leads 37, 38, 39. The latter are carried to the source of high potential and with the jacket 40 maintain the inner surface of insulation 41 and the entire core at a potential which prevents disturbances or excessive stresses on the insulation 41 or spaces within the insulation 41. Charging currents to insulation 41, carried from the source by wires 37, 38, 39 to the jacket 40 into the insulation 41, are picked up by the semi-conductive coating 42 and returned or drained to the ground by the braid 43.

What is claimed is:

1. In an electric cable including insulation for a conductor of electric current, a semi-conducting layer in intimately-contacting continuous form at a surface of the insulation comprising a carrier selected from the group consisting of flexible insulating paints and lacquers, said carrier having conductive particles therein in amount to provide a surface resistivity with a lower limit of an order of ohms per square of area under normal operating conditions, and said layer serving to carry charging current to a conductive element having electrical contact with the layer at intervals sufficiently close along the length of the cable for maintaining the electrical potential of any portion of said semi-conducting layer at a value precluding harmful electrical disturbances.

2. In an electric cable including insulation for a conductor of electric current, a semi-conducting layer in intimately-contacting continuous form at a surface of the insulation comprising a carrier selected from the group consisting of flexible insulating paints and lacquers, said carrier having conductive particles therein in amount to provide a surface resistivity of the order of a few ohms to 100 megohms per square of area under normal operating conditions, and said layer serving to carry charging current to a conductive element having electrical contact with the layer at intervals sufficiently close along the length of the cable for maintaining the electrical potential of any portion of said semi-conducting layer at a value precluding harmful electrical disturbances.

3. In an electric cable including insulation for a conductor of electric current, a semi-conduct-

ing layer in intimately-contacting continuous form at a surface of the insulation comprising a normally insulating lacquer having an elastomer as the film-forming constituent and conductive particles in the lacquer in amount to provide a surface resistivity with a lower limit of an order of ohms per centimeter squared under normal operating conditions, and said layer serving to carry charging current to a conductive element having electrical contact with the layer at intervals sufficiently close along the length of the cable for maintaining the electrical potential of any portion of said semi-conducting layer at a value precluding harmful electrical disturbances.

4. In an electric cable according to claim 3 in which the elastomer comprises a chloroprene polymer.

5. In an electric cable according to claim 3 in which the elastomer comprises a plasticized vinyl chloride type polymer.

6. In an electric cable according to claim 3 in which the elastomer comprises an element-convertible alkyd resin.

7. In an electric cable according to claim 3 in which the particles are conductive carbon.

8. In an electric cable including insulation for a conductor of electric current, a semi-conducting layer in intimately-contacting continuous form at a surface of the insulation comprising a flexible preformed-film carrier selected from the group consisting of insulating paints and lacquers, said carrier having conductive particles therein in amount to provide a surface resistivity with a lower limit of an order of ohms per square of area under normal operating conditions, and said layer serving to carry charging current to a conductive element having electrical contact with the layer at intervals sufficiently close along the length of the cable for maintaining the electrical potential of any portion of said semi-conducting layer at a value precluding harmful electrical disturbances.

9. In an electric cable including insulation for a conductor of electric current, a semi-conducting layer in intimately-contacting continuous form at a surface of the insulation comprising a flexible base material having associated therewith a carrier selected from the group consisting of insulating paints and lacquers, said carrier having conductive particles therein in amount to provide a surface resistivity with a lower limit of an order of ohms per square of area under normal operating conditions, and said layers serving to carry charging current to a conductive element having electrical contact with the layer at intervals sufficiently close along the length of the cable for maintaining the electrical potential of any portion of said semi-conducting layer at a value precluding harmful electrical disturbances.

10. Cable suitable for X-ray voltages comprising in combination a core including an insulated conductor, a jacket comprising a carrier of insulating character selected from the group consisting of paints and lacquers and conductive particles in the carrier to impart semi-conductivity, and a non-insulated wire enclosed within and contacting the jacket along its length; insulation enclosing the core and intimately contacting the jacket; a semi-conductive film on the outer surface of the insulation; a conductor in contact with the film along the length of the cable; and an enclosing sheath.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
90,089	Foucant	May 18, 1869
1,199,789	Hochstadter	Oct. 3, 1916
1,235,373	Peek	July 31, 1917
1,290,673	Sonneborn	Jan. 7, 1919
1,348,248	Steinberger	Aug. 3, 1920
1,585,125	Simons	May 18, 1926
2,142,625	Zoethout	Jan. 3, 1939
2,165,738	Van Hoffen	July 11, 1939
2,211,584	Ruben	Aug. 13, 1940
2,282,832	Spooner	May 12, 1942
2,322,702	Peterson	June 22, 1943

FOREIGN PATENTS

Number	Country	Date
756	Great Britain	1880
19,882	Great Britain	1914
404,519	Great Britain	Jan. 18, 1934
450,805	Great Britain	July 24, 1936
526,895	Great Britain	Sept. 27, 1940

OTHER REFERENCES

"Rubber Chemistry & Technology," vol. 15, 1942, pages 146 to 157; article therein entitled "Electrically Conducting Neoprene and Rubber," by B. J. Habgood et al.