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J. F. S. ABBOTT ET AL

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INSULATED ELECTRICAL CONDUCTOR AND METHOD OF MAKING SAME

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FIG. 1

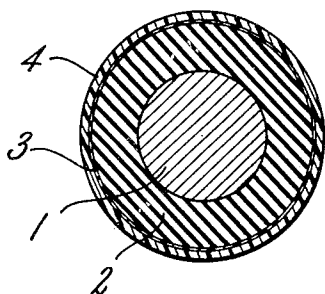
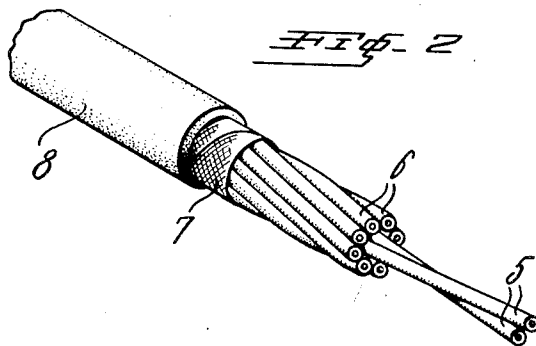


FIG. 2



INVENTORS
JOHN F. S. ABBOTT
CARL W. OTTO
BY
Robert J. Patterson
ATTORNEY

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INSULATED ELECTRICAL CONDUCTOR AND METHOD OF MAKING SAME

John F. S. Abbott, West Barrington, and Carl W. Otto, Riverside, R. I., assignors to United States Rubber Company, New York, N. Y., a corporation of New Jersey

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6 Claims. (Cl. 174—120)

This invention relates to an insulated electrical conductor and to a method of making the same.

Heretofore it has been the practice to insulate electrical conductors with insulation consisting of a very thin layer of rubber (for example, a layer .018" thick on #14 A. W. G. wire for 600 volt service) deposited from highly purified natural rubber latex or from butadiene-styrene rubbery copolymer (commonly referred to as "GR-S") latex, either of these latices containing less than 10% of compounding ingredients. Such insulation exhibits extremely good electrical properties and resistance to normal aging and, in the case of natural latex rubber, excellent tear and tensile strengths. However, the high rubber content of such insulation results in low resistance to abrasion, oil, light and ozone. These factors have been found of little importance as regards life of insulated conductors within the jackets of multi-conductor cables, but can cause difficulty at exposed terminations.

To avoid the possibility of trouble at exposed terminations and also to promote cable flexibility and resistance to impact, such conductors are frequently enclosed in individual textile braids. However, the braids add substantially to the diameter, weight and cost of cables having many conductors, and also slow production by the requirement of the extra and slow braiding operation. In addition, the braids introduce a component which frays readily, which may wick moisture into the cable, and which may be susceptible to fungus attack, so that a fungicidal varnishing operation is also usually required after braiding.

To offset these disadvantages, efforts have been made to eliminate the braids completely by applying over the rubber insulating layer a layer of neoprene (polychloroprene) deposited from neoprene latex. However, the resulting construction does not exhibit the desired color fastness in light and although the neoprene layer resists attack or deterioration by oil, it permits oil to be transmitted and to harm very severely the underlying rubber insulation. In addition, the neoprene layer contains certain constituents (probably rubber-compatible, low molecular weight polymers) which, unless very special precautions are taken, may transfer to the underlying rubber insulation, drastically reducing insulation resistance.

The present invention relates to an insulated electrical conductor and method of making the same which overcome the foregoing disadvantages. More particularly, the conductor of our invention eliminates the complication and expense of applying the outer braid and provides improved abrasion-resistance, improved resistance to light-discoloration, improved resistance to both oil attack and oil transmission, greatly improved resistance to ozone attack, absence of wicking and tendency to fray, resistance to attack by fungi, and other advantages. A noteworthy advantage of our conductor is that it makes pos-

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sible a substantial reduction in overall diameter of the conductor as compared to one which is braided. The conductor of our invention is completely free from the above-mentioned difficulties at exposed terminations of multi-conductor cables. At the same time our conductor achieves the foregoing advantages and new results without any adverse effect upon the physical or electrical properties of the rubber insulation. In addition, because of the toughness and the smooth, glossy surface of the outer protective layer of our insulated conductors, multi-conductor cables made therewith show improved resistance to impact and improved flexibility, particularly in contrast to cables containing neoprene latex coated conductors.

In the accompanying drawing:

Fig. 1 is a cross-section of an insulated conductor made in accordance with our invention, and

Fig. 2 is a perspective view, partly cut away, of a multi-conductor cable embodying conductors made in accordance with our invention.

We have discovered that the foregoing objectives can be achieved by applying to a metallic conductor by multiple application, as by dipping with drying after each application, of latex dispersions, first an insulating layer of either natural rubber or a rubbery butadiene-styrene copolymer, second, a tie layer of a mixture of the same type of rubber as is used in the insulating layer, a vinyl resin, and an oil-resistant copolymer which is a plasticizer of the vinyl resin and third, an abrasion-, oil-, light-, and ozone-resistant outer protective layer comprising a mixture of the vinyl resin and the plasticizing copolymer used in the tie layer. After application of these three layers, we subject the resulting assembly to additional heating (i. e., heating in addition to that employed to effect drying of each coating of latex) to complete the vulcanization of the insulating rubber layer and the rubber in the tie layer and the conversion of the several layers into a tightly bonded composite conductor covering.

The vinyl resin preferably is either polyvinyl chloride or a copolymer of vinyl chloride with a lesser amount of a copolymerizable monomeric compound containing as its sole unsaturation a single olefinic double bond, examples of such monomers being vinyl acetate, vinylidene chloride and diethyl maleate.

The plasticizing copolymer preferably is one of butadiene and acrylonitrile, typically in proportions of from 15 to 40% of combined acrylonitrile, the balance being butadiene. It can be rubbery or it can have a materially lower Mooney viscosity and molecular weight than the rubbery copolymers. For example it can have a Mooney viscosity (measured with the 1.5" rotor after 4 minutes at 212° F.) below 35 and a molecular weight below 85,000 compared to a Mooney viscosity of 50 or more and a molecular weight of 100,000 or more for ordinary butadiene-acrylonitrile rubbery copolymers.

The sequential applications of the latex coatings can be carried out with any suitable equipment and manner, usually involving application of a uniform coating of latex by dipping followed by passage of the wire vertically upwardly through a drying zone without disturbing the coating. A preferred arrangement of latex applicators and drying tower is that shown in Bartlett U. S. Patent 2,353,987. As soon as one coat has been applied and dried, the next coat is applied and dried, this being continued until the desired thickness has been built up and the latex being changed at appropriate points to enable building up of the three distinct layers as described herein.

In the typical practice of our invention, after building up on the metallic conductor a layer of suitable thickness directly deposited from highly purified natural rubber latex or from butadiene-styrene rubbery copolymer latex (either latex preferably containing not more than 10% of compounding ingredients which, it will be understood, include those necessary for vulcanization), we apply, in one or more dipping operations with intermediate drying, a thin tie layer from a latex mixture composed of the same latex as that used in making the rubber insulating layer in admixture with a latex of polyvinyl chloride or similar vinyl resin, e. g. a copolymer of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer, and a plasticizing butadiene-acrylonitrile copolymer. We then apply, typically by several dipping applications with intermediate drying, the outer layer from a latex of the vinyl resin and the plasticizing butadiene-acrylonitrile copolymer used in the tie layer. The relative proportion of the vinyl resin and the plasticizing butadiene-acrylonitrile copolymer in this outer layer is the same as in the tie layer.

For the latex of the vinyl resin and the copolymer plasticizer thereof which is used to form the outer layer and which is used in admixture with the natural rubber or GR-S latex in forming the tie layer, we can employ the material known as "Geon Polyblend Latex." The "Geon Polyblends" available in latex form are aqueous colloidal dispersions of a vinyl resin of the type described above and a butadiene-acrylonitrile copolymer which is a plasticizer therefor. An example is "Geon Polyblend Latex 550×34" the solids of which consist of about 70% of vinyl resin and about 30% of butadiene-acrylonitrile plasticizing copolymer together with a small amount of fixed alkali soap and other minor constituents.

This material is made by a blending procedure during the course of manufacture, in accordance with which a mixture is formed of the vinyl resin and of the butadiene-acrylonitrile plasticizing copolymer in much more intimate association than is the case when a mixture is made by simple physical mixing of the separately prepared latices of vinyl resin copolymer and of butadiene-acrylonitrile plasticizing copolymer. It is understood that the monomeric components of one of the vinyl resin and the butadiene-acrylonitrile plasticizing copolymer are added to a pre-formed latex of the other after which the added monomeric components are polymerized in a manner known to the art as "piggyback polymerization." For example, monomeric vinyl chloride is added to a pre-formed latex of the butadiene-acrylonitrile copolymer and polymerized in situ or a mixture of monomeric butadiene and acrylonitrile is added to a preformed latex of polyvinyl chloride and polymerized in situ. This type of polymerization is sometimes referred to as involving "seeding" the emulsion polymerization of one component with a latex of the other component. The added monomeric material can be in the form of an emulsion or can be emulsified as added. This method of manufacture has the result that upon heating the dried deposit of latex solids the components fuse together much more readily than would otherwise be the case. Furthermore, the fused film exhibits properties superior to those of a film formed from a mixture of the separately prepared latices. However, we can, though less preferably, employ a simple physical mixture of the separately prepared latices in practicing our invention.

We prefer to use a latex of the vinyl resin and the plasticizing butadiene-acrylonitrile copolymer which has been substantially freed from permanent, i. e., non-volatile, water-soluble materials, especially fixed alkali, by pre-treatment in any suitable way, e. g., by creaming in known manner. The use of a latex so treated in forming the tie layer and the outer layer of the conductor of our invention has the great advantage of greatly reducing the water-susceptibility of the layers surrounding the rubber insulation. Thus a deposit formed from uncreamed vinyl resin-nitrile copolymer latex absorbs and transmits much more water than a deposit from the same latex which has been creamed or otherwise treated to substantially free it from water-soluble materials, especially fixed alkali. The excellent bonding of the outer layer to the underlying rubber insulation which is achieved by the use of our tie layer prevents the severe blistering which might occur if uncreamed latex were used and the tie layer were omitted. Although removal of fixed alkali and similar

materials from the latex is not absolutely essential, nevertheless it is preferred because of the better water-resistance and electrical properties obtained.

In the use of the above-described purified latex of vinyl resin and plasticizing copolymer, we have found it desirable to employ a small proportion of stabilizer, such as organo-metallic compounds containing tin or lead, to increase light-fastness. For example, 0.5% dibutyl tin-dilaurate based on total latex solids is desirable in light-colored coatings.

In practicing our invention we first build up a layer of natural rubber or GR-S sufficiently thick to provide the necessary insulation. We do this by sequential dipping in rubber latex containing the necessary vulcanizing and other compounding ingredients, with intermediate drying to remove water between successive dips. We then apply our tie layer by dipping in a mixture of the same rubber latex which was used in making the insulating layer and a creamed and stabilized latex of the vinyl resin and the plasticizing copolymer. This tie layer can be formed by a single dip or by several dips with intermediate drying. The tie layer is preferably very thin, typically less than 2 mils (.002") in thickness. This tie layer is preferably formed from a mixture of the rubber latex used in the insulating layer and the vinyl resin-plasticizer latex in proportions corresponding to from 10 to 70% by weight of solids furnished by the natural rubber or GR-S latex and correspondingly from 90 to 30% solids furnished by the vinyl resin-plasticizer latex. We can use a 50/50 (on a dry or solids basis) mixture of the natural rubber or GR-S latex and the vinyl resin-plasticizer latex in all of the dipping operations by which the tie layer is built up. Alternatively, we can use different proportions in the several mixtures used to form the tie layer. For example, we can first dip the rubber-coated wire in a latex mixture relatively high in the natural rubber or GR-S latex and then, after drying, dip it in a mixture containing a preponderant proportion of the vinyl resin-plasticizer latex. Thus we could form the tie layer with two dips, the first using the natural rubber or GR-S latex and the vinyl resin-plasticizer latex in a ratio of 70/30 and the second using a mixture of these latices in a 30/70 ratio (both on a solids basis). We can use more than two dips to form the tie coat, the content of natural rubber or GR-S latex gradually decreasing from the first to the last dip. After drying the final dip coat used in building up the tie layer, we build up the outer layer by sequential dipping and drying using the creamed and stabilized vinyl resin-plasticizer latex. Although we can build up this outer layer to any thickness ranging from 2 to 10 mils or more, we much prefer to build it up to a thickness less than 5 mils, say from 2 to 4 mils, because in this way a marked reduction in space requirements is achieved. After drying of the final latex dipped coating used in forming the outer layer, we then heat the coated conductor to finish vulcanization of the rubber in the insulating and tie layers and to effect fusion of the resin and plasticizer in the tie layer and in the outer layer and tight bonding and coalescence at the interfaces of the rubber insulating layer and the tie layer and of the outer layer and the tie layer whereby tight adhesion of the outer layer to the rubber insulating layer is achieved. This vulcanization and fusion are partially effected during the drying of the latex dipped coats which typically is carried out at temperatures of about 250–275° F. for from about two to about five minutes per dip. The vulcanization and fusion are completed by final heating at a considerably elevated temperature, typically from about 300 to 325° F. for from about one to about three minutes.

Our outer layer makes an excellent coating for the purpose of protecting the underlying rubber insulation even though the outer layer is only .002–.004" thick as compared to about .005–.007" thickness of braid. The outer layer can be brightly colored with excellent light-fastness. It is resistant to both damage and penetration by oils and greases. It is highly ozone- and fungus-resistant and its abrasion-resistance is substantially better than that of the commonly used rayon braid.

The butadiene-acrylonitrile copolymer is an excellent non-migratory plasticizer for the vinyl resin used in the tie layer and outer layer. Since this plasticizer is of a polymeric type, no migration of it to the underlying rubber insulation can take place as would be the case with ester type and similar high-boiling organic liquid plasticizers; thus, harmful physical and electrical effects due

to such plasticizer migration are completely obviated in the present invention, both the tie layer and the outer layer being free from ester or like migratory high-boiling organic liquid plasticizers. In addition, since vinyl polymers are incompatible with the rubber of the underlying insulating layer, no transfer of harmful minor vinyl constituents to such insulating layer can take place with possible resulting reduction in the high insulation resistance of the rubber. The avoidance of such transfer in our invention is to be contrasted with the transfer which, unless great care is taken, may take place when it is attempted to form an outer layer from neoprene latex, this transfer being evidenced by drastic loss in insulation resistance of the rubber.

It will be seen that in spite of the commonly accepted fact of incompatibility between the natural rubber or GR-S used in our insulating layer and polyvinyl chloride or similar vinyl resins we have found that a remarkably tight bond of the outer polyvinyl chloride-nitrile copolymer layer to the insulating layer is achieved by our tie bond. A good measure of bond strength is obtained by observing the behaviour of the composite insulated conductor after immersion for say one week in water at 70° C. In such a test our protected insulated conductor shows very low water absorption as well as good resistance to blistering.

It will be understood that the natural rubber or GR-S latex used in forming the insulating layer and as a component of the mixture used in forming the tie layer is compounded with vulcanizing ingredients, including sulfur and conventional vulcanization accelerators, in amounts less than 10%, sufficient to vulcanize the rubber content upon exposure to the final heating step described above.

The relative proportions of vinyl resin and butadiene-acrylonitrile plasticizing copolymer or other plasticizing polymer used in the tie layer and in the outer layer can vary widely but typically range from 50 to 80% by weight of vinyl resin and correspondingly from 50 to 20% of the polymeric plasticizer. We prefer to employ approximately 70% of vinyl resin and 30% of plasticizing copolymer. The abrasion-resistance falls off as the vinyl resin-plasticizing copolymer ratio is changed from 70/30 to 60/40.

Referring now to the accompanying drawings:

In Fig. 1 we show a metal conductor 1, usually of copper, which may be tinned, provided with an insulating natural rubber or GR-S layer 2, a tie layer 3 and an outer vinyl resin-plasticizing copolymer layer 4, layers 2, 3 and 4 being built up in the manner described above by latex dips with intermediate drying and the assembly finally being subjected to vulcanizing and fusing heat to complete vulcanization of rubber layer 2 and of the rubber components of layer 3, to effect fusing and fluxing of the resin and plasticizer in layers 3 and 4 and to effect coalescence between layers 2 and 3 and layers 3 and 4 at the interfaces. This coalescence forms a bond which is practically integral at the interfaces so that separation is difficult if not impossible.

In Fig. 2 we show a multi-conductor cable embodying conductors made as shown in Fig. 1. The cable of Fig. 2 embodies a pair of twisted conductors 5 around which are disposed eight conductors 6 applied by a cable machine and laid in a direction opposite to the direction of twist of conductors 5. Conventional fibrous cable tape 7 is applied by helically winding it around the ten conductors shown, the purpose of this tape being to prevent penetration of the outside jacket stock into the interstices between conductors 6. Over the tape 7 a continuous jacket 8 is applied in any conventional manner, typically by extrusion. Jacket 8 can be of lead or of plastic, e. g., vinyl resin, or of any suitable natural or synthetic rubber, providing that vulcanization of such rubber is carried out at a temperature, say about 70° C., which is below the deformation temperature of the vinyl resin outer jackets of the individual conductors.

It will be seen that we are able to apply an outer protective layer in a thickness which would be impossible to attain if it were attempted to form it by application, e. g. by extrusion, of a solid vinyl resin-plasticizing copolymer mixture. It would not be possible to apply such materials in a thickness less than about 10 mils by extrusion, whereas with our invention, it is possible to apply a tie layer and an outer layer having a combined thickness of less than 7 mils. In addition, by the use of

our tie layer and our latex application technique we obtain a far better bonding of the outer layer to the rubber insulation than would be possible in any other way, as by extrusion of a solid mixture. The degree of adhesion of our outer layer to our underlying rubber insulating layer is so great that if one attempts to remove the outer layer the surface of the underlying layer of rubber is usually roughened by small tears. A contributing factor to the unusual adhesion in our conductor is the fact that we build up all three layers sequentially with no substantial delay after drying of each latex dip coat so that the surface of each underlayer is new and fresh with the result that the succeeding layer adheres unusually well. Another factor in the unusual adhesion of the layers of our invention is the fusion and coalescence effected during vulcanization. This fusion and coalescence contribute greatly to the degree of adhesion.

In contrast to the excellent results achieved by means of our tie layer, we have found experimentally that when attempts are made to apply the latex of vinyl resin and nitrile copolymer plasticizer directly over the natural rubber or GR-S layer, i. e., without interposing our tie layer, the resulting construction is deficient in two important respects: (1) the outer layer may readily be "collared-back," i. e., pushed back at the ends of the conductor, as when the wire is drawn over an object with moderate pressure; this "collaring-back" exposes the underlying rubber insulation and destroys the desired protection; and (2) it is not possible to apply the outer layer in the required smooth, even film, apparently because of poor wetting of the underlying rubber by the vinyl resin-nitrile copolymer latex; even in the wet latex state the widely differing natures of the rubber and of the plastic materials are so strongly evident that the wet plastic latex does not adhere uniformly to the underlying dry, hot rubber layer; the plastic latex flows unevenly around the wire and retracts unevenly along the wire; as it dries the plastic film is thus uneven and blistered; use of blended latices to form a tie layer avoids this difficulty and makes it possible to "run" our construction smoothly. The second defect might conceivably be overcome by increasing the wettability of the rubber layer and the wetting qualities of the vinyl resin-nitrile copolymer latex, but this would be difficult and would introduce undesirable foreign elements, namely, non-volatile wetting agents, into both layers with adverse effects upon the electrical characteristics of the construction.

The following examples illustrate our invention more fully:

Examples 1 to 5

Number 14 A. W. G. tinned copper wire was used. There was first built up on this wire a layer of natural rubber .018" thick (Example 1) by several dips in natural rubber latex, the solids of which contained over 90% of rubber. The latex contained sulfur in amount sufficient to vulcanize the rubber content to a soft vulcanized state. It also contained small amounts of zinc oxide and other conventional compounding ingredients such as accelerators and anti-oxidants. After each dip the wire was dried to remove water.

To portions of the resulting rubber-coated wire there was immediately applied the tie layer and resin outer layer of our invention by first dipping in a mixture of the same natural rubber latex and (Example 2) "Geon Polyblend Latex 552" (solids comprising vinyl chloride resin and nitrile copolymer in 60/40 ratio), (Example 3) "Geon Polyblend Latex 550×34" (solids comprising vinyl chloride resin and nitrile copolymer in 70/30 ratio), (Example 4) creamed "Geon Polyblend Latex 552," or (Example 5) creamed "Geon Polyblend Latex 550×34," in relative proportions such that both latices furnished an equal weight of solids (i. e., the solids furnished by the natural rubber latex and by the "Geon Polyblend Latex" in Examples 2 to 5 were in a 50:50 ratio), drying to remove water, and then dipping several times in the same "Geon Polyblend Latex" as was used to form the tie layer, to build up an outer layer .003" thick. In all cases the coated conductor was finally heated at 300° F. to vulcanize the natural rubber in the insulating layer, and, in the case of Examples 2 to 5, to fuse the resin and plasticizer in the tie and outer layers and effect coalescence of the three layers at the interfaces.

The resulting conductors were then tested. The following data were secured:

tion makes it readily possible to make a conductor which presents the advantages of a rubbery insulating layer pro-

Example No.-----	1	2	3	4	5
Type of Coating-----	.018" Rubber-----	.018" Rubber, .003" "Geon Polyblend Latex 552."-----	.018" Rubber, .003" "Geon Polyblend Latex 550 X 34."-----	.018" Rubber, .003" Creamed "Geon Polyblend Latex 552."-----	.018" Rubber, .003" Creamed "Geon Polyblend Latex 550 X 34."-----
Ozone Resistance—Time to crack at ozone concentration of .013%, bent around .125" mandrel.	15 min. cracked-----	3 hrs. No cracks-----	3 hrs. No cracks-----	3 hrs. No cracks-----	3 hrs. No cracks.
Water Absorption, 7 days at 70° C., Mgs./in. ²	15.0-----	60.5-----	52.5-----	59.0-----	28.3.
Water Blistering: 2 weeks at Room Temp----- 1 week at 70° C-----	None----- do-----	Large----- do-----	Large----- do-----	Small----- Very Small-----	Very Small. Do.
Flame Test: Horizontal----- Vertical-----	Burns readily----- do-----	Burns less readily than 1. do-----	Burns less readily than 1. do-----	Burns less readily than 1. do-----	Burns less readily than 1. Do.
Abrasion Test (Inches of abrasive tape passed over sample before shorting).	58 in. (78 in. with rayon braid).	72 in.	96 in.	72 in.	90 in.
Dielectric Constant in R. T. Water: 1 day----- 7 days----- 14 days----- Percent Inc., 1-14 days----- Percent Inc., 7-14 days-----	2.75----- 2.81----- 2.85----- 3.6----- 1.4-----	3.06----- 3.13----- 3.20----- 4.6----- 2.2-----	2.87----- 2.99----- 3.07----- 7.0----- 2.7-----	3.12----- 3.24----- 3.28----- 5.1----- 1.2-----	2.87----- 2.98----- 3.04----- 5.9----- 1.6-----
Oil Immersion 24 hr., 121° C-----	Badly Swollen. No strength.	Slightly Swollen, approximately 50% tensile retention.	Slightly Swollen, approximately 50% tensile retention.	Slightly Swollen, approximately 30% tensile retention.	Slightly Swollen, approximately 50% tensile retention.
Insulation Resistance 1 hr., R. T. Water, Megohms, 1000'.	11,500-----				11,000.

Example 6

A multi-conductor, lead sheathed cable was prepared using conductors made according to Example 5 except that the rubber insulating layer was .015" thick. After one year the conductors were found to exhibit an average insulation resistance value of 20,600 megohms—1000 feet. In contrast, similar conductors jacketed with .015" of rubber insulation and a surrounding layer, .003" thick, of neoprene latex had an average value of 7,580 megohms—1000 feet.

Multi-conductor cables made in accordance with our invention are extremely satisfactory under high humidity conditions, as in manholes, which cause considerable trouble at terminal headers using multi-conductor cables made with conductors having rubber insulation with a braided cover. In addition, the conductors of our invention are less subject to abrasion and "make up" better than conductors insulated with natural rubber protected by an outer layer of neoprene.

The following example shows the absence of any evidence of migration from our vinyl resin layer to the underlying rubber layer:

Example 7

A conductor was prepared exactly like that of Example 5, except that the tie layer was omitted. Processing was poor in that the "Polyblend Latex" wet the underlying rubber insulation poorly, resulting in runbacks and uneven coating after drying and vulcanization. Furthermore, the coating was readily pushed back over the rubber. To determine if any migration could occur from the vinyl coating to the latex rubber insulation, tensile and elongation tests were performed on the insulation without aging and after various accelerated aging periods, the coating being left on the insulation during aging, but being removed for testing. The results were as follows:

	Unaged	Aged		
		96 hr., Air Oven, 70° C.	96 Hr., O ₂ Bomb, 70° C., 300 p. s. i.	168 hr., O ₂ Bomb, 70° C., 300 p. s. i.
Tensile, p. s. i.-----	4,353	4,070	4,133	3,510
Percent of original-----		93.6	95.0	80.7
Elongation, percent-----	870	870	880	830
Percent of original-----		100	101.3	95.5

The excellent retention of physical properties after aging indicates absence of migration of plasticizer from the vinyl outer coating to the rubber insulation.

From the foregoing many advantages of our invention will be apparent to those skilled in the art. Our inven-

tion makes it readily possible to make a conductor which presents the advantages of a rubbery insulating layer protected by the outer resin layer against the deleterious action of many influences commonly encountered, including ozone, oil, light, abrasion, etc. The disadvantages of an outer braid are entirely obviated. At the same time the invention makes it easily possible to effect an overall reduction in the diameter of the conductor which makes it possible to have more current carrying capacity in a given cross-sectional area, especially in multi-conductor cables. These advantages are accompanied by a reduction in inflammability and with no decrease in insulation resistance.

It will be understood that if desired we can compound either or both the vinyl resin and the plasticizing copolymer used in the tie layer and the outer layer. For example, we can incorporate with the vinyl resin-plasticizing copolymer latex conventional compounding ingredients for the nitrile component, e. g., sulfur and conventional curatives and compounding ingredients commonly used with such a copolymer. Alternatively or in addition, we can include materials which modify the vinyl resin provided they do not introduce any undesired effect. An example would be a phenolic resin which could be dispersed in the vinyl resin-plasticizing copolymer latex and converted to insoluble, infusible form during the final vulcanization and fusion step. Light and heat-resisting stabilizers may be added as required. Many other modifications can be made in our invention without departing from the spirit thereof.

Where reference is made herein to highly purified natural rubber latex, those skilled in the art will understand that this refers to natural rubber latex which has been treated in known manner, as by creaming or centrifuging, to remove non-rubber ingredients especially water-soluble proteinaceous material, for example, in the manner shown in Rice, U. S. Patent 1,936,994.

Having thus described our invention, what we claim and desire to protect by Letters Patent is:

1. A method of making an insulated electrical conductor which comprises applying to a metallic conductor by multiple application, with drying to remove water after each application, of latex dispersions, first, an insulating layer of a rubber selected from the group consisting of natural rubber and rubbery butadiene-styrene copolymers, second, a tie layer comprising a mixture of a rubber selected from said group, a vinyl resin selected from the group consisting of polyvinyl chloride and copolymers of vinyl chloride and a copolymerizable monomer, and an oil-resistant butadiene-acrylonitrile copolymer which is a plasticizer of said vinyl resin, and, third, an abrasion-, oil-, light- and ozone-resistant outer protective layer comprising a mixture of said vinyl resin and said plasticizing copolymer, and subsequently subjecting the assembly to additional heating to complete vulcan-

ization of the rubber in said insulating and tie layers and form a composite conductor covering wherein said outer layer is tightly bonded to said insulating layer by said tie layer and wherein said layers are coalesced at their interfaces.

2. A method as set forth in claim 1 wherein said tie layer contains from 10 to 70% of said rubber and correspondingly from 90 to 30% of said vinyl resin and said plasticizing copolymer.

3. An insulated electrical conductor comprising a metallic conductor, a surrounding insulating layer of a rubber selected from the group consisting of natural rubber and rubbery butadiene-styrene copolymers, said layer being deposited directly from a latex of said rubber, a thin tie layer comprising a mixture of a rubber selected from said group, a vinyl resin selected from the group consisting of polyvinyl chloride and copolymers of vinyl chloride and a copolymerizable monomer, and an oil-resistant butadiene-acrylonitrile copolymer which is a plasticizer of said vinyl resin, surrounding said insulating layer, said tie layer being deposited directly from a latex mixture of a latex of said rubber and a latex of said resin and said butadiene-acrylonitrile copolymer, and an abrasion-, oil-, light- and ozone-resistant outer protective layer comprising a homogeneous mixture of said vinyl resin and said plasticizing copolymer, said outer layer being deposited directly from a latex of said resin and said buta-

diene-acrylonitrile copolymer, the rubber in said insulating and tie layers being vulcanized and said layers being coalesced at their interfaces.

4. A conductor as set forth in claim 3 wherein said tie layer is less than 2 mils in thickness and wherein said outer layer is less than 5 mils in thickness.

5. A multi-conductor cable comprising a plurality of conductors as set forth in claim 3 and a surrounding sheath.

6. A conductor as set forth in claim 3 wherein said tie layer contains from 10 to 70% of said rubber and correspondingly from 90 to 30% of said vinyl resin and said plasticizing copolymer.

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