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INSULATED ELECTRICAL CONDUCTOR

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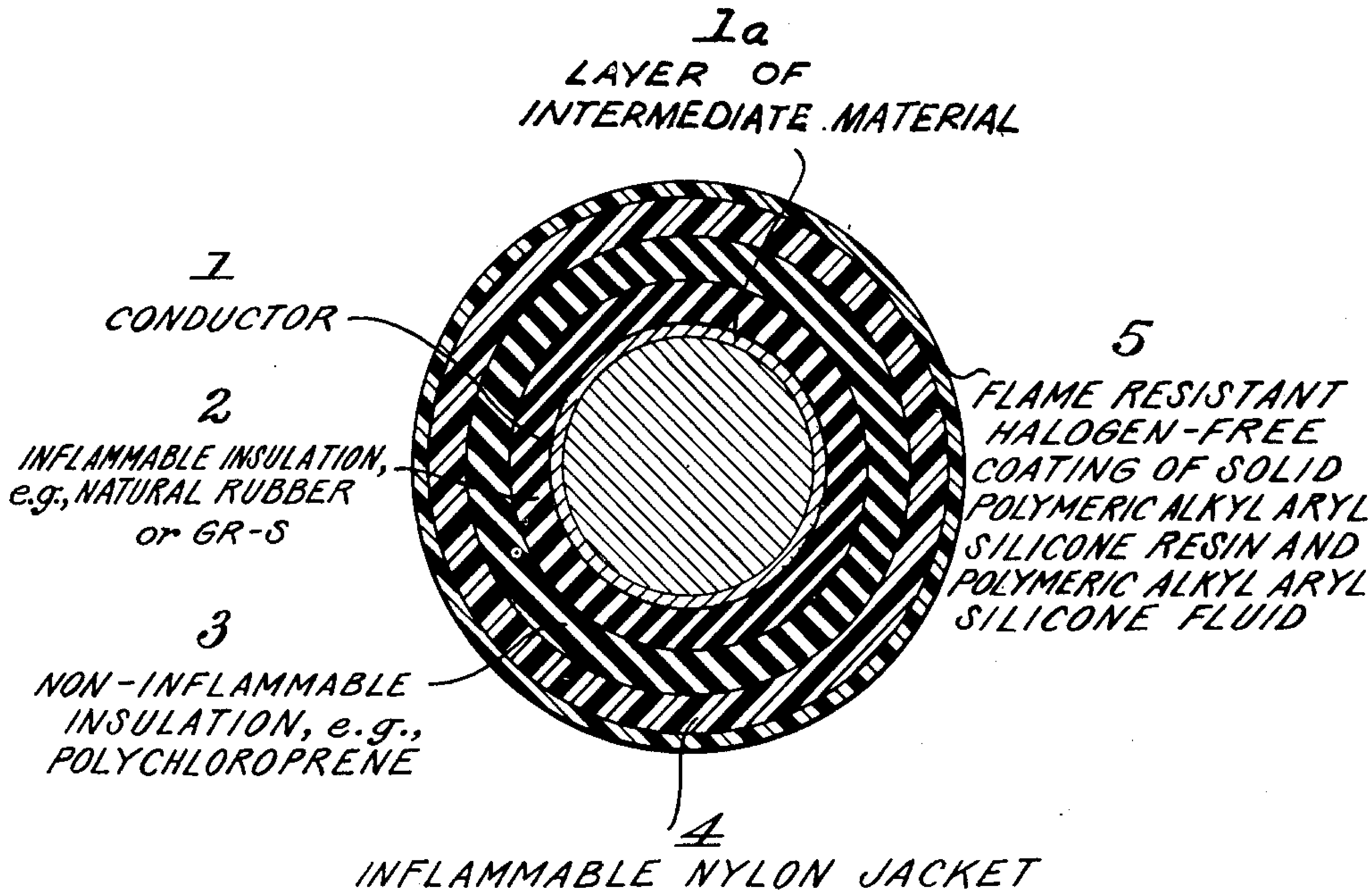

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INSULATED ELECTRICAL CONDUCTOR

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This invention relates to an insulated electrical conductor and more particularly to an electrical conductor having a surrounding jacket of inflammable material, which in accordance with the invention is provided with an outer coating rendering it flame-resistant so that it will meet the requirements of the Underwriters' Laboratories for rubber-covered wires and cables.

The accompanying drawing portrays in cross-section a typical electrical conductor embodying the present invention.

A serious problem which has arisen in connection with insulated electrical conductors and particularly in connection with nylon-jacketed, rubber-insulated wire has been failure to meet the Underwriters' Laboratories flame-resistant requirements for rubber-covered wire. The Underwriters' flame test is carried out by igniting for 30 seconds by applying an illuminating gas flame from a Tirrell burner to the insulation on a horizontally supported conductor, withdrawing the burner flame, and determining the length which is burned before the flame goes out. A burned length of not over 2" in either direction from the midpoint of flame application is permitted for rubber-covered wire. Untreated nylon-jacketed rubber-covered wire burns for its full length and so does not comply with the Underwriters' requirements. Accordingly, it was necessary to find a method of treating such wire so as to cause it to pass the flame test.

A full description of the above flame test is given on pages 4 and 5 of the Underwriters' Laboratories, Inc., bulletin dated September 17, 1945, titled "Emergency Requirement—Rubber-Covered Wires and Cables."

The present invention is based upon our discovery that wire having an inflammable nylon jacket can be rendered flame-resistant and flame-quenching so as to meet the Underwriters' flame test outlined above, by providing the outer inflammable nylon jacket with a coating of an unhalogenated solid polymeric alkyl aryl silicone resin in homogeneous admixture with an unhalogenated nonvolatile polymeric alkyl aryl silicone fluid (i. e., liquid). It was surprising and unexpected to find that a relatively thin coating of such a silicone resin and fluid mixture would impart flame-resistance and flame-quenching ability to an inflammable jacket, because it was supposed that the polymeric alkyl aryl silicones were inflammable, it being stated in the patent to Rochow 2,258,222 that it is necessary to introduce halogen atoms into the aryl nucleus of such silicones to impart

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flame-resistance thereto. Thus Rochow states that non-halogenated methyl phenyl silicone burns upon application of a flame and that even the mono- and di-halogenated derivatives of methyl phenyl silicone may not be wholly flame-proof. It was therefore unexpected that the halogen-free coating of our invention would impart flame-resistance and flame-quenching ability.

While we are not limited to any theory as to the mechanism by which our invention operates, we believe that, during the application of flame during the test, the silicones burn and decompose, leaving a thin film of silica over the surface of the inflammable nylon jacket. Upon removal of the igniting flame, this film quickly acts to quench the still-burning molten nylon. This flame-quenching probably results because the silica film acts as an effective seal against the contact of atmospheric oxygen with the inflammable nylon. The thinness of the silicone resin film precludes the possibility that flame-quenching results from cooling by heat conductance, and there are not present in the silicones any halogens or other materials capable of forming a gaseous sealing layer.

Our invention is particularly applicable to wire which is insulated with rubber and jacketed with nylon. Rubber provides an unusually flexible insulation with excellent electrical and physical properties. The nylon jacket surrounding the rubber serves to give a smoother, harder, more abrasion-resistant outer surface than is provided by rubber. As is well-known, nylon is a synthetic linear polyamide. The nylon used for this purpose is generally available in a grade suitable for wire jacketing, and is applied by conventional hot extrusion methods in such a way that the nylon jacket fits tightly over the rubber insulation, due to its high tensile strength and to its shrinkage upon cooling. The speed of extrusion and subsequent forced cooling are such that no harmful effect of heat is produced in the rubber insulation. It is desirable to add a suitable pigment to the nylon before extrusion so as to give the finished insulated electrical conductor any desired color, thereby facilitating identification. Although the nylon may be considered flame-quenching under certain test conditions, it is not so under the conditions of the Underwriters' Laboratories test outlined above. Various methods of increasing its flame resistance may be employed which involve addition to the nylon of suitable chemicals or fillers in relatively large amounts. However, these methods result in harmful changes in other properties of the nylon, such as increase in water absorption, reduction in abrasion resistance, or decrease in resistance to cracking when bent at low temperatures. The method of our invention avoids all such harmful effects.

The rubber insulation may be applied in any manner which insures that the rubber will be disposed concentrically to the metal conductor. Preferably it is applied in the form of latex using the apparatus disclosed in Bartlett Patent 2,353,987. The latex is coagulated and water is removed by drying in the known manner before application of a succeeding layer. The wire may be plated with tin or with lead alloy *1a* before application of the rubber to prevent interaction between the metal of the wire and components of the rubber jacket, especially sulfur; or a jacket *1a* of polyethylene or other suitable flexible intermediate material may be applied directly upon the wire before applying the rubber coating or coatings.

Our invention can be practiced with an insulated and jacketed electrical conductor where the insulation is composed entirely of inflammable natural or synthetic rubber and the jacket is composed of inflammable nylon. However, in this case it is necessary to employ an excessively heavy outer coating of our silicones which is expensive and may be insufficiently flexible. Accordingly, we prefer to employ a composite insulation comprising a layer of inflammable natural rubber or a rubbery copolymer of butadiene and styrene known as "GR-S," either of which has extremely high electrical insulating characteristics and which is deposited from a highly purified latex compound, over which is applied a layer of approximately equal thickness of non-inflammable synthetic rubber, especially polychloroprene, also deposited from a latex compound. We have found that such a composite insulation is flame-resistant under the conditions of the Underwriters' Laboratories flame test, but that the polychloroprene layer is not effective, even when increased in thickness, in imparting the required degree of flame-resistance to a superimposed jacket of inflammable nylon.

The alkyl aryl silicones used in the final coating of our invention are well-known materials being available commercially and being described in the Rochow patent cited above and in "An Introduction to the Chemistry of the Silicones" by E. G. Rochow, published in 1946 by John Wiley & Sons, Inc., New York, on pages 80 to 82. As is well-known, these materials vary widely in total substitution and in molecular weight. We prefer to employ those silicones wherein the alkyl group is methyl and the aryl group is phenyl. In such silicones one methyl group and one phenyl group are ordinarily attached to the same silicon atom, although there may be some dimethyl attachments. The molar proportions of alkyl and aryl groups in the silicones used are almost equal, say from 0.9 to 1.3 alkyl groups per aryl group, and the ratio of the total hydrocarbon groups to silicon is about 1.8, i. e., from 1.7 to 1.9. Resins in which the proportion of alkyl is higher than that of aryl, say from 1.1 to 1.3 alkyl group per aryl group are preferred, in order to minimize brittleness.

The silicone polymers are believed to have the unit structure:

$$-\overset{\displaystyle R}{\underset{\displaystyle Ar}{\overset{|}{\underset{|}{Si}}}}-O-$$

where R is an unhalogenated alkyl radicals, usually not higher than propyl and generally methyl, and Ar is an unhalogenated aryl radical, especially phenyl, although it may be a homolog of phenyl, e. g., tolyl, xylyl, etc. Ar is almost invariably monocyclic.

These silicones are usually prepared by the hydrolysis of an alkyl aryl dichlorosilane, followed by dehydration and condensation, which are carried out by heating the hydrolysis products to a suitable elevated temperature. The condensation is stopped while the polymers are still in the fusible soluble stage.

The mechanism whereby solid silicone resins or silicone fluids are produced is well-known to the art. Generally speaking, whether a fluid or a solid silicone is obtained depends upon the average molecular weight or chain length of the linear polymers produced, the silicone oils or fluids having relatively short average chain length and the solid silicone resins having considerably greater average chain length.

We prefer to employ a mixture of two solid and one fluid alkyl aryl silicone polymers of substantially different characteristics. Better results are obtained in this way than by using a single solid resin or mixture of two resins. We have obtained unusually good results by employing a relatively large proportion of a solid alkyl aryl silicone resin of relatively high molecular weight, which if used alone would give a film which would be unduly brittle and would flake off when the conductor was bent, in conjunction with both a fluid and a solid alkyl aryl silicone polymer of lower molecular weight, either of which when used alone would deposit a film which would remain tacky and sticky. The latter silicone polymers function as softeners for the brittle silicone resin. The proportion of the lower molecular weight solid resin employed may range up to 15% by weight based upon the brittle solid silicone resin. The amount of fluid alkyl aryl silicone polymer employed should be sufficient to render the coating adequately flexible but not sufficient to result in undesirable tackiness or stickiness. Amounts thereof ranging from 5 to 15% based upon the brittle solid alkyl aryl silicone polymer have been found to be satisfactory.

The fluid alkyl aryl silicone polymer serves as a softener and plasticizer for the solid polymeric alkyl aryl silicone resin or resins. Thus, if the mixture of solid and fluid polymers described in the preceding paragraph is used, both the silicone fluid and the lower molecular weight, normally tacky solid resin serve to soften the normally brittle solid resin. The reason for using both of these softeners is that better results are obtained as the mixture is more complex. Moreover use of the lower molecular weight solid resin enables a corresponding reduction in the amount of the fluid polymer required. This enables a substantial reduction in cost since the fluid polymer is the more expensive of the two softeners. It has not proved possible to dispense entirely with the fluid polymer because when no fluid is used it is impossible to obtain the requisite combination of flexibility and freedom from tackiness, and in fact optimum results are obtained using from 8 to 10 parts of the fluid polymer in conjunction with from 8 to 12 parts of the normally tacky solid resin per 100 parts of the normally brittle solid resin.

The solid alkyl aryl silicone polymer or polymers and the fluid alkyl aryl silicone polymer are preferably all dissolved in a suitable volatile organic solvent, especially an aromatic hydrocarbon, to form a solution of a suitable concentration which is applied to the nylon-jacketed rubber-insulated wire in any desired manner, as by dipping, using the apparatus disclosed in Bartlett Patent 2,353,987. Toluene is especially suitable as a solvent for the resin or resins and the silicone fluid. The amount of toluene used is preferably such that the resulting solution contains between 20% and 25% of non-volatile material, i. e., polymeric alkyl aryl silicones. Usually the solution consists of the polymeric alkyl aryl silicones and the toluene solvent. When the solution contains less than 20% of the silicones, a single application deposits a film which is too thin for flame-retardance or flame-quenching, while solutions containing more than 25% of the silicone give a film which is too thick and which tends to flake off upon bending the wire.

The thickness of silicone film applied by our invention is preferably about 0.0005'' although it may range from 0.0004'' to 0.0008''.

No catalyst is present in the solution used to treat the wire. The solid polymeric alkyl aryl silicone resin or resins and the polymeric alkyl aryl silicone fluid are blended in such proportions as to avoid tackiness, while still retaining suitable flexibility, in the dried film. Those skilled in the art can readily select suitable alkyl aryl silicone polymers and blend them properly, in the light of this specification.

The drying step can be carried out at any temperature sufficiently elevated to volatilize the solvent. In the usual case toluene is used as the solvent and is driven off at a temperature ranging from 175° F. to 250° F. The removal of the solvent at the higher temperatures in this range is generally accompanied by some advancement of the several silicone polymers used toward an infusible insoluble state.

The outer silicone coating of our invention is characterized by excellent moisture-resistance, flexibility, tight adhesion to the outer surface of the nylon jacket, and chemical and electrical inertness.

In the drawing, there is shown a wire **1** of any suitable metal, usually copper, which is provided with an outer layer *1a* formed by plating with tin or lead alloy or composed of polyethylene or like flexible intermediate material, a composite insulating layer composed of an inflammable insulation layer **2** (of natural rubber or GR-S) and a non-inflammable insulation layer **3** (usually of polychloroprene) both of which are deposited from latex. The layer **3** is surrounded by a continuous inflammable nylon jacket **4** over which is superimposed the flame-resistant and flame-quenching coating **5** of the present invention. The coating **5** is a continuous unbroken layer of solids deposited from the above-described coating solution.

Example

Nylon-jacketed rubber-insulating building wire of the type portrayed in the drawing was dipped in the following solution:

	Parts by weight
Dow Corning DC #2103 Silicone Resin	166.7
Dow Corning DC #802 Silicone Resin	20.0
Dow Corning DC #550 Silicone Fluid	8.3
Toluene	324.0
Total	519.0
Total Non-volatile content	22.8%

DC #2103 is a solution of a normally brittle solid polymeric methyl phenyl silicone resin dissolved in toluene to a 60% concentration. DC #802 is a 50% solution of a normally tacky solid polymeric methyl phenyl silicone resin in toluene. DC #550 consists of a non-volatile polymeric methyl phenyl silicone fluid. Break-down of non-volatiles thus becomes:

	Parts by weight
Dow Corning #2103 solids	100
Dow Corning #802 solids	10
Dow Corning #550 non-volatile	8.3

This solution was applied continuously to the wire by dipping, followed by drying in a tower operating with temperatures of about 180° F. at the bottom and about 230° F. at the top. The resulting film was about 0.0005'' in thickness. It was flexible, non-tacky and non-sticky.

Treatment in the manner described in this example caused the wire to pass the Underwriters' Laboratories horizontal flame test. The untreated wire burned for its full length when subjected to this flame test whereas the treated wire of this example burned for only three inches, the flame being extinguished after three inches of the insulation had been burned, and the burned area extending only 1½'' in each direction from the midpoint of the area to which the igniting flame had been applied.

Use of Dow Corning Silicone Resin #2103 alone under the same conditions as were used in the example results in a brittle film which flakes upon bending the wire. Use of Dow Corning Silicone Resin #802 alone under the same conditions deposits a film which remains tacky and sticky. When #802 resin is added as a softener to #2103 (no #550 fluid being used), no combination was found which gave both flexibility and non-tackiness. However, use of some #802 resin in the mixture is desirable because it acts as a softener for the #2103 resin and thus makes it possible to reduce substantially the amount of relatively expensive #550 fluid required. However the amount of the #802 resin used should be so limited that the resulting film is not tacky or sticky.

If it is attempted to use #550 fluid alone, a liquid film is obtained. Use of 5% of #550 fluid with #2103 resin imparts some flexibility while use of over 15% of #550 fluid results in undesirable tackiness. By using from 8 to 12% of #802 resin with #2103 resin, it is possible to get a perfectly satisfactory film with from 8 to 10% of the #550 fluid.

From the foregoing description, it will be seen that the present invention provides a simple, economical and highly effective method of imparting flame-resistance to normally inflammable insulated wire so as to cause it to pass the Underwriters' Laboratories horizontal flame test. The coating of the present invention does not impart any undesirable properties to the wire. The application of the coating does not injure the nylon jacket which is insoluble in the solvent, typically toluene, generally used for the silicone resin or resins and the silicone fluid. The coating of the present invention is moisture-resistant, has good electrical and physical properties, and is mold-resistant. It does not change the appearance of the insulated wire and it does not increase significantly the frictional resistance against movement when in contact with other surfaces. In other words, it does not increase significantly the "drag" of the wire. The coating of the invention is economical in material cost and its application does not require expensive equipment or control.

Many other advantages of our invention will be apparent to those skilled in the art.

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

1. An insulated electrical conductor comprising a metallic electrical conductor, an insulating layer of inflammable rubber surrounding said conductor, an insulating layer of polychloroprene surrounding said layer, the conductor with said two insulating layers being flame-resistant in the Underwriters' Laboratories flame test in which the horizontally supported conductor is ignited with a flame for 30 seconds and the length burned before the flame goes out is determined, a burned length of not over 2'' in either direction from the mid-point of flame application being considered as passing the test, a continuous jacket of inflammable nylon surrounding said last-named layer, said nylon consisting of a synthetic linear polyamide, said nylon jacket being meltable, and rendering the conductor non-flame-resistant in said flame test, and an outer, thin, continuous, flexible, dry, non-tacky, non-sticky coating of a homogeneous mixture of an unhalogenated solid polymeric alkyl aryl silicone resin and an unhalogenated non-volatile polymeric alkyl aryl silicone fluid, said coating rendering the nylon-jacketed conductor flame-resistant in said flame test, said coating being tenaciously adhered to the outer surface of said nylon jacket, being moisture-resistant, having good electrical and physical properties, and not significantly increasing the frictional resistance of the conductor to external surfaces, said coating imparting the property that when the insulated conductor is exposed to flame said coating decomposes and deposits a thin film of silica over the surface of said nylon jacket, said silica film upon removal of the igniting flame acting to quench the burning nylon.

2. The conductor of claim 1 wherein said coating is formed of a mixture consisting essentially of an unhalogenated solid polymeric alkyl aryl silicone resin which is of relatively high molecular weight and if used alone would be unduly brittle and flake off upon bending the conductor, from 8 to 12 parts per 100 parts of said resin of an unhalogenated solid polymeric alkyl aryl silicone resin which is of lower molecular weight and if used alone would be tacky and sticky, and from 8 to 10 parts per 100 parts of said first-named resin of an unhalogenated non-volatile polymeric alkyl aryl silicone fluid, said fluid and said last-named resin serving as softeners for said first-named resin.

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