

May 30, 1944.

C. S. FULLER

2,349,952

ELECTRICAL CONDUCTOR

Filed April 22, 1939

FIG. 1

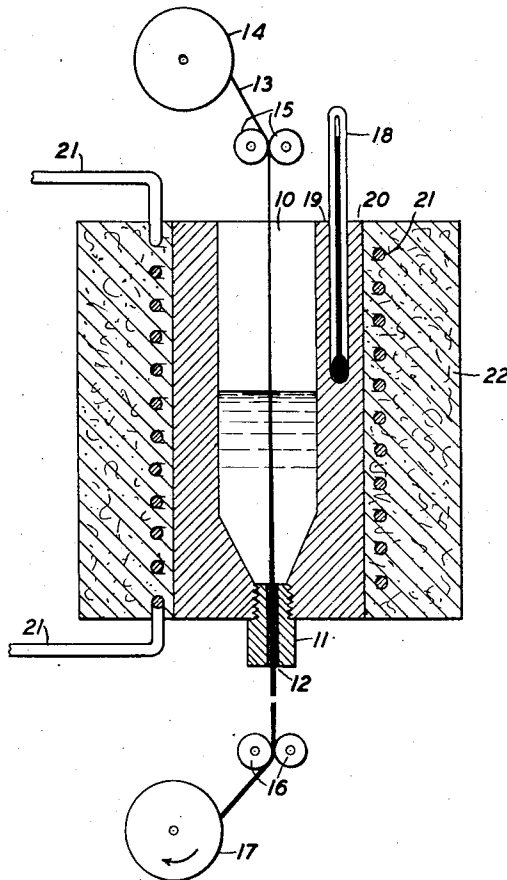


FIG. 2



FIG. 3

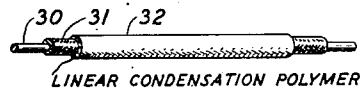
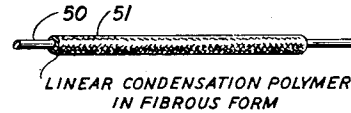


FIG. 4



FIG. 5



INVENTOR
C. S. FULLER
BY
T. H. Jackson
ATTORNEY

UNITED STATES PATENT OFFICE

2,349,952

ELECTRICAL CONDUCTOR

Calvin S. Fuller, Chatham, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 22, 1939, Serial No. 269,502

8 Claims. (Cl. 174-121)

The present invention relates to electrical devices and more specifically to electrical conductors.

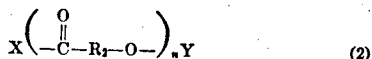
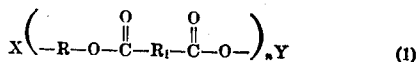
This application is a continuation-in-part of the application of C. S. Fuller, Serial No. 210,678, filed May 28, 1938.

An object of the invention is an electrical conductor having a covering of insulating material which has superior electrical properties, high flexibility, elasticity and resistance to abrasion and which is capable of being applied to the conductor in the molten state.

A further object is an electrical conductor insulated with a fibrous covering having over it a transparent moisture-resistant layer which has high flexibility, elasticity and resistance to abrasion and which is capable of being applied to the fibrous covering in a molten state.

These objects are attained by covering the conductors with a layer containing a synthetic linear condensation polymer of high molecular weight. To be suitable for the purposes of the present invention the polymers employed should be free from any substantial tendency to hydrolyze in the presence of moisture, should have a softening point above ordinary atmospheric temperatures, should be fusible without decomposition, should be capable of being formed into a fluid melt and should have a sufficiently high degree of polymerization to impart to the polymer the property of permanent crystalline orientation under stress.

Suitable polymers are of the type described in U. S. Patents 2,071,250, 2,071,251, 2,071,252, 2,071,253, 2,130,523 and 2,130,948 to W. H. Carothers. From a practical standpoint the most important for the present use are the polyesters, polyamides, polyester-amides and various copolymers of the aforementioned types. The polyesters may have either of the two following general structural formulae:



Where R and R₁ are divalent organic radicals having chain lengths the sum of which is greater than 6 atoms,

R₂ is a divalent organic radical having a chain length greater than 4 atoms,

X and Y are suitable monovalent terminal groups, and

n is an integer having an average value sufficient to insure the proper degree of polymerization.

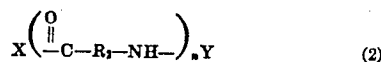
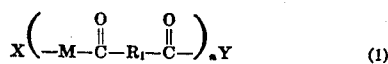
R, R₁ and R₂ may be chosen from the suitable aliphatic, aromatic, alicyclic, araliphatic or heterocyclic radicals.

The first type of polyester is prepared by the reaction of a glycol with a dicarboxylic acid, the reaction being carried on until the desired degree of polymerization is obtained. This may be accomplished by any suitable method, such as that described in the above-mentioned patents to Carothers or by the methods described in the copending application of C. S. Fuller, Serial No. 210,677, filed May 28, 1938.

The polyesters of the second type may be prepared by the reaction of molecules of an hydroxy acid with one another.

Copolyesters, formed by the reaction of two or more different glycols with a dicarboxylic acid, two or more dicarboxylic acids with a glycol, or two or more different members of both types of reactants, or by the reaction of two or more hydroxy acids, are also suitable for the present invention. Physical mixtures of polyesters, which may be formed by melting polyesters together without reaction, may also be employed.

The polyamides have the two following general types of structural formulae:



Where M is any suitable aliphatic, araliphatic, alicyclic or heterocyclic organic radical containing two amino nitrogen atoms, the radical being linked by means of these nitrogen atoms to the adjacent carbon atoms in the polyamide chain,

R₁ is a divalent organic radical preferably having a chain length such that the sum of the chain lengths of R₁ and M is greater than 4.

R₂ is a divalent organic radical preferably having a chain length greater than 4 atoms,

X and Y are suitable monovalent terminal groups, and n is an integer having an average value sufficient to insure the proper degree of polymerization.

The first type of polyamide may be prepared by reacting any suitable diamine with a dicarboxylic acid or a reactive derivative of a dicarboxylic acid. The second type may be prepared by the autoreaction of an amino acid.

Copolyamides, formed by using, in each case, more than one member of each type of reactant, are also suitable. Physical mixtures of various polyamides, formed by melting them together without reaction, may also be employed.

Polyester-amides, formed by reacting a diamine and a glycol with a dicarboxylic acid (as, for instance, by reacting a glycol with a salt of a diamine and a dicarboxylic acid), or by reacting an hydroxy acid with an amino acid, or by reacting an hy-

droxy amine with a dicarboxylic acid, are also desirable materials. In some instances it is desirable to employ physical mixtures of the various copolymers or physical mixtures of simple polymers with copolymers.

The properties of these high molecular weight synthetic linear condensation polymers, when prepared from properly purified reactants, are such as to render them ideally suited for the purposes of the present invention. They are not strictly amorphous materials, as are resins, nor are they wholly crystalline solids, but rather they possess to a certain extent the properties of both types of substances. It is believed that the long chain-like molecules produced by the linear condensation are of such nature that portions of adjacent molecules tend to crystallize together upon solidification, leaving the remaining portions of the same molecules in an amorphous state.

The properties resulting from this unique intermolecular structure are very desirable for the purposes of the present invention. The crystallinity imparts a sharp softening point to the substances, while their partially amorphous nature is responsible for their high degree of flexibility. The polymers referred to above are fusible without decomposition and can be chosen to be sufficiently fluid in their molten state to permit the impregnation or coating of fibrous materials in that state without the use of a solvent and can be chosen to have a melting point sufficiently low to make it possible to impregnate or coat heat-destructible fibres with the molten material. This property of high fluidity in a molten state is difficult to find in substances which are otherwise suitable as insulating coverings for conductors.

When the average molecular weight of these polymers is sufficiently high, they possess the property of cold drawing. Thus when thin fibres are formed from these materials and subjected to tensile stress, the fibres are permanently elongated and a change in the physical properties of the material takes place. The fibres usually become more transparent and increase in tensile strength and elasticity. X-ray examinations show that the crystals of the substances become permanently oriented in the direction of the fibre axis after such tensile stress is applied. Condensation polymers of this high molecular weight are referred to in U. S. Patent 2,071,250 as synthetic linear condensation superpolymers.

This property is of great value when the polymers are used as a protective or insulating coating for wire. A somewhat similar crystal orientation is believed to take place when the protective coating is subjected to abrasion or any other type of stress which would ordinarily tend to destroy the covering. Thus, the already tough and elastic covering has its toughness and elasticity increased by the very forces which would ordinarily tend to destroy it. Any rubbing or shearing stress tends to orient the crystals in such a direction that the polymers offer the greatest possible resistance to destruction through a continuance of the application of the force.

If the average molecular weight of the polymers is such that they are capable of being cold drawn the polymeric coverings are unusually tough, flexible and elastic, even when only slightly oriented as by the incidental orientation involved in the ordinary coating procedure. In the form of thin films they are sufficiently transparent to permit color identification through them.

In some cases the coatings themselves may be colored by means of suitable pigments or dyes.

As indicated above, the polymers find their most effective use in connection with conductors having a covering of fibrous material. In wire for indoor use, such as is encountered in and around telephone switchboards and associated distributing equipment of a telephone exchange, it is common to employ fibrous materials such as textiles, paper or paper pulp as insulation. At low humidities these fibrous materials afford a very superior insulation. However, at high humidities, the moisture absorption of these materials very materially lowers their insulation resistance and their dielectric strength and increases their capacity.

Therefore, it has been found necessary to employ a moisture-proofing impregnant such as wax to exclude moisture or to employ an insulating coating material to improve the electrical properties at high humidities. Since the dielectric constants of the fibrous coverings when dry are, in general, lower than those of any impregnant which might be employed, it is ordinarily more desirable to use a coating than to impregnate the fibrous material.

To be satisfactory as such a coating a material should be highly flexible, elastic, transparent, moisture-resistant and resistant to abrasion. It is also necessary that it possess good electrical properties, particularly at high humidities.

In addition, it is very desirable that the coating material be capable of being applied to the conductor in a molten state. In the past, materials which have been found satisfactory from the standpoint of physical and electrical properties have not possessed this advantageous characteristic of being capable of being reduced to a fluid melt without the use of a volatile solvent, whereas waxes and similar materials capable of being applied from a melt were not resistant to abrasion and introduced a fire hazard. For example, it is well known that substances like cellulose acetate, polystyrene or similar high molecular weight materials which are often employed to coat electrical conductors are incapable of forming fluid melts on heating. This is believed due to the fact that these substances possess a net-like molecular structure which is maintained even above the softening points of these materials. The linear condensation polymers on the other hand, when properly prepared from pure ingredients suitably chosen, possess an essentially linear rather than net-like molecular structure which permits fluidity at elevated temperatures. This high fluidity of their belts admirably suits the linear condensation polymers for the purposes of coating electrical conductors or impregnating fibrous coverings. In this property of high fluidity the linear condensation polymers are unique among the high molecular weight insulating materials. The use of a volatile solvent to accomplish coating or impregnation involves additional expense in manufacture and may also introduce a fire hazard. Further the drying out of the solvent must be carried out slowly in order to avoid blistering; this greatly limits the speed of the coating process and also limits the thickness of coating which may be applied in a single operation.

Synthetic linear condensation polymers of the type above mentioned are extremely valuable as coatings for this type of conductor due to their transparency, flexibility, elasticity, abrasion re-

istance, moisture resistance, and their electrical properties. In addition their property of crystalline orientation under stress uniquely fits them for use on conductors, since any bending, twisting or abrasion which would ordinarily tend to destroy the coating serves in the case of these materials to toughen the coating so as to make it more flexible, more elastic, more transparent and more abrasion resistant. In addition to these desirable properties, the polymers may, as indicated above, be applied to conductors in a molten state, thus eliminating the necessity for the use of a volatile solvent.

The valuable electrical properties of these polymers when used as an insulating covering over a fibrous insulating layer are shown in the following tables. The measurements in these tables were made at various humidities after the insulating materials had come to substantial equilibrium as to moisture content. Therefore, the effect of the moisture exclusion of the coatings, which would ordinarily greatly improve the electrical properties of the insulations at high humidities by maintaining the fibrous material in a drier state, is not shown. The values in the tables therefore represent the additive values of the electrical properties for the fibrous covering and the polymeric coating, each being in substantial equilibrium, as to moisture content, with the surrounding atmosphere. In each case #22 A. W. G. wires covered with the indicated fibrous covering and coated with the indicated polymer were employed.

TABLE I.—A. C. grounded conductance, microhms per foot at 38° C. Polymer employed is reaction product of ethylene glycol and sebacic acid

Sample	Relative humidity			
	65	75	85	90
Pulp (uncoated).....	0.50	4.4	30.2	105.0
Pulp coated with polymer.....	0.27	0.5	0.5	0.5
Double-cotton (uncoated).....	0.73	2.2	15.9	42.5
Double-cotton coated with polymer.....	0.53	1.0	1.1	0.9

TABLE II.—D. C. insulation resistance, megohms per 10 feet. 38° C. Polymer employed same as in Table I

Sample	Relative humidity			
	65	75	85	90
Pulp (uncoated).....	2.5	0.4	0.04	0.04
Pulp coated with polymer.....	778.0	486.0	292.0	186.0
Double-cotton (uncoated).....	6.1	1.2	0.1	0.06
Double-cotton coated with polymer.....	390.0	143.0	46.0	11.7

TABLE III.—A. C. grounded capacitance, micro-microfarads per 10 feet. 38° C. Polymer employed same as in Table I

Sample	Relative humidity			
	65	75	85	90
Pulp (uncoated).....	560	783	1,516	2,785
Pulp coated with polymer.....	308	372	514	552
Double-cotton (uncoated).....	424	567	1,208	2,197
Double-cotton coated with polymer.....	397	530	803	906

TABLE IV.—A. C. breakdown. 38° C. 90% relative humidity. 60 cycles. Polymer employed same as in Table I

Sample	Voltage
Pulp (uncoated).....	500-530
Pulp coated with polymer.....	1,320-2,300
Double-cotton (uncoated).....	650-750
Double-cotton coated with polymer.....	1,410-1,470

TABLE V.—Insulation resistance 38° C. 85% relative humidity. Polymer employed is the reaction product of 0.90 mole of ethylene glycol, 0.10 mole of decamethylene diamine, and 1.00 mole of sebacic acid

Megohms per 19½" length	
Rag pulp (uncoated).....	0.67
Rag pulp coated with polymer.....	115.0
Linters pulp (uncoated).....	0.38
Linters pulp coated with polymer.....	57.0

TABLE VI.—Insulation resistance 38° C. 85% relative humidity. Polymer employed is reaction product of decamethylene diamine and sebacic acid

Megohms per 19½" length	
Rag pulp (uncoated).....	0.67
Rag pulp coated with polymer.....	41.00
Linters pulp (uncoated).....	0.38
Linters pulp coated with polymer.....	35.0

Much the same advantages are obtained as to physical properties and ease of application when these polymers are coated on conductors previously insulated with layers of enamel or rubber or similar materials. A very effective protective coating for the enamel or rubber is produced in this manner.

Similarly the properties of these polymers suit them very well for coating bare wires. The advantages of such wires over enameled or lacquered wires are numerous. It has been necessary to apply enamels by means of a volatile solvent with the consequent disadvantages discussed above, whereas the polymers may be applied from a melt. The abrasion resistance of the polymeric coverings is tremendously greater than that of enameled wires due to the properties discussed above.

The enormously greater abrasion resistance is illustrated by the following tests. Two #22 A. W. G. wires, one of which was enameled in the conventional way with an oil-varnish type of enamel and the other coated from a hot melt of decamethylene sebacamide to the same coat thickness were subjected to rotary abrasion. The two wires were hung over a steel mandrel 2 inches in diameter under a tension of 500 grams. The mandrel was rotated at the rate of 1 revolution per second. At the end of 4 minutes the enameled wire was worn through to the conductor whereas examination of the wire coated with the decamethylene sebacamide showed no apparent flattening of the coating due to wear.

In addition wires of this type overcome one of the greatest objections to enameled wire, the inability to solder through the enamel. It has always been necessary to remove the enamel before soldering. Where a large number of soldering operations are required, considerable expense and loss of time are involved in this procedure. With polymer-covered wire this difficulty is avoided since the polymers are readily melted away during the soldering operation.

The polymeric coatings are also chemically

more stable than enameled wires over long periods of time, thus insuring longer effective life of the insulation even where the wires are not exposed to abrasion or other destructive physical forces.

In electrical properties the polymeric coatings are fully comparable to good enamel coatings.

A further advantage possessed by conductors coated with these polymers lies in the fact that such a coating possesses a smooth slippery surface. In tinsel cords where a number of highly flexible conductors are grouped together in a single bundle, it is essential that the adjacent surfaces of the conductors be well lubricated, since the bundle is subjected to frequent and severe bending. Unless the conductors are free to slide past one another, the flexibility of the bundle is impaired and the insulation is subjected to excessive wear. It has been found that coatings of the above-described polymers, particularly those formed from ingredients possessing long aliphatic chains in their molecules, possess a lubricating action superior to any wax or other lubricant hitherto available. The necessity for adding an additional lubricant is therefore avoided when the individual wires possess an insulating coating of these polymers and any danger of disappearance of the lubricant is avoided. This lubricating action is particularly surprising in view of the remarkable toughness also possessed by the polymeric coatings.

In conductors for outdoor use, bare or insulated wires are often covered with fibrous materials impregnated with saturants and finishing compounds designed to protect the fibrous material against disintegration and to protect the insulating layer beneath. In the case of the bare wires, the impregnated fibrous material acts as a durable insulating layer. In the case of conductors having an insulating layer such as enamel or rubber beneath the impregnated fibrous material, the impregnated layer acts as a protective covering for the insulation.

In both these cases the polymers described above act as very desirable impregnants because of their physical and electrical properties and their ability to be applied in a molten state. These impregnated wires have been more fully described and claimed in the copending application of C. S. Fuller and A. R. Kemp, Serial No. 240,630, filed November 16, 1938.

The manner in which the polymers may be applied to wire will be better understood by reference to the accompanying drawing, in which:

Fig. 1 represents a sectional view of an apparatus for applying the polymeric covering to conductors;

Fig. 2 is an isometric view of a bare wire coated with a synthetic linear condensation polymer;

Fig. 3 is an isometric view of a conductor covered with a fibrous material which is, in turn, covered with a coating of a polymer;

Fig. 4 is an isometric view of a conductor insulated with enamel or rubber, which is, in turn, covered with a coating of a polymer; and

Fig. 5 is an isometric view of a conductor covered with a polymer in fibrous form.

In Fig. 1 a reservoir 10 in a block of metal 20 contains the molten polymer. A replaceable bushing 11 having an orifice 12, through which the conductor 13 passes, is mounted at the bottom of the reservoir. The orifice 12 is of a diameter slightly greater than the conductor. The conductor 13 is supplied from a drum 14 and passes between rollers 15, which serve to guide

the conductor through the reservoir 10, and then through the orifice 12. The wire then passes over a second set of guide rollers 16 to a collecting drum 17. A thermometer 18 is placed in a thermometer well 19 to indicate the temperature of the polymer in the reservoir. A resistance winding 21 embedded in an insulating material 22 completely surrounds the block 20 to supply the necessary heat for maintaining the polymer at the desired temperature.

To coat the wire it is drawn through the reservoir and then through the orifice. If the wire is covered with a fibrous material, it is drawn through the reservoir at such a rate that no substantial impregnation takes place. Since the wire is relatively cool when it enters the bath of molten polymer, it tends to chill the molten substance and prevent it from completely penetrating the fibrous covering. The orifice serves to remove excess polymers from the surface of the conductor and to regulate the thickness of the polymeric coating. After the wire emerges from the orifice, the coating should be permitted to solidify before the wire passes through the rolls 16. The sharp softening point of the polymers causes them to harden rapidly, but if desired, water-cooling may be used to speed up solidification.

Bare wires and wires insulated with fibrous material, rubber, enamel or similar substances may be coated in the same manner.

If impregnation of a fibrous covering rather than coating is desired, a heating chamber may be placed beyond the orifice in which the polymeric coating is caused to penetrate the fibrous covering thoroughly. If desired, pressure may be applied to the bath of molten polymer to force the polymer above the wire more easily.

In some instances, the use of a small amount of a non-volatile low molecular weight solvent which solidifies at atmospheric temperatures may be desirable to decrease the viscosity of the melt. Examples of such substances are diphenyl, which melts at about 71° C. and beta naphthol which melts at about 122° C. At elevated temperatures the diphenyl acts as a solvent and serves to thin the molten polymer so that it may more easily coat or penetrate the fibrous covering on the wire. When the polymer is cooled, the diphenyl solidifies out and forms a solid mixture with the polymer.

When the wire is covered with an organic fibrous material and a molten bath is used for impregnation as described above, a polymer should be chosen which has a melting point sufficiently low so that the wire may be coated without weakening the fibres from excessive exposure to heat. Similarly, if the wire is insulated with rubber or other insulating material, care must be taken to prevent any damage to the insulation from too high a temperature. When the wire is covered with cellulose fibres such as cotton braid, paper braid, or paper pulp, the coating temperature is desirably between 100° and 200° C. To make possible the use of these temperatures the polymers should preferably have a melting point below about 170° C. By melting point is meant the temperature at which the polymer is converted to a definitely liquid state. However, the polymers should preferably have a softening temperature above about 60° C., so that they will not soften under ordinary atmospheric conditions.

Where the wire is bare or covered with a heat

resistant material such as a coating of mineral fibres, the coating temperature may obviously be higher.

At the coating temperature the polymers should be sufficiently fluid so that coating may readily take place. Preferably the polymers should be capable of being reduced to an absolute viscosity less than about 5,000 poises in the molten state.

A polymer which has been found to give very good results for coating or impregnating textiles is polyethylene sebacate, which may be produced by the reaction of substantially equal molecular proportions of sebacic acid and ethylene glycol at 200° C. in a stream of an inert gas. It softens at approximately 72° C. and at 130° C. forms a viscous melt which may be readily applied to wire, as described above.

Another very satisfactory polymer is polyethylene propylene sebacate, which may be produced under the conditions described above by the reaction of ethylene glycol, an amount of propylene glycol equal to about 5 per cent of the total glycol, and an amount of sebacic acid equivalent to the total glycol. This substance melts in about the same range as polyethylene sebacate. Similar results are obtained when other glycols, such as diethylene glycol, which form polymers with sebacic acid having melting points below that of polyethylene sebacate are substituted for propylene glycol.

As examples of other suitable polymers for the purposes of the present invention may be mentioned those prepared by the reaction of the following materials:

<i>Polymer melting point (approximately), °C.</i>	
10-hydroxy decanoic acid.....	76
Ethylene glycol and sebacic acid.....	72
Ethylene glycol and succinic acid.....	105
Decamethylene glycol and adipic acid.....	74
Decamethylene glycol and sebacic acid.....	76
Decamethylene glycol and dodecamethylene dicarboxylic acid.....	83
Diethylene glycol and sebacic acid.....	39
Hexamethylene glycol and succinic acid.....	57
Ethylene glycol and azelaic acid.....	45
11-amino undecylic acid.....	170
11-methyl amino undecylic acid.....	170
6-amino caproic acid.....	205
Hexamethylene diamine and adipic acid.....	250
Piperazine and sebacic acid.....	155
Pentamethylene diamine and octadecandioic acid.....	167
Ethanol amine and sebacic acid.....	85
Ethylene glycol, propylene glycol and sebacic acid (containing .1 to 10% propylene glycol based on total glycol).....	72
Ethylene glycol, diethylene glycol and sebacic acid (containing .1 to 10% diethylene glycol based on total glycol).....	72
Decamethylene diamine and sebacic acid.....	197
Propylene diamine, decamethylene diamine and sebacic acid.....	144
Decamethylene diamine, decamethylene glycol and sebacic acid.....	152
Decamethylene diamine (½ mole), ethylene glycol (½ mole), sebacic acid (1 mole).....	140
Propylene diamine (½ mole), ethylene glycol (½ mole), dodecamethylene dicarboxylic acid (1 mole).....	160

Examples of other suitable polymers are polymeric forms of trimethylene azelate, diethylene glutarate, ethylene succinate sebacate, ethylene

triethylene heptadecamethylenedicarboxylate or the products resulting from the self-esterification of 11-hydroxy stearic acid or a hydroxy undecylic acid.

In general, the copolymers and particularly the copolymers containing both ester and amide linkages are preferable to the simple polymers, since their melting points may be readily adjusted by varying the amounts of the ingredients and since the copolymers do not possess the slight tendency to decrease in flexibility and strength after a number of years, which is sometimes possessed by the simple polymers. It has also been found that the copolymers when added to the simple polymers cause the same desirable retention of flexibility. Particularly desirable in this respect are physical mixtures prepared by melting together polyesters with small proportions of copolymers containing ester and amide linkages.

The polyamides are, in general, higher melting than the polyesters and are therefore sometimes more desirable since they solidify more rapidly upon emerging from the coating bath. The copolyamides and copolyesters, in general, have lower melting points than their separately condensed constituents. However, copolymers containing both ester and amide linkages have melting points intermediate between those possessed by the individual polyamide and polyester.

To possess the property of cold drawing which was described above and which is necessary to impart the quality of self-toughening to the polymeric coatings, the polymers must possess a very high degree of polymerization. The degree of polymerization is indicated generally by the relative viscosity of the substance in dilute solution.

Relative viscosity is the ratio between the viscosity of the substance in a suitable solvent and the viscosity of the solvent itself. This value can be obtained conveniently by comparing with the viscosity of chloroform the viscosity of a solution of 0.4 gram of the polymer in sufficient chloroform to form 100 cubic centimeters of solution.

The property of cold drawing begins to appear in synthetic linear condensation polymers when their relative viscosity, measured as above, exceeds about 1.2.

The region in which the cold drawing appears may also be expressed in terms of the average molecular weight of the polymer. The average molecular weight may be estimated by means of viscosity measurements according to the following relationship given by Staudinger in his book entitled "Die hochmolekularen organischen Verbindungen" (1932, Berlin):

$$\frac{\eta_r - 1}{C} = K_m M$$

where

η_r = relative viscosity of the solution.

C = concentration of the solution in mols of the repeating group of the polymer per litre of solution,

K_m = a constant characteristic of the series of polymers, and

M = average molecular weight of the polymer.

Cold working begins to appear at an average molecular weight of about 7,000 but appears more definitely at about 8,000 to 10,000.

In Fig. 2 is shown a bare wire 25 covered with a coating 26 of a polymer of the above-described type.

In Fig. 3 is shown a wire 30 covered with a fibrous material 31 which is, in turn, covered with a coating 32 of a polymer of the above-described type. The fibrous material may consist of woven served, knitted or braided textile or mineral fibres, paper braid, paper pulp or a combination covering. There is no substantial impregnation of the polymer into the covering.

In Fig. 4 is shown a wire 40 having an insulating covering of enamel, rubber, or similar material and a protective exterior covering 42 of a polymer of the above-described type.

In Fig. 5 is shown a wire 50 covered with woven or braided fibres formed of a polymer of the above-described type. These fibres are preferably oriented as described above, by subjecting them to tensile stress, before they are placed on the wire.

Obviously, the coating may be carried on at ordinary temperatures by means of a solution of polymers in a suitable volatile solvent. This coating is carried on using the customary process of coating wires with solutions of coating materials in which a coating of a solution of the polymer in a volatile solvent is applied to the wire and then the volatile solvent is dried out of the coating. However, it is an advantage of the polymers above described that they may be applied in a molten state and, in general, it will not be advantageous to employ a volatile solvent.

It is to be understood that the invention is not limited to the use of individual polymers in the coatings on conductors. Thus mechanical mixtures of the various suitable polymers may be employed. Other desired materials which have no harmful effect, such as mineral or other fillers, dyes, pigments, solvents which are solid at ordinary temperatures, resins and cellulose derivatives may be added to the polymers to modify their properties or decrease their cost.

Whenever the term "polyester" is used in the appended claims it is intended to include those

more complex polyesters referred to above as "copolyesters," as well as the polyesters of simpler constitution.

Although the invention has been described in terms of its specific embodiments, it is to be understood that it is of general application and is limited only by the scope of the appended claims.

What is claimed is:

- 10 1. A mechanically durable, insulated telephone switchboard wire having a high insulation resistance at high humidities, consisting of a conducting metal core insulated with a layer of organic fibrous insulating material and an outside coating of a cold drawing polyester.
- 15 2. An electrical conductor comprising a conducting metal core, a covering of organic fibrous insulating material over said metal core and an outside coating of a cold drawing condensation polymer.
- 20 3. A conductor as described in claim 2 wherein the outside coating comprises a cold drawing polyester prepared from ethylene glycol and succinic acid.
- 25 4. An insulated electrical conductor, which is capable of being soldered without stripping of its insulation, comprising a conducting metal core and a coating immediately over said metal core comprising a cold drawing polyester.
- 30 5. An electrical conductor comprising a conducting metal core surrounded by a covering comprising a cold drawing condensation polymer.
- 35 6. A conductor as described in claim 5 wherein the covering comprises a cold drawing polyester.
7. An electrical conductor provided with a continuous coating of a synthetic linear condensation superpolymer immediately over said conductor.
- 40 8. An electrical conductor provided with an adherent continuous coating of a cold drawing condensation polymer.

CALVIN S. FULLER.