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INSULATED ELECTRICAL CONDUCTOR

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9 Claims. (Cl. 117—128.4)

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This invention relates to the art of insulating electrical conductors with thermoplastic coating compositions and to the article obtained thereby.

It is known to coat electrical conductors with compositions of various plastic materials such as nylon, polyethylene, cellulose derivatives, etc., in order to provide a coating which is tough and durable. The use of such compositions for this purpose has been attended with varying degrees of success but in general has been satisfactory under many and varied conditions.

Under some conditions, however, and particularly where the coated wire is subjected to considerable crushing and/or abrasion, or to immersion in salt water or similar corrosive solutions, these compositions do not have the requisite toughness and resistance to corrosive solutions to withstand prolonged usage. Under other conditions, compositions of this nature containing mineral oil are subject to the disadvantage that the mineral oil has a tendency to exude, leaving an oily residue on the surface of the coating.

It is therefore an object of this invention to provide an improved coating for an electrical conductor which does not exude oil from the surface thereof.

It is a further object of the invention to provide an electrical conductor insulated with a composition which has improved electrical properties and greater resistance to the deleterious effects of corrosive solutions such as salt water.

It is a still further object of the invention to provide an electrical conductor insulated with a composition which has increased toughness and increased resistance to cut-through, crushing and abrasion and which at the same time is highly flexible and will maintain its flexibility at temperatures as low as —50° C.

These and other objects of the invention will become apparent as the description proceeds.

It has been discovered in accordance with this invention that the above objects may be attained by extrusion coating an electrical conductor with

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a composition composed of the following ingredients in the stated proportions,

	Parts
Ethyl cellulose (43.5 to 50%) ethoxyl, 50 to 1000 centipoises viscosity)	100
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%)	0 to 42
Paraffin base oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32

in which the ratio of ethyl cellulose plus polyvinyl butyral to paraffin base oil plus partially hydrogenated mixture of isomeric terphenyls is within the range from about 5 to 1 to about 3 to 1. Other desirable ingredients such as stabilizers, dyes, pigments, etc., may optionally be included.

The compositions of the invention may be compounded on a hot two-roll mill or in a Banbury mill, granulated and then extruded around the wire. Alternately the ingredients may be premixed, colloided in the extruder and then extruded around the wire. Thickness of the coating will vary with the conditions of use and materials used but will generally be from about 0.005 to about 0.100 inch.

The following specific examples of compositions which may be utilized as coatings for electrical conductors are illustrative:

EXAMPLES 1–10

A number of plastic compositions were compounded in a Banbury mixer for a time from about 5 minutes to about 10 minutes and at a temperature of about 300° F. and then sheeted on a two-roll mill. The sheets were then granulated and fed to a No. 1 Royle extruder for extrusion around a No. 22 B & S tinned copper wire. The temperature conditions for extrusion were as follows:

	Degrees F.
Die temperature	380–420
Head temperature	380–420
Barrel extension temperature	350–380
Barrel temperature	240–290

The plastic compositions and the characteristics of the coated wire are set forth in Table I below.

Table I

ETHYL CELLULOSE FORMULAE AND RESULTS OF TESTS ON INSULATIONS APPLIED TO NO. 22 TINNED WIRE

[All parts are by weight]

	Example—									
	1	2	3	4	5	6	7	8	9	10
Ethyl Cellulose (Ethoxyl content 46.8 to 48.5%, viscosity 100 centipoises)	62.0	62.0	67.0	59.0	------	------	------	------	62.0	62.0
Ethyl Cellulose (Ethoxyl content 46.8 to 48.5%, viscosity 200 centipoises)	------	------	------	------	62.0	66.0	63.0	77.0	------	------
Polyvinyl Butyral (Hydroxyl content 11.25% to 13.25%)	15.0	15.0	15.0	18.0	15.0	16.0	19.0	------	15.0	15.0
Menthylphenol	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fractol A	11.5	15.0	9.0	11.5	11.5	9.0	9.0	11.5	11.5	21.4
Partially hydrogenated mixture of isomeric terphenyls	11.5	8.0	9.0	11.5	11.5	9.0	9.0	11.5	------	------
Hydroabietyl Sebacate	------	------	------	------	------	------	------	------	11.5	------
Vistanex Mol. Wt. 80,000	------	------	------	------	------	------	------	------	------	0.8
Primol D	------	------	------	------	------	------	------	------	------	0.8
Coating Thickness (mils)	9.5	10.0	9.5	8.5	8.0	9.0	9.0	10.0	10.0	8.0
Low Temp. Flexibility (per cent good):										
−30° C	100	58	78	58	88	70	90	95	68	68
−20° C	100	98	100	88	100	100	93	100	93	73
−10° C	100	100	100	100	100	100	100	100	100	100
Cut Resistance (grams)	500	500	500	500	500	600	800	700	200	50
Cut Resistance (grams/mil)	53	50	53	59	63	67	89	70	20	6
Abrasion Resistance (rev.)	9.5	10.0	9.5	11.5	8.0	9.0	10.0	10.0	2.5	2.0
Abrasion Resistance (rev./mil)	1.0	1.0	1.0	1.35	1.00	1.00	1.11	1.00	0.25	0.25
Half Hitch Cut (lb.)	16.2	15.0	18.2	17.1	17.0	17.5	19.3	18.5	18.0	7.2
Half Hitch Cut (lb./mil)	1.71	1.50	1.92	2.01	2.13	1.95	2.17	1.85	1.80	0.90
Overall Flexibility Rating	1.00	0.85	0.93	0.82	0.96	0.90	0.94	0.98	0.87	0.80
Overall Toughness Rating	1.00	0.94	1.04	1.21	1.14	1.14	1.39	1.13	0.56	0.29

Example 1 to 8 illustrate the low temperature flexibility and toughness of the wire coatings of the present invention. Compositions such as those of Example 1 give optimum combined flexibility and toughness. An increase of Fractol A and a corresponding decrease of partially hydrogenated mixture of isomeric terphenyls gives somewhat lower flexibility and toughness as shown in Example 2. Increasing the proportion of ethyl cellulose with a corresponding decrease in plasticizer gives compositions of increased toughness but decreased flexibility as shown in Example 3. Increasing the ratio of polyvinyl butyral to ethyl cellulose gives increased toughness and decreased flexibility as shown in Example 4.

The use of the higher viscosity ethyl cellulose of Examples 5 to 8 generally gives greater toughness but poorer flexibilities than the use of the lower viscosity ethyl cellulose of Example 1. Examples 9 and 10 illustrate the adverse effects on toughness of omitting partially hydrogenated mixture of isomeric terphenyls. In Example 9 the partially hydrogenated mixture of isomeric terphenyls was replaced by 11.5 parts of hydroabietyl sebacate. Cut resistance dropped from 500 (Example 1) to 200 and abrasion resistance from 9.5 (Example 1) to 2.5. In Example 10 the 11.5 parts Fractol A and 11.5 parts partially hydrogenated mixture of isomeric terphenyls of Example 1 were replaced with 21.4 parts Fractol A, 0.8 part Vistanex (polymer formed by low temperature polymerization of isobutylene, molecular weight 80,000) and 0.8 part Primol D (mineral oil). Cut resistance dropped to 50, abrasion resistance to 2.0 and half hitch cut to 7.2.

In the examples low temperature flexibility was determined by tying a loose overhand knot in a sample of the wire at room temperature, then conditioning the sample at the desired low temperature for about ½ hour, then pulling the knot tight and inspecting the sample for visible cracks in the vicinity of the knot. The sample was then rated on a scale from 0 to 100, the upper value of 100 being assigned when no cracks appeared.

In the cut-resistance test, a suitable length of coated wire was pulled horizontally over the sharp (right angle) edge of a steel plate. The free end of the wire was loaded with one of a series of weights thereby inducing a right angle bend in the wire. As the wire was pulled over the sharp edge, the weight was raised and the wire coating scraped. The load was increased until the coating failed, i. e., until the bare wire was exposed. Results were expressed in terms of the greatest load which could be applied prior to failure.

Abrasion resistance was determined by suspending the coated wire over a horizontally mounted cylinder covered with emery cloth (Jewel, grit, number 2) and which was rotated at 235 revolutions per minute. The coated wire was anchored at one end, passed over the cylinder, and held taut by a 500 gram weight fastened to the free end. The abrasion resistance was measured in terms of the number of revolutions of the abrasive-covered cylinder required to wear through the insulation and was reported in terms of revolutions per mil thickness of coating.

Half hitch cut was determined by tying together two sections of the coated wire and then forming a half hitch knot in such manner that contact between the two sections was made rather than making contact within the same section. The knot was then placed under sufficient tension to cause the wires to cut through the insulation and form an electrical contact. The force necessary to accomplish this was taken as the half hitch cut and was expressed in pounds or pounds per mil of coating thickness.

The over-all flexibility rating was obtained by averaging the low temperature flexibility at −10, −20 and −30° C. The over-all toughness rating was obtained by dividing the numerical values for cut resistance (g./mil), abrasion resistance (rev./mil), and half hitch cut (lb./mil), by the corresponding numerical values of Example 1 (as a control), to give three new values for each formula in terms of a comparative ratio with the

control, adding the three new values together and dividing by three to obtain the average.

In accordance with the present invention optimum results are obtained when the ratio of paraffin base oil to partially hydrogenated mixture of isomeric terphenyls is about 1 to 1. The resulting wire coating is highly flexible and tough and does not exude oil under any conditions of use. Satisfactory coatings are also obtained when this ratio is varied from about 24 to 13 to about 5 to 32. However, when ratios of paraffin base oil to partially hydrogenated mixture of isomeric terphenyls greater than about 24 to 13 are used the oil has a tendency to exude from the surface of the coating, thus rendering the coated wire unfit for many uses. This is illustrated in Table II below which sets forth the results of tests on several compositions. These compositions were compounded and extruded on wire in a manner similar to that set forth in Examples 1 to 9. The test consisted in placing samples of each composition in an oven at 70° C. and heating them at this temperature for 24 hours to induce exudation. Results are as shown in Table II.

Table II

EXUDATION TESTS ON WIRES COATED WITH ETHYL CELLULOSE COMPOSITIONS

Composition No	1	2	3	4
Ethyl Cellulose (43.5 to 50 % ethoxyl, 100 centipoises viscosity)	62	62	62	62
Fractol A	23	17	11.5	6
Partially hydrogenated mixture of isomeric terphenyls		6	11.5	17
Polyvinyl Butyral	15	15	15	15
Menthylphenol	1	1	1	1
Cadmium Yellow	0.75	0.75	0.75	0.75
Titanium Dioxide	0.25	0.25	0.25	0.25
Exudation	Yes	Yes	No	No
Abrasion Resistance (rev./mil)	1.5	1.8	2.4	3.0

It is apparent from the above data that when no partially hydrogenated mixture of isomeric terphenyls or a relatively small ratio of partially hydrogenated mixture of isomeric terphenyls to Fractol A is used exudation of oil from the wire coating results. It is also apparent that as the ratio of partially hydrogenated mixture of isomeric terphenyls to Fractol A increases the abrasion resistance also increases. However, when this ratio exceeds about 32 to 5, abrasion resistance, as well as flexibility falls off, thus rendering such coatings unsuitable for many uses. It will thus be seen that the results according to the present invention are only obtained when both the paraffin base oil and the partially hydrogenated mixture of isomeric terphenyls are present within the particular range of ratios stated.

The amount of paraffin base oil plus partially hydrogenated mixture of isomeric terphenyls to be used in a particular case will vary with the other ingredients of the composition and with the relative proportions of each. Generally the ratio of ethyl cellulose or ethyl cellulose plus polyvinyl butyral to paraffin base oil plus partially hydrogenated mixture of isomeric terphenyls will vary from about 5 to 1 to about 3 to 1. Higher ratios give some improvement in toughness but lack the required flexibility. Lower ratios do not give the desired toughness. Based on the above ratios, the use of 100 parts ethyl cellulose and up to 42 parts polyvinyl butyral, the amounts of paraffin base oil plus partially hydrogenated mixture of isomeric terphenyls may vary from about 20 parts to about 47 parts. It is preferred to use from about 33 parts to about 41 parts.

The paraffin base oil utilized in the examples is Fractol A. However, any mineral oil which is liquid and non-volatile at ordinary atmospheric temperatures may in general be used for plasticizing the ethyl cellulose. These may include lubricating oils such as S. A. E. 20, S. A. E. 30 and S. A. E. 40, steam cylinder and general lubricating oils sold under the designations of Teresso No. 52 or Teresso No. 65, ordinary transformer oil, and white refined mineral oils such as White Oil, Nujol, and Fractol. Highly refined mineral oils which are tasteless and odorless such as Nujol and Fractol are preferred.

Partially hydrogenated mixture of isomeric terphenyls has been found to be unique for the purposes of the present invention and when used with a paraffin base oil in the proportions stated produces a nonexuding coating having exceptionally good flexibility and toughness. The term "partially hydrogenated mixture of isomeric terphenyls" as herein used refers to the material sold by Monsanto Chemical Company under the designation "Monsanto HB-40 Oil." It may be prepared in accordance with the teaching of U. S. Patent 2,364,719.

The ethyl cellulose which has been found useful in the plastic wire coatings of the present invention may have an ethoxyl content between about 43.5 and 50%. Optimum results are obtained when the ethoxyl content is within range from about 46.8 to about 48.5% and hence this range is preferred. Viscosity types found useful may vary from about 50 to 1000 centipoises. However, it is preferred to utilize viscosity types having viscosities between about 50 and 200 centipoises. The viscosities indicated are those of a 5% by weight solution of ethyl celluluose in a solvent mixture consisting of 80% toluene and 20% 2B-alcohol at 25° C.

Although satisfactory wire coatings may be economically produced without the use of polyvinyl butyral, the inclusion of this material in specified amounts is highly desirable for many uses because of the increased toughness and improved electrical properties which it gives to the coating. Inclusion of up to 42 parts of polyvinyl butyral per 100 parts of ethyl cellulose gives improved abrasion and crush resistance and increased resistance to immersion in corrosive solutions such as salt water while at the same time maintaining good flexibility at low temperatures. Amounts in excess of 42 parts based on 100 parts ethyl cellulose becomes incompatible with the ethyl cellulose, thus complicating the extrusion operation and reducing the flexibility of coatings. Amounts less than about 9 parts usually do not impart the desired toughness. It is preferred to use from about 13 parts to about 29 parts of a polyvinyl butyral having a hydroxyl content of 11.25% to 21.0%.

The use of a stabilizer is not required but is desirable in most cases to prevent degradation and decrease in viscosity of the ethyl cellulose from the heat present during the compounding and extrusion operations. Stabilizing agents which may be used are, for example, diphenylamine, phenyl beta napthylamine, carbazole, diphenylguanidine, sym. dibetanapthyl paraphenylene diamine, hydroquinone monobenzyl ether, hydroquinone monomethyl ether, hydroquinone monobutyl ether, hydroquinone monoamyl ether, menthylphenol, copper salts such as copper nap-

thenate, cupric chloride, cupric acetate, etc. The amount of stabilizer included in the composition will preferably be no more than the amount necessary to provide the desired heat stability and will not exceed about 5 parts per 100 parts of composition. Preferably the amount of stabilizer used, if any is necessary, will be from about 0.5 to about 1.5 parts per 100 parts of composition.

Modifying agents such as dyes and pigments may be incorporated in the compositions, provided that the materials used do not have unfavorable electrical properties. Suitable dyes of this nature are such oil-soluble dyestuffs as Sudan Red R, Oil Red GRO, Du Pont Oil Red, Du Pont Oil Yellow, etc. Suitable pigments are silica, lithopone, talc, precipitated chalk, fine clay, asbestine, titanium dioxide, barium sulfate, calcium sulfate, chromium oxide, zinc oxide, antimony oxide, zinc sulfide, etc., ground to a suitable fineness. Dyes and pigments may be incorporated in amounts up to about 5 parts per 100 parts of composition and preferably up to about 1.5 parts per 100 parts of composition. These materials are incorporated by adding them to the ingredients charged to the Banbury or roll mill used in compounding the insulation.

The ingredients of the compositions defined above may be compounded together by any suitable means such as by milling on hot rolls or in internal mixers of the Banbury type. Alternately in some cases compounding may take place directly in the extrusion apparatus without previous milling or similar treatment. During the milling operation the temperature of the heated rolls may be from about 275° F. to about 320° F. to provide plastic compositions of good uniformity. The milling time should be from about 5 to 30 minutes and preferably from about 10 to 15 minutes. Longer times are undesirable due to the possibility of degradation of the ethyl cellulose.

After compounding, the plastic may be rolled into sheets on heated rolls and then granulated for feeding to the extruder. The temperature of the rolls during sheeting of the plastic may be from about 210° F. to about 240° F. Alternately the plastic composition from the Banbury mill may be granulated and fed directly to the extruder.

The extruder may be any well-known type of machine suitable for the purpose. A No. 1 Royle extruder has been found to work quite satisfactorily. In the extrusion operation the wire to be coated is fed through a heated die and the heated plastic is caused to flow through the die and around the wire. Wire speeds from about 300 to about 550 feet per minute have been found suitable though higher speeds are possible. Before entering the die the wire is preferably heated to a temperature from about 150° F. to about 300° F. so as not to chill the plastic too rapidly.

The temperature of the plastic as it is extruded will, of course, depend upon a number of factors. Under the conditions of Example 1 the temperature of the plastic at the time of extrusion will desirably be of the order of about 390° F. Extrusion temperatures will generally vary from about 350° F. to about 420° F. and will preferably be within the range from about 380° F. to about 410° F.

Following extrusion the coated wire may, if desired, be subjected to a suitable annealing operation. This, however, is optional and may be deleted.

The coated wire of the present invention is characterized by its excellent low temperature flexibility and by its toughness as exemplified by high resistance to crushing, abrasion and cut-through. It is further characterized by good resistance to corrosive solution such as salt water and the absence of oil exudation under any conditions of use. These characteristics make it particularly suitable for many important industrial uses, such as insulation for leg wires for electric blasting caps, where failures may prove to be dangerous.

What I claim and desire to protect by Letters Patent is:

1. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 100 centipoise viscosity)	100
Mineral oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32

said insulated conductor being characteried by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

2. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
Parafin base oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

3. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
White refined mineral oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32

said insulated conductor being characteried by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

4. An insulated electrical conductor compris-

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	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
Mineral oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%)	Not more than 42

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

5. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
Paraffin base oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%	Not more than 42

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

6. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
White refined mineral oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%)	Not more than 42

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

7. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
Mineral oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%)	13 to 29

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

8. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
Paraffin base oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%)	13 to 29

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

9. An insulated electrical conductor comprising an electrical conductor and as insulation therefor a plastic composition comprising

	Parts
Ethyl cellulose (43.5 to 50% ethoxyl, 50 to 1000 centipoise viscosity)	100
White refined mineral oil	5 to 24
Partially hydrogenated mixture of isomeric terphenyls	13 to 32
Polyvinyl butyral (hydroxyl content 11.25 to 13.25%)	13 to 29

said insulated conductor being characterized by freedom from any tendency to exude oil, flexibility at −10° C., cut resistance of at least 50 grams per mil of insulation thickness, abrasion resistance of at least 1.0 revolution per mil of insulation thickness and half-hitch cut resistance of at least 1.5 pounds per mil of insulation thickness, said plastic composition being applied to said electrical conductor by extrusion at elevated temperature and pressure.

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