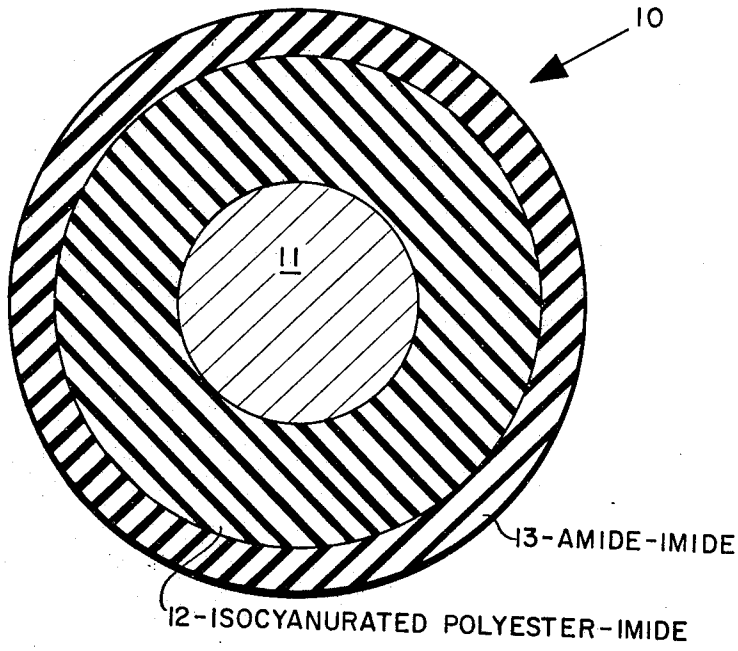
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DUAL IMIDE COATED ELECTRICAL CONDUCTOR

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INVENTORS
E.H. OLSON, R.P. ARNDT and R.H. FILIUS
BY
V.F. Volk
THEIR AGENT

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DUAL IMIDE COATED ELECTRICAL CONDUCTOR

Emil H. Olson, North Muskegon, and Rudolph P. Arndt, Muskegon, Mich., and Ronald H. Filius, Orange, Calif., assignors to Anaconda Wire and Cable Company, a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

Electrical conductors such as magnet wire and magnet strip are insulated with a polyesterimide undercoat comprising a polyester of tris(2-hydroxyethyl)isocyanurate, and an overcoat of a polyamide-imide.

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 505,359, filed Oct. 27, 1965, now pending.

BACKGROUND OF THE INVENTION

This application relates especially to the manufacture of insulated conductors generally referred to as magnet wire or magnet strip. Magnet wire and magnet strip carry the currents that generate magnetic and electrical fields in transformers, motors, generators, solenoids, magnets and related apparatus. Manufacturers of such apparatus express a continuing desire to make the apparatus more compact, sturdy, durable and capable of performing well at higher temperatures. At the same time, to keep their costs down, they require insulated products that can be made into coils at very high speeds. To withstand these high speeds of dereeling and winding, stopping and starting, the insulation on the conductors must be tough and abrasion resistant. The electrical industry has, accordingly, established a number of standard tests for evaluating magnet wire and strip of which it will be sufficient to describe the following tests for magnet wire:

Overload tests

"Figure of Merit."—These have come into prominence in recent years because of the increasing use of magnet wire at elevated temperature, the miniaturization of design, the cost saving feature of designing closer to the maximum ability of the component parts of an apparatus, and the search for a rapid means of screening materials relative to thermal stability. The Figure of Merit, B, of wire enamel is determined by connecting a twisted pair of No. 18 AWG (American Wire Gage) insulated copper wires across four terminals that automatically pay an initial 36 ampere current through the pair and increase the current stepwise 2 amperes every 3 minutes. The Figure of Merit is calculated as:

$$B=0.01225t+4\times10^{-6}t^2$$

where t represents the time in seconds to burn-out as determined by shorting of the pair at 115 volts.

Mandrel pull

This test measures the windability of the coated wire

and is important where the wire will be wound into coils on high-speed equipment. A thirty-inch sample of wire supporting a three-pound weight is rapidly pulled over a mandrel that has a diameter five times the wire diameter. This is repeated until three cracks appear in the coating and the number of pulls recorded.

Repeated scrape

An 0.016 inch diameter steel needle under 700 grams load is scraped along the wire for a distance of ⅜ inch at 60 strokes per minute. The number of strokes before a current flow is indicated between the needle and the conductor at 12 v. potential is recorded.

Heat shock

Specimens of wire are stretched to 10% elongation and wrapped around a mandrel the same diameter as the wire. The mandrel is placed in a circulating-air oven at 200° C. or at 250° C. for 1 hour and any cracking of the wire enamel is recorded.

Solvent shock

Specimens of wire are stretched 15%, wrapped around a mandrel the same diameter as the wire and then immersed in boiling xylene for 10 minutes. Any cracking of the enamel is recorded.

Polyesters have been long used as magnet wire enamels and more recently there have been marketed enamels wherein tris(2-hydroxyethyl)isocyanurate has constituted a portion of the polyols of the ester formations. Even more recently there have been introduced polyesterimides and isocyanurated polyesterimides which include within the polyester chain linkages formed from trimellitic anhydride and aromatic diamines such as diaminodiphenylmethane, and diaminodiphenylether also known as p,p'-methylenebis(aniline) and p,p'-oxybis(aniline). Commercial examples of such polyesterimides are known as Imidex–E, available from the General Electric Co., and Isomid, available from Schenectady Chemicals Co. When these enamels have exhibited excellent thermal stability their relatively low heat shock and solvent shock performance has resulted in a class F rating rather than class H to which they would otherwise be entitled. There is also marketed the polyamide-imide enamel formed from trimellitic anhydride and diaminodiphenylmethane. This material has a higher temperature rating, but it is considerably more expensive than the polyester enamels.

SUMMARY

We have discovered that the heat shock and solvent shock of isocyanurated esterimide enamels can be improved to a surprising degree by an overcoat of a double pass of polyamide-imide whereby very little extra cost is added by the introduction of the more expensive enamel. Even more surprisingly we have found, as shall be shown, that wire so coated, and comprising only a minor portion of the polyamide-imide will actually outperform a 100% polyamide-imide enamelled wire with regard to the very important property of mandrel pull.

We have invented an insulated electrical article comprising a conductor such as a copper wire, a wall of isocyanurated polyesterimide covering the conductor and a lesser wall of polyamide-imide electrical insulation directly covering the polyesterimide insulation. Preferably our polyesterimide comprises the reaction product of tris(2-

hydroxyethyl)isocyanurate; trimellitic anhydride; terephthalic acid, dimethylterephthalate, isophthalic acid, dimethylisophthalate, and mixtures thereof; and diaminodiphenylmethane; and our polyamide-imide comprises the reaction product of trimellitic anhydride and diaminodiphenylmethane.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing the figure shows a section of a magnet wire made to our invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the figure a magnet wire indicated generally by the numeral **10** has a conductor **11** covered with a layer **12** of isocyanurated polyesterimide enamel and immediately over it a layer **13** of polyamide-imide enamel. Although we have shown a conductor **11** that is circular in section it will be understood that square or rectangular conductors or conductors in the form of flat strips or foils may also be used within the scope of our invention.

The layer **12** comprises a polymeric resin formed by reacting the ester obtained by combining tris(2-hydroxyethyl)isocyanurate with dimethylterephthalate, with trimellitic anhydride and 4,4'-diaminodiphenylmethane. The quantity of diacid-diimide precursor used is such that 7–25 molar percent of the total carbonyl content of the resin after being totally cured is due to imide groups. The tris(2-hydroxyethyl)isocyanurate imparts maximum heat aging properties to the enamel **12** but other polyols may be substituted for the isocyanurate up to 50 equivalent percent within the scope of our invention. Such substitute polyols include glycol, glycerol, pentaerythritol, 1,1,1-trimethylolethane, 1,1,1-trimethylolpropane, sorbitol, manitol, dipentaerythritol, butane-diol-1,4; pentane-diol-1,5; butene-2-diol-1,4; butyne-2-diol-1,4; 2,2,4,4-tetramethyl-1,3-cyclobutanediol, hydroquinone dibetahydroxyethyl ether, and 1,4-cyclohexanedimethanol.

EXAMPLE 1

	G.
Tris(2-hydroxyethyl)isocyanurate	810
Dimethylterephthalate	486
Cresol	100
Cerium naphthenate	5
Calcium naphthenate	1.5

The listed components are heated slowly until 3 mols of methanol distil off at about 200° C.; diluted with 850 g. of cresol and cooled to 90° C. Thereafter 745 g. of trimellitic anhydride and 382 g. of 4,4'-diaminodiphenylmethane are added. The water is distilled off, and after the precipitate has become clear it is diluted with cresol to a concentration of about 60%. Thereafter 1.7% of the solid resin weight of butyl titanate and 0.28% of p-toluenesulfonic acid are added along with cresol, solvent-naphtha, and xylene to a solids content of about 30%.

Although we have employed 4,4'-diaminodiphenylmethane as the divalent amine for combination with trimellitic anhydride, other divalent aromatic diamines such as diaminobiphenyl, diaminodiphenyl ether, diaminodiphenyl sulfide, diaminodiphenylsulfone, diaminoditolyl ether, diaminodiphenyl propane, 4,4'-thioaniline-diphenyl ether, 4,4'-diaminotriphenylamine, and the like are included within the scope of our invention. Where additional cross linking is desired isocyanates such as the trimer of a trisubstituted phenol or cresol blocked cyanuric acid may be added, up to about 8 percent, on a solid basis.

EXAMPLE 2

	G.
Polymer of trimellitic anhydride and 4,4'-diaminodiphenylmethane	400
N-methylpyrrolidone	100
Dimethylacetamide	1100
Toluene as required.	

The polymer of Example 2 is commercially available from the Amoco Corp. and can be made by the method, described in Netherlands Octrooiaanvrage No. 6,400,422, of reacting the anhydride monomer having an acyl halide group in the 4-ring position with diamine. The toluene is added to reduce the solution to the desired viscosity for enamel application.

Magnet wire was manufactured by continuously coating #18 AWG copper wire with the polyesterimide enamel of Example 1 in four passes of a commercial enameling oven wherein each coat was baked for about 1 minute at 400° C., and in one double pass applying the polyamide-imide enamel of Example 2 so that the total build was about 0.0032, and the contribution to this thickness of the outer layer was about 0.0006. The enameled wire thus made was compared with #18 copper wire coated with an .0034 build of the polyesterimide alone and also with the polyamide-imide alone and tested by the overload, mandrel pull, repeated scrape, heat shock, and solvent shock tests hereinbefore described. The results are given in the table.

TABLE

	Amide-imide over polyesterimide	Polyesterimide alone	Amide-imide alone
Mandrel pull, pulls	9-10	7	6
Repeated scrape, strokes	88	30	100+
Heat shock, 200° C., appearance	OK	Failed	OK
Heat shock, 250° C., appearance	OK	Failed	OK
Solvent shock appearance	OK	Failed	OK
Overload, figure of merit	7.93	5.54	9.85

By reference to the table it is seen that a surprisingly small addition of the amide-imide (only two passes through the enameling machine out of six) has the effect of greatly improving the overload resistance. This is true, we have found, both with and without varnishes. It is seen also to improve the solvent resistance. In addition to the test reported in the table this improvement is shown by the fact that the solvent craze of 1-inch mandrel wraps during ten minute immersions in xylol at room temperature is slight or nonexistent for the amide-imide overcoated wire but severe for polyesterimide wire without the overcoat.

The table also shows improved toughness and windability for the overcoated wire as reflected by the repeated scrape and mandrel pulls, and, most surprisingly, the performance in mandrel pull of the overcoated wire exceeds even the 100% amide-imide coated wire performance.

Most important, commercially, however, is the startling improvement in 200° and 250° C. heat shock that results from the single pass of the wire through the amide-imide enamel.

We have invented a novel and useful article of which the foregoing description has been exemplary rather than definitive and for which we desire an award of Letters Patent.

We claim:

1. An insulated electrical article comprising:

(A) a metallic conductor,

(B) a wall of isocyanurated polyesterimide electrical insulation covering said conductor, and

(C) a lesser wall of polyamide-imide electrical insulation directly covering said polyesterimide insulation.

2. The article of claim **1** wherein said polyesterimide comprises the reaction product of tris(2-hydroxyethyl)-isocyanurate; trimellitic anhydride; a compound selected from the group consisting of terephthalic acid, dimethylterephthalate, isophthalic acid, dimethylisophthalate, and mixtures thereof; and an aromatic diamine.

3. The article of claim 2 wherein said diamine is diaminodiphenylmethane.

4. The article of claim 1 wherein said poyamide-imide insulation comprises the reaction product of trimellitic anhydride and an aromatic diamine.

5. The article of claim 4 wherein said diamine is diaminodiphenylmethane.

6. An insulated electrical article comprising:

(a) a copper wire,

(b) a wall of isocyanurated polyesterimide electrical insulation covering said wire, and

(c) a lesser wall of polyamide-imide electrical insulation directly covering said polyesterimide insulation.

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WILLIAM D. MARTIN, Primary Examiner

R. HUJACK, Assistant Examiner

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