

1

3,022,200  
**MAGNET WIRE AND METHOD OF  
 MAKING SAME**

Ernest C. Koerner, Ralph Hall, and Earl L. Smith, Fort Wayne, Ind., assignors to Phelps Dodge Copper Products Corporation, Fort Wayne, Ind., a corporation of Delaware

Filed Oct. 12, 1960, Ser. No. 62,235  
 18 Claims. (Cl. 117-218)

This invention relates to insulated electrical conductors and more particularly to such a conductor, especially magnet wire, having improved insulation of the varnish or enamel type, and to a method of making the same.

Over recent years, there has been increasing use of thermosetting polyester resins for electrical insulation purposes, as for insulating magnet wire. The thermosetting polyester resins used for wire insulation are of various forms but commonly consist essentially of the reaction products of a polyhydric alcohol, a glycol and a dicarboxylic acid or a lower alkyl ester thereof, the resin being commonly cured with a metal catalyst such as zinc, titanium, litharge, lead, etc. Such resins have shown remarkable thermal stability when measured in accordance with standard procedures in the electrical industry, such as the dielectric twist procedure of AIEE No. 57. Moreover, they are readily soluble in organic solvents and can be applied to bare copper or aluminum wire by conventional coating methods using wiping dies followed by curing at high temperature (500-1000° F.), the resin solution generally being applied in multiple coats each cured before application of the next coat.

Examples of polyester resins of the type described, which have been used to advantage for magnet wire insulation, are:

(1) An ester of terephthalic or isophthalic acid reacted with glycerine and/or pentaerythritol plus small quantities of silanes or siloxanes, and

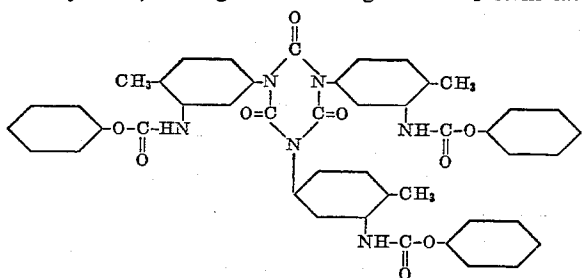
(2) Esters of terephthalic or isophthalic acid reacted with:

(a) Glycerine or pentaerythritol and

(b) Ethylene glycol or butane diol 1,4 or a mixture thereof.

These various polyesters are disclosed in U.S. Patents 2,686,739, dated August 17, 1954; 2,686,740, dated August 17, 1954; 2,889,304, dated June 2, 1959; and 2,936,296, dated May 10, 1960.

Certain modified polyester resins of the thermosetting type have also been so used. These are produced by adding to the dihydric and polyhydric alcohol-terephthalic acid polyester in essentially linear form a substantial proportion of another reactant, such as an isocyanate of the more thermally stable type, which serves as the predominant cross-linking agent in curing the resin on the conductor. One such isocyanate commonly used for this purpose is the trimer of a trisubstituted phenol or cresol blocked cyanuric acid (such as Mondur SH, a product of Mobay Chemical Company, Pittsburgh, Pennsylvania) having the following structural formula:



2

These isocyanate resins, such as Mondur SH, tend to improve thermal stability, slightly reduce heat and solvent shock and, because of their active cross-linking, harden and toughen the finished film as well as improve its electrical properties.

These prior resins of particular utility in the present invention can be described as a thermosetting polyester or modified polyester which is either (a) the cured reaction product of both di and polyhydric alcohols and a dicarboxylic acid or its ester (generally an ester of iso or terephthalic acid) or (b) formed by adding to the components included under (a) above, in linear polymeric form, a cross-linking reactant such as an isocyanate of the type described above, and curing the resin with this additional reactant. More briefly, they may be described as thermosetting polyester or modified polyester resins of the dihydric alcohol-polyhydric alcohol-dicarboxylic acid type, hereinafter referred to at times as "thermosetting polyester resins." The inclusion of a metal catalyst in the resin solution, such as zinc, lead, titanium, etc., tends to promote cross-linkage and increase the cure rate.

The use of such thermosetting polyester resins for magnet wire insulation has been dictated by the need for greater resistance to prolonged heating to permit operation of an electrical device using the magnet wire at higher temperature without sacrifice in the life of the device. However, a basic deficiency in magnet wires coated with them is that they are subject to what is known in the magnet wire industry as heat shock and solvent shock. That is, when they are stretched or bent (as during winding and assembly) and then heated, the coating can develop cracks. These cracks are voids or open spaces in the insulation and can cause failure in service of electrical devices in which the wire is used. Also, when the film or coating is stretched and bent (as in normal winding of electrical devices) and then immersed in varnish containing organic solvents such as xylol, naphthas, etc., the hot solvent during baking causes the film or coating to crack and peel (solvent shock), this being another cause of electrical failures.

Eliminating or reducing the heat shock and solvent shock in these thermosetting polyester-coated wires has been recognized as obviously desirable; but so far as we are aware those skilled in the art have not heretofore succeeded in doing so. For one thing, it is not apparent how the thermosetting polyester itself could be modified effectively for this purpose without detracting from its overall properties which make it desirable as wire insulation. Moreover, while polymers such as "Formvar" (polyvinyl formal-phenolic, Patent 2,307,588) or "Formvar" reacted with a urethane (Hall et al. application Serial No. 551,193, filed December 5, 1955) when applied to the bare wire do not cause heat shock, we find that they do not overcome the heat shock problem when coated over a thermosetting polyester on the wire. On the other hand, although a polymer such as nylon (poly hexamethylene adipamide) does not heat shock when applied to the bare wire and will eliminate heat shock when applied as an outer coating, nylon does not have the thermal resistance of the polyesters and therefore seriously detracts from the thermal resistance of the finished wire, making it an unacceptable Class F (155° C.) rated product.

The principal object of the present invention, therefore, is to provide an electrical conductor insulated with a thermosetting polyester or modified polyester of the type described but which substantially eliminates heat shock and solvent shock without detracting from the desired properties of the polyester insulation. A further object is to provide such a conductor suitable for continuous operation up to 155° C. (Class F) or higher.

Another deficiency in these polyester-coated wires is a