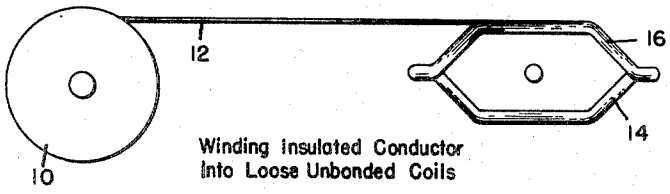
May 2, 1950 C. D. KIFER ET AL 2,506,026

METHOD OF BONDING CONDUCTORS

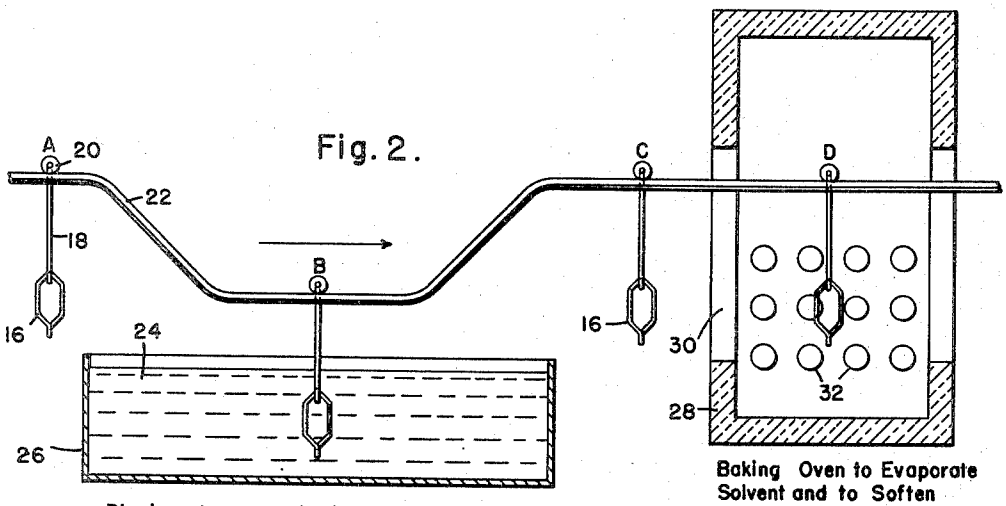
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Fig. 1.



Winding Insulated Conductor Into Loose Unbonded Coils

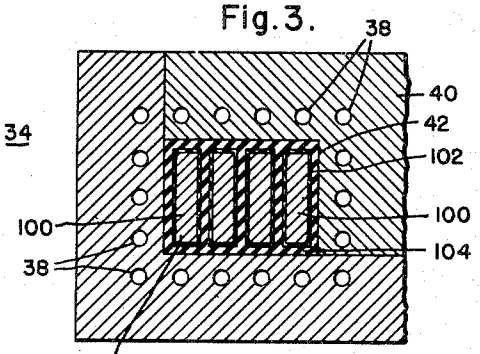
Fig. 2.



Dipping Loose Coils in a Thermoplastic Composition

Baking Oven to Evaporate Solvent and to Soften Thermoplastic by Heat

Fig. 3.



Cold Pressing of Hot Coil to Shape and Consolidate Turns by Solidifying Thermoplastic

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METHOD OF BONDING CONDUCTORS

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This invention relates to a method of producing bonded conductors and in particular for forming consolidated coils and windings having a predetermined shape and form.

The object of this invention is to provide a process for treating an insulated electrical conductor with a thermoplastic which bonds the conductor into a consolidated coil.

Another object of the invention is to provide a process for rapidly forming consolidated coils from an insulated conductor comprising the steps of forming a loose coil from the conductor, providing a hot coating of a thermoplastic to the loose coil, and then pressing the coated coil in a cold mold to consolidate the coil and solidify the thermoplastic by cooling it in the cold mold.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

For a better understanding of the nature and objects of the invention, reference should be had to the following detailed description and drawing, in which:

Figure 1 is a view in elevation showing the winding of a loose coil;

Fig. 2 is a view in elevation, partly in section, showing subsequent treating steps applied to the loose coil; and

Fig. 3 is a fragmentary cross sectional view through a coil in a cold press.

In accordance with this invention, we provide a rapid, efficient and economical method of producing consolidated coils bonded with a thermoplastic. Briefly, the process comprises first forming a plurality of turns of an insulated conductor into a loose unbonded coil. The loose coil is then treated to apply to all of the turns of the conductor a coating of a thermoplastic, the thermoplastic being applied preferably as a solution or emulsion. The loose coil with the applied thermoplastic is then treated to evaporate the solvent or liquid carrier if an emulsion is employed, and heated to bring the thermoplastic coating on the turns to a temperature at which it is moldable. The hot coil with its applied coating is then subjected to a cold pressing operation in a cold mold in which the turns of the coil are compacted and the hot thermoplastic is molded and solidified into a coherent body or matrix in which the conductors are embedded. This process lends itself to high speed operation

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and entails a minimum of handling. Other advantages will be apparent hereinafter.

Referring to Fig. 1 of the drawing, there is illustrated the first step of the process, namely, forming a loose unbonded coil from an insulated conductor. As illustrated, there is drawn from a supply spool 10 an insulated conductor 12 which is applied to a form 14 on which a plurality of turns of the conductor 12 are loosely and roughly shaped into the unbonded coil 16. It is desirable that the turns of the conductor 12 be loose and separate from one another to facilitate subsequent operations. The type of coil or winding 16 shown in the figure is exemplary. There are many other varieties of coils or windings that can be prepared either by a coil winding machine or on a form, or by hand. Thus, hairpin coils, shuttle wound coils and spool wound coils may be prepared in all varieties of shapes, sizes and the like. The turns forming the coil need not be complete loops but may comprise separate U-shaped loops. The coil 16 may be formed with separators such as strips of cloth or paper between turns or between layers of turns.

The insulated conductor 12 may comprise any suitable flexible electrical conductor, for example copper wire, copper strap and braided copper. Silver, aluminum, steel and other conductor metals may be employed. The insulation on the conductor may be composed of any of the usual types of insulation, organic or inorganic, or combinations thereof. Thus, in many cases, the insulation need only be a coating of wire enamel. However, our invention is particularly well adapted for making coils from conductors insulated with fibrous insulation, such, for example, as asbestos, cotton, glass fibers, and the like.

In some instances, bare copper, such as strap copper, is formed into a loose coil, and the turns are then wrapped with mica tape. This is necessary where the copper is severely deformed in winding the coil, and any insulation on the copper would be ruptured or torn during the coil forming operation. Regardless of the nature of the conductor, it is wound into the loose coil 16 comprising a plurality of turns insulated from one another and having spaces present between turns, the spaces being of such

dimensions that liquid compositions may readily penetrate between the turns.

The loose unbonded coil 16 is then treated as illustrated in Fig. 2 of the drawing. The coils 16 are mounted at position A on hangers 18 carried by rollers 20 movable along a track 22. The coils 16 are moved from left to right to position B as shown in Fig. 2. The coils 16 are dipped into a thermoplastic contained in a tank 26 containing a thermoplastic composition 24. The thermoplastic composition 24 is preferably a solution of an electrically insulating thermoplastic in a volatile organic solvent or an emulsion or suspension of a thermoplastic in a volatile liquid carrier such as water. Suitable thermoplastics for use in the practice of the invention are polyvinyl chloride, polyvinyl acetate, polyvinyl chloride-acetate copolymer, polyvinyl formal, polyvinyl acetal, polyvinylidene chloride, ethyl cellulose, cellulose acetate, cellulose butyrate, nylon, polystyrene, and polyethylene. Mixtures of these or other thermoplastics may be employed. We prefer to use thermoplastics that are hard and do not soften appreciably below 200° F. If necessary, the thermoplastic may carry plasticizers, dyes, and small amounts of other natural or synthetic resins, such as shellac, phenol formaldehyde and alkyd resins. Volatile solvents for the thermoplastics are well known and need not be listed here. Emulsions or suspensions of the thermoplastics are available to the trade and may be employed with advantage.

After the coil 16 has been dipped in the thermoplastic composition 24, it is removed from the solution with an adherent coating of the thermoplastic composition and moved to position C. The coil 16 may be air dried at position C to remove a part or most of the organic solvent in the thermoplastic composition, or the water or other liquid carrier if an emulsion of the thermoplastic has been applied. Air drying is advantageous if the coated loose coils are to be stored before completion of the process.

However, for the most rapid processing the coated coils 16 are not air dried at position C but are immediately moved into position D in oven 28 where they are heated, as by infrared lamps 32. Openings 30 in the oven are present to permit the coils to be introduced into the oven and removed therefrom and also to permit the escape of any volatile solvent or liquid carrier in the thermoplastic coating.

For most purposes in the electrical industry, it is desirable to employ thermoplastics that do not soften appreciably below 200° F. The thermoplastics above listed are all relatively hard below 200° F. and therefore adequately meet this requirement.

In the oven 28, the temperature of the coil 16 with its applied thermoplastic coating is brought to a value at which the thermoplastic is soft and moldable under relatively low pressure. Temperatures of about 300° F. are suitable for practically all of the resins specifically listed above. However, in some cases the temperature of the coil and its applied thermoplastic may be just above 200° F., though this requires high pressures in subsequent molding operations. Temperatures of 400° F. to 450° F. may be employed with considerable advantage with some of the thermoplastics since the molding of the thermoplastic is greatly facilitated at these elevated temperatures.

The steps of the process illustrated in Fig. 2 may be carried out without a conveyor—as by hand dipping and hanging the dipped coils in the oven. Batches of the coils can be dipped in a frame or basket and the frame or basket moved into the oven.

When the coil 16 has reached the desired elevated temperature of above 200° F. at position D, it is withdrawn from the oven and promptly placed in a cold mold wherein the coil is immediately subjected to pressure sufficient to compact the turns of the coil together and to cause the applied hot thermoplastic to flow and be molded into a coherent body or matrix in which turns of the conductor are embedded after which the cold mold cools and hardens the thermoplastic to a solid state. This step is illustrated in Fig. 3 of the drawing showing a cold mold 34 comprising a die 34 cooperating with a mating die 40 both provided with conduits 38 for the circulation of cold water or a refrigerant. The dies 34 and 40 provide a mold cavity 42 of predetermined shape. The consolidated coil comprises the conductor turns 100 provided with conductor insulation 102 embedded in a matrix or body 104 of the thermoplastic which was molded by the cooperating dies 34, 40 to the shape of the cavity 42 and then cooled to a temperature sufficient to solidify the thermoplastic into a coherent matrix. It will be evident that the thermoplastic 104 unites the conductor turns 100 together as well as providing an exterior coating of insulation that may serve as ground insulation for the entire consolidated compact coil. The dies 34 and 40 may be separated and the consolidated coil removed therefrom within a few minutes after the hot coil is placed therein. The coil is then ready for further manufacturing operations. In many cases the consolidated coil is wrapped with mica tape, glass fiber tape, asbestos tape, paper or other wrapping to provide ground insulation.

It will be observed that the process illustrated in the drawing and described herein can be conducted in a very brief period of time. The time from the beginning of winding of a coil to the production of a completed cold pressed coil may be as little as 15 minutes or less, depending on the size and type of coil. Large, complex coils may require greater periods of time.

While dipping is illustrated in Fig. 2 as the mode of applying of the thermoplastic composition to the loose coil, we have employed other coating means, such for example, as spraying, flowing and brushing of the thermoplastic composition onto the coil. Each of these modes of application of the thermoplastic composition has given good results. The thermoplastic composition 24 may be heated to facilitate coating and to expedite solvent removal. Very thick compositions when so heated, as up to 240° F. became quite fluid and penetrating.

One of the reasons for the speed secured with our process is the preparation of loose unbonded coils in the initial step. The loose unbonded coils permit the rapid and complete penetration of the thermoplastic composition between the coil turns. Only a few seconds dipping, for example, is necessary to secure a complete coverage of every portion of the coil. This may be contrasted with the time required for penetration of a tightly wound coil which may require vacuum and pressure impregnation, sometimes for hours, to secure adequate penetration into the innermost interstices of such type coils. Furthermore, the loose coil with the applied coating of thermoplastic composition can be

heated much more thoroughly in a short time in an oven than can be effected with a tightly wound coil. Solvent evaporates much more readily and completely from the loosely wound coils than is possible with a tightly wound coil. Therefore, an important feature of our invention is to provide a loose unbonded coil in the initial step. In such a loose coil, the conductor turns may not touch one another at any point though for most practical processes the coil turns may touch at an occasional point, and distinct spaces are present between the major length of all the turns.

The amount of thermoplastic applied to the loose coils will depend on the amount of thermoplastic desired in the final product as well as on the amount of porous or fibrous insulation initially present in the conductors since the fibrous insulation will be impregnated with the thermoplastic.

While we have illustrated an infrared lamp heating element in Fig. 2, it will be appreciated that other forms of heating may be employed, such for example, as a hot air oven or a gas burner oven or an electrical resistance element. In all cases, the loose coils absorb heat better and the solvent is removed more rapidly than with a tightly wound coil.

It will be understood that the coils are heated in air in order to drive off the solvent from the thermoplastic. The air may be circulated by forced draft means or the like in order to expedite the removal of solvent.

We have found that solutions of the thermoplastic are most suitable for treating the loose coils because they may be kept at a relatively constant low viscosity and solids content. The low viscosity of the solutions enables rapid and complete penetration thereof between the coil turns. The relatively constant viscosity and solids content of the solutions enable thin coatings of selected thickness to be applied to any given coil so that its subsequent pressing in the cold mold is facilitated, and good consolidated coils of substantially constant shape and size are produced.

For certain purposes, hot melt coatings composed of a molten thermoplastic may be applied to the loose coils. The coil turns must be quite well separated to permit the hot melt thermoplastic to penetrate and coat all the turns. A large quantity of the thermoplastic is picked up because of the cooling effect of the coil tending to congeal a heavy layer of thermoplastic on the turns. However, the coil with the hot melt coating need not be heated but may be immediately placed in a cold mold and consolidated.

It is to be understood that the above-detailed description and drawing are only exemplary of the process since other means for carrying out these steps will be apparent to those skilled in the art.

We claim as our invention:

1. In the process of producing a consolidated formed coil from a conductor insulated with a fibrous covering, the steps comprising forming a plurality of turns of the fibrous covered conductor into a loose unbonded coil, applying to the loose coil a coating of a solution of a thermoplastic in a volatile organic solvent, heating the coated coil in air to evaporate the solvent and to bring the thermoplastic on the coil to a temperature at which it is moldable, the evaporation of the solvent and heating being expedited by the looseness of the coil turns, and pressing the heated coil with the applied thermoplastic in a cold mold to compact the turns of the coil and to mold and then solidify the thermoplastic by cooling effected by the cold mold into a coherent matrix in which the conductors are embedded.

2. In the process of producing a consolidated formed coil from an insulated conductor, the steps comprising forming a plurality of turns of the insulated conductor into a loose, uncompacted coil, dipping the loose coil into a liquid thermoplastic composition comprising a thermoplastic that is hard at room temperature and a liquid carrier, removing the coil from the thermoplastic composition with a coating of the composition applied to the turns of the insulated conductor, heating the coated loose coil in air to evaporate the liquid carrier and to heat the thermoplastic to a temperature at which it is moldable, and pressing the heated coil with the moldable thermoplastic thereon in a cold die to compact the turns of the coil and to mold and then to cool the thermoplastic into a coherent solid matrix in which the conductor turns are embedded.

3. In the process of producing a consolidated insulated winding from a conductor, the steps comprising forming a plurality of turns of the conductor into a loose uncompacted winding with insulation applied to the turns, applying to the turns of the insulated winding a coating of a thermoplastic, heating in air the loose winding and applied thermoplastic coating to a temperature at which the thermoplastic is moldable, and pressing the winding with the heated thermoplastic coating in a cold mold to compact the turns of the winding into a consolidated member and to mold and then solidify the thermoplastic by cooling it by contact with the cold mold into a coherent matrix in which the turns of the conductor are embedded.

4. In the process of producing a consolidated formed coil from an insulated conductor provided with a fibrous covering, the steps comprising forming a plurality of turns of the conductor into a loose uncompacted coil, applying to the loose coil a coating of thermoplastic composition comprising a thermoplastic that is hard and relatively unmoldable below 200° F., and a volatile organic solvent for the thermoplastic, heating the coated coil in air to a temperature above 200° F. to evaporate the solvent and to heat the thermoplastic of the coating to a temperature at which it is moldable, and pressing the heated coil with the applied thermoplastic in a cold die at a temperature of below 100° F. to compact the turns of the coil under sufficient pressure to mold the thermoplastic into the fibrous covering, and then to cool and solidify the thermoplastic into a coherent body in which the conductors are embedded.

5. In the process of producing a consolidated coil from an insulated conductor, the steps comprising forming a plurality of turns of the insulated conductor into a loose uncompacted coil, applying to the loose coil a coating of a composition comprising a thermoplastic and a volatile solvent for the thermoplastic, evaporating solvent from the coated loose coil thereby leaving a coating of the thermoplastic on the coil, heating the coated loose coil to a temperature at which the thermoplastic is moldable, and pressing the heated loose coil in a cold die to compact the turns of the coil and to mold and then to cool the thermoplastic into a solid matrix in which the conductor turns are embedded.

6. In the process of producing a consolidated insulated coil from a conductor, the steps comprising forming a plurality of turns of the conductor into a loose uncompacted coil with insulation applied to the turns, applying to the turns of the loose coil a hot coating of a thermoplastic, and pressing the coil in a cold mold to compact the turns of the coil, to mold the hot thermoplastic into predetermined shape and then to solidify the thermoplastic by cooling it by the cold mold into a matrix in which the turns of the conductor are embedded.

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