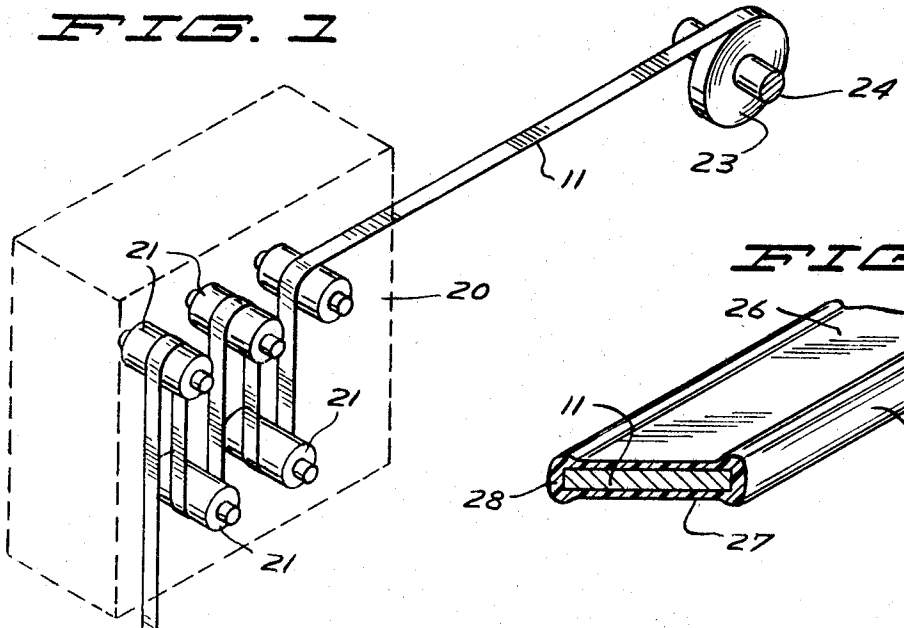
May 12, 1970 G. V. MARCELL ET AL 3,511,680

EDGE COATING OF FLAT WIRES

Filed July 5, 1966

FIG. 1



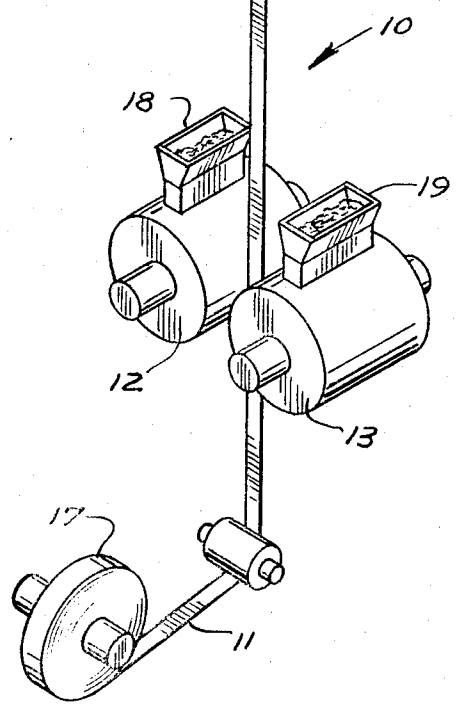


FIG. 3

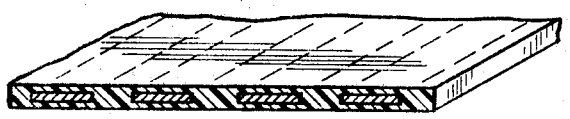


FIG. 4

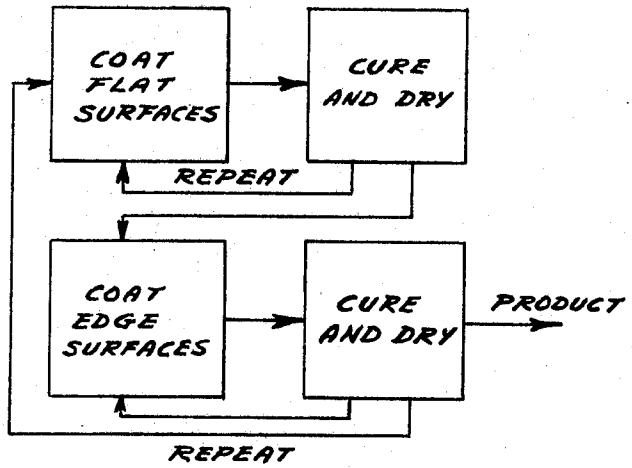


FIG. 5

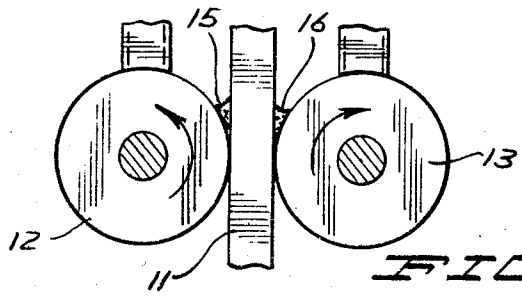


FIG. 2

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EDGE COATING OF FLAT WIRES

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Int. Cl. B44d 1/02
U.S. Cl. 117—43 3 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus and technique for the coating of the edge surfaces of flat ribbon conductors with an adherent coating of a dielectric insulating material, which includes means for passing the ribbon conductors between a pair of generally axially aligned rollers, the edge surfaces of the conductor being disposed adjacent to and generally tangentially to the confronting surfaces of the roller so as to form a fillet of dielectric material along the edge surface of the conductor.

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

The present invention relates generally to a technique for coating the edges of relatively thin substantially flat ribbon conductors, and more specifically to a technique for coating the edge surfaces of these thin ribbon conductors with a film of a heat curable resinous substance, which can be cured to a substantially rigid form so as to establish a uniform integral bond of a dielectric substance about the periphery of the ribbon conductor which is both mechanically and electrically continuous and uniform.

In the past, various attempts have been made at coating the entire periphery of various ribbon-like conductors, such as, for example, those certain ribbon-like conductors having a cross-sectional thickness dimension which is less than about 8 mils. When conductors approach this extremely thin cross-sectional dimension, they become exceedingly difficult if not impossible to coat along the edge surfaces thereof. This is due in part to the inherent tendency of the surface tension of the coating substance per se to restrict its coating function to only the major surfaces of the ribbon-like conductor. Attempts at coating the major surfaces of the thin ribbon-like conductors, while simultaneously attempting to coat the edge surfaces thereof will normally not succeed because of the inherent tendency of the surface tension of the coating material to gather or accumulate this material along the broad surfaces of the conductor. This unfortunately results in ruptured coatings or extremely thin coatings and thereby leaves the edges generally exposed and accordingly does not provide the required electrical and environmental protection for the conductor along the lateral dimensions thereof.

In accordance with the present invention, the edge surfaces of the conductor are coated with an adherent bond of dielectric by means of a roller or other surface which is itself being continuously provided with a film or other coating of material for transfer to the edge surfaces of the conductor. This edge-coating operation may occur either prior to or subsequent to the coating of the flat surfaces of the conductor. Generally speaking, it is preferred that the coating be cured at least through the "B-stage" or further, in order to enhance the over-all ultimate cure of the dielectric coating substances. Furthermore, it is generally preferred that multi-passes be employed with

the coating material in order that a strong, complete and integral film be available to the conductor. After the individual ribbon conductors have been encapsulated, the encapsulation including the coating of the flat surfaces and the edge surfaces, the ultimate integral coating is finally cured and dried, and the conductor as coated is then ready for its ultimate disposition or use. If desired, one of the final coatings along the edges may be a conductive coating prepared in a manner similar to the dielectric coating using, for example, dispersion of a finely divided metal such as copper, silver or the like. Such an arrangement may find application as a multi-conductor unit such as, for example, a combination word-sense line-inhibit line for use in data processing applications.

The present invention finds application in the preparation of high-density flexible cables, which flexible cables normally employ a plurality of spaced apart flat ribbon-like conductors, these conductors normally being spaced substantially equally, from edge-to-edge, across the width of the flexible cable assembly. In order to create a high-density flexible cable of this type which is capable of handling high potential differences between adjacent conductors, the edge surfaces of the conductors must be effectively coated with a substantial dielectric insulation layer integrally bonded to the surface of the conductor.

Therefore, it is an object of the present invention to provide an improved technique for coating the edge surfaces of flat ribbon-like conductors with a coating of a dielectric insulation.

It is yet a further object of the present invention to provide an improved technique for the application of a dielectric coating to the edge surfaces of a flat ribbon-like conductor having a cross-sectional thickness dimension of less than about 8 mils.

It is still a further object of the present invention to provide an improved technique for applying a uniform integral coating of a dielectric insulation to the edge surface of a flat ribbon-like conductor, the coating being applied in heat-curable form to these edge surfaces, and capable of being thereafter cured to a substantial insulating layer of proper and desirable mechanical and electrical properties.

It is yet a further object of the present invention to provide an improved technique for applying a coating of a dielectric insulation material to the edge surfaces of flat ribbon-like conductors wherein the coating is applied as a viscous heat-curable substance to these edge surfaces, the application being made by means of a pair of oppositely disposed axially aligned spaced apart rollers with the flat ribbon-like conductor disposed and moving substantially tangentially relative to the spaced apart confronting surfaces of the axially aligned rollers.

Other and further objects of the present invention will become apparent to those skilled in the art upon a study of the following specification, appended claims, and accompanying drawing wherein:

FIG. 1 is a perspective view of a system arranged for coating the edge surfaces of a flat ribbon conductor in accordance with the technique of the present invention;

FIG. 2 is a detail end view of a pair of edge coating rollers disposed in generally axially aligned relationship with a flat ribbon conductor running generally and tangentially to the confronting surfaces of the rollers;

FIG. 3 is a detail perspective view of a cross-section of a conductor having an adherent dielectric insulation film bonded to the surfaces thereof;

FIG. 4 is a view similar to FIG. 3, on a slightly smaller scale, showing an assembly of these flat ribbon conductors in a high-density pattern; and

FIG. 5 is a schematic diagram showing the various steps which may be carried out in the preparation of a

coated flat ribbon conductor product in accordance with the present invention.

In accordance with the preferred modification of the present invention, and particularly as illustrated in FIG. 1 of the drawings, the system shown generally at **10** provides an arrangement for coating the edge surfaces of the flat ribbon-like conductor **11**, and further provides an arrangement for drawing the coated conductor through treating zones and onto take-up rolls subsequent to the application of the coating material to the edge surfaces thereof. Generally, the flat ribbon conductor **11** is passed through the area between the confronting surfaces of the rollers **12** and **13**, such as is shown in detail in FIG. 2, the surface of the rollers **12** and **13** being continuously provided with a film of a heat curable dielectric insulation material, such as is shown in the fillets **15** and **16**. This material may be applied to the surfaces of the rollers **12** and **13** by any conventional means, such as, for example, by means of a pair of hoppers **18** and **19** which are provided with doctor blades or the like for controlling the thickness of the film on the surface of the rollers. The system provides a technique for applying a coating to the edges of the flat ribbon conductors in a uniform manner which coating will resist rupture or breaking away, even when the conductors are less than about 8 mils in thickness.

After receiving the coating on the edge surfaces, the conductor is passed through a heating zone **20**, this heating zone **20** including a plurality of idler rolls **21—21** which are journaled for free rotation, and which accordingly provide a multitude of flights, runs or passes within the chamber **20**. It will be appreciated that the time-temperature cure relationship for the dielectric insulation being employed will determine the conditions within the environment of the chamber **20**, and those skilled in the art can readily adapt the requirements of the parameters of the curing cycle to the needs and requirements of the chamber **20**. The single criteria fulfilled is that the material remain within the confines of the chamber **20** for a period sufficiently long to provide a substantially complete cure of the material coated onto the edges of the flat ribbon-like conductor. After leaving the chamber **20**, the flat ribbon-like conductor **11** is taken up on a take-up spool **23**, this spool being journaled for axial rotation about the central shaft **24**.

It will be observed that this operation may take place on a roll-to-roll basis, for efficiency in operation. Also, it will be appreciated that a plurality of stages may be employed in the system whereby the flat surfaces are initially coated, and the ribbon then moved through a chamber such as the chamber **20** for curing the material on the surface of the conductor. In the event that flat surfaces are being coated and the material subsequently cured thereon, it will normally be desirable to provide a reasonably long initial pass within a heating chamber such as the chamber **20** to accomplish substantial or significant cure of the material prior to its being passed directly over and upon a roller surface.

With particular attention being directed to FIG. 3, it will be seen that the conductor **11** is provided with an adherent film such as a dielectric insulation film along the flat surfaces such as is shown at **26** and **27**, together with an edge coating of such an adherent film such as is shown at **28** and **29**. The over-all cross-sectional configuration can be stated to be in the form of a "dog-bone," with the edge surfaces being built up to an extent greater than the composite or aggregate thickness of the layers **26** and **27** and the conductor **11**. With reference to FIG. 4 of the drawings, it can be observed that the individual conductor elements **11** together with the dielectric insulation coatings applied thereto, are encapsulated between layers of an insulating substance such as a film of a relatively flexible material such as polyethylene terephthalate or other polyester substances, polyimide-amide materials, epoxy based substances and the like.

These film forming materials are of course, generally commercially available.

In FIG. 5, there is shown a schematic illustration of the operations which may be employed in carrying out the various aspects of the present invention. Generally, the starting point is selected as the coating of the flat surfaces, such as in the upper lefthand corner of FIG. 5, this being followed by a curing and drying operation, which operations may be repeated, if necessary to achieve the appropriate thickness of coating on the major surfaces of the flat ribbon conductor. Subsequent to the flat surface coating operation, the edge surfaces are coated and this edge surface coating cured and dried. This coating of the edge surfaces may be repeated a number of times in order to achieve the proper thickness desired on the product. If desired, a final flat surface coating may be applied, this being followed, if desired, by an additional coating of the edge surfaces after which the system is cured and dried, and the product obtained therefrom. It will be appreciated that these various operations may be established on a continuous basis between individual stations arranged in spaced relationship between a supply roll such as is shown at **17**, and the take-up roll such as is shown at **23**. As indicated, previously, a coating of a conductive film may be applied to the surface of the dielectric film to form a multiconductor system.

As a raw material for the dielectric insulation coating, a polyimide-amide solution may be employed, this solution normally being thickened by the addition of a finely divided powder thereto, such as, for example, a silicate such as a quantity of powdered silica, or the like. Powdered silicon dioxide is available commercially under the name "Cab-O-Sil" or "Aerosil." A hydrophobic material may be preferred as a powder filler for many systems. Polyimide-amide film forming solutions are available commercially. It has been found that the relatively viscous solution proper for coating thin conductors may contain from 3–5 percent S_iO_2, with a dielectric base material of polyimide-amide in a solvent such as DMSO or the like, the polyimide-amide solution constituting 15–18 percent of the mixture, balance solvent. The resultant material will have the proper viscosity for coating ribbon-like conductors in accordance with the technique of the present invention. It has been found that this composition becomes too viscous when more than about 6 percent of S_iO_2 is added to the mixture. A similar amount of magnesium silicate has been found to be appropriate for the coating composition. The curing cycle will generally constitute a technique for driving the solvent from the film and thereafter curing the polymer material. The individual curing cycles are preferably interrupted at the "B-stage" in order to render the coating somewhat more flexible and thereby less likely to crack under the curing process.

Generally, a coating of about 0.1 to about 0.2 mil thick (after curing) can be deposited per coating pass. Preferably, this is built up to about 1 mil thickness after the total number of passes has been completed. When applied in accordance with the present invention, this coating is generally uniform about the surface of the conductor and will minimize any oxidation reaction along the surface of the conductor.

The illustration in FIGS. 1 and 2 shows the wire proceeding in the same direction as the mating or confronting surfaces of the individual rollers **12** and **13**. It will be appreciated that a technique may be utilized wherein the roller surfaces move counter to the direction of motion of the conductor being coated. The provision of a fresh film of curable material on the surface of the roller is thus believed to contribute to the coating capability of these thin edge surfaces.

The coating of the major surfaces of the flat conductor may preferably be accomplished by utilizing a pair of rollers as shown for the edge coating concept, or as an alternative, a technique employing felt pads disposed in

contact with the major surfaces of the flat ribbon conductor may be employed. At any rate, the techniques employed for coating the major surfaces are not deemed critical to the operation, since various known techniques may be suitably employed.

In order to remove a substantial quantity of the solvent employed in the raw dielectric coating solution substance, the coating, upon leaving the coating zone or station may be exposed to a flow or blast of heated air. This technique will achieve a substantial solvent removal at the time that the conductor is leaving the coating station.

For best coating techniques, it is generally preferred that the conductor, for example copper be reasonably free of adherent oxide or sulfide films. Accordingly, reasonable cleaning and deoxidizing steps may be employed immediately prior to the initiation of the coating operation. Until the coating film covers substantially the entire surface of the conductor, the exposure to high temperatures and atmospheres should be avoided. Generally speaking, a curing cycle of less than about 400° F. should be employed prior to the time the entire surface of the conductor is coated. Subsequently, during the various additional coating operations, curing temperatures of up to about 700° F. may be encountered without risking damage to the surface of the conductor ribbon. If desired, a deoxidizing operation may be added on an in-line basis to the remaining steps in the sequence.

What is claimed is:

1. The method of coating the edge surfaces of flat ribbon conductors with an adherent coating of a dielectric insulating material comprising:

(a) coating the flat surfaces of said ribbon conductor with an adherent coating of a dielectric insulating material;

(b) curing said coating of dielectric insulating material to a generally hardened state;

(c) maintaining a generally uniform raw film of a coating along the confronting surfaces of a pair of generally convex members with a raw film of a dielectric insulating material;

(d) drawing the flat ribbon conductor through a gap zone formed by said generally convex surfaces with the edge surfaces of said conductor being disposed in contact with said raw film and generally tangentially to the confronting convex surfaces; and

(e) curing said edge coating of dielectric insulating material to a generally hardened state.

2. The edge coating method as defined in claim **1**, being particularly characterized in that said convex members are rollers rotating in a peripheral direction of movement which substantially matches the direction and rate of movement of the flat ribbon conductor through said gap zone.

3. The edge coating method as defined in claim **1**, being particularly characterized in that means are provided for thermally curing said curable resin after each coating operation.

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U.S. Cl. X.R.

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