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(54) Improvements in or relating to electrical ribbon cable.

(57) An electrical ribbon cable comprises a plurality of electrical conductors (30) arranged in side-by-side array with at least one insulating layer (31, 32) formed of material containing PTFE electrically insulating each conductor (30) from an adjacent conductor. Adjacent faces of the insulating layer (31, 32) are thermally bonded to one another. Insulating layers (31) may be provided around individual conductors (30), in a serpentine arrangement (32) interwoven between the conductors (30), or bonded to upper or lower faces of the conductor array. The cable may be formed with bends in the plane of the width of the cable.

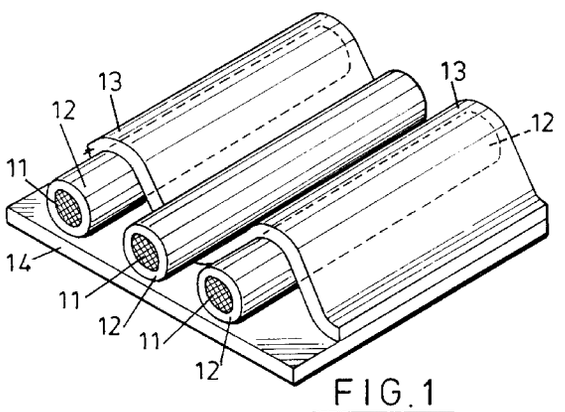

FIG.1

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This invention relates to electrical ribbon cable and to a method of its production. Such ribbon cables are well known and consist of a plurality of substantially parallel electrical conductors disposed in a common plane and insulated from each other by an insulating material.

Ribbon cables are used for a variety of applications including, particularly, the interconnection of components in electrical and electronic systems and subsystems. Ribbon cables have significant advantages over cables of circular cross-section having a plurality of individually insulated electrical conductors housed in an annular outer insulating sheath. For example, ribbon cables take up less space, have greater flexibility and tend to have improved electrical characteristics as compared with similar cables of circular cross-section.

It has previously been proposed to manufacture ribbon cables by various techniques. In one previously proposed method a thermoplastic insulant is extruded over a plurality of electrical conductors as they are fed through a profiled die. This method is only effective when resins are used which are truly thermoplastic and can be processed through conventional thermoplastic processing equipment. Such resins include, for example, polyvinyl chloride, polyethylene and polyvinylfluoride.

In many applications, however, polytetra-fluoroethylene (PTFE) polymer is the desirable insulant for such ribbon cable due to its ability to withstand high temperatures, its low dielectric constant and its flexibility. PTFE, however, cannot be processed by conventional thermoplastic techniques. One method used to make PTFE ribbon cable is described in our US Patent No. 3,082,292 and consists of laminating a number of electrical conductors, insulated or uninsulated, between two or more layers of unsintered PTFE tape. The lamination is effected by passing the conductors and their associated PTFE layers through a nip formed by a pair of profiled rolls. The profiled rolls cause portions of the PTFE tapes on opposing sides of the conductors to be brought into contact with each other at locations intermediate the conductors in order to form webs therebetween. The product is subsequently heat treated at a temperature above 327°C to sinter the PTFE to coalesce at the webs. This process has disadvantages in that, due to the necessity of forming webs of significant extent between individual conductors, a ribbon cable cannot be produced which is as narrow in width as a ribbon cable produced by the above-described process of thermoplastic extrusion. An additional disadvantage of PTFE insulated cable as produced by the method described in US Patent No. 3,082,292 is that due to the intermediate webs, the cable cannot be formed easily into bends in the plane of its width. This formability is desirable to allow routing of the cable within confined spaces.

An object of the present invention is to provide a PTFE insulated ribbon cable in which the aforesaid disadvantages are obviated or mitigated.

The cable is formed by thermally bonding an array of conductors separated by one or more layers of PTFE containing insulating material. The insulating layers may be of various configurations such that adjacent conductors may be separated by one, two or three layers of insulating material.

According to one aspect of the present invention, there is provided an electrical ribbon cable comprising a plurality of elongated electrical conductors arranged in side-by-side array; and at least one insulating layer containing PTFE contiguous with and electrically isolating each conductor from an adjacent conductor whereby each conductor is spaced from an adjacent conductor by a distance not greater than substantially three times the thickness of the insulating layer.

Preferably, the insulating layer closely surrounds the periphery of each conductor and each individual insulating layer is thermally bonded to the insulating layer of the adjacent conductor.

In a first modification of the invention the ribbon cable includes a serpentine insulating layer containing PTFE interwoven between adjacent insulated or uninsulated conductors or groups thereof.

In a further modification, a planar insulating layer containing PTFE is thermally bonded to at least one of the upper and lower faces of an array of insulated electrical conductors.

According to a further aspect of the present invention there is provided a method of producing an electrical ribbon cable, comprising the steps of:

providing a plurality of elongated electrical conductors;

arranging the conductors in side-by-side array;

arranging at least one sheet of insulating material containing PTFE and a thermoplastic material to pass between and separate said conductors; and

heating the insulating material to a level sufficient for the thermoplastic material to melt sufficiently for adjacent portions of said at least one sheet of insulating material to coalesce to form at least one insulating layer contiguous with and electrically insulating each conductor from an adjacent conductor.

Preferably, the insulating material is arranged between the conductors to space each conductor from an adjacent conductor by a distance not greater than substantially three times the thickness of the sheet of insulating material.

The sheet of insulating material may be threaded between adjacent conductors or groups thereof or each conductor may be individually wrapped. Further sheets of insulating material may be located on the faces of the array of conductors.

By the term "PTFE-containing" as used herein in relation to insulation is meant polytetrafluoroethylene modified by a thermoplastic inclusion. An example of

such a suitable material is described in our co-pending International Patent Application No. PCT/GB91/00661 filed 26 April 1991. Said insulating material comprises an admixture of a thermoplastic copolymer of tetrafluoroethylene and perfluoro (propyl vinyl ether) together with polytetrafluoroethylene.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a fragmentary perspective view of a first embodiment of ribbon cable in accordance with the present invention prior to thermal treatment;

Fig. 2 is a diagrammatic cross-sectional view of the ribbon cable of Fig. 1 being fed through the nip of laminating rolls prior to heat treatment;

Fig. 3 is a cross-sectional view of a section of the finished ribbon cable shown in Figs. 1 and 2;

Figs. 4 to 8 are diagrammatic illustrations of sections of alternative embodiments of the present invention; and

Fig. 9 is diagrammatic view of a configuration assumed by ribbon cable according to the invention after a moulding operation.

Referring to Figs. 1 to 3, a ribbon cable comprises an array consisting of a plurality of elongated electrical conductors 11, each conductor 11 consisting of seven ropes of twenty four strands of 0.051 mm diameter bare copper wire. Each conductor 11 is individually insulated by insulation 12 from an adjacent conductor by being wrapped in PTFE-containing insulating tape of 0.23 mm thickness. The individually insulated conductors 11 are then heat treated by passing them through a 3-metre heated oven at a temperature of about 400°C and a speed of 2.5 metres per minute to allow the insulation 12 to form a homogeneous layer contiguous with and closely surrounding each conductor 11.

After cooling, the insulated conductors are then combined with first and second carrier layers or sheets 13,14 of PTFE containing insulating tape. The layers 13, 14 are of substantially the same thickness as the insulation 12. As can be seen from Fig. 1, the layer 13 is planar and is located across the lower face of the array of conductors 11. The layer 14 on the other hand is interwoven in serpentine manner between adjacent conductors 11. The combination of insulated conductors 11 and carrier tapes 13,14 is then passed in tension through the nip of co-operating upper and lower pressure rolls 15 and 16 which serve to laminate together the insulated conductors 11 and the tapes 13,14. As can be seen from Fig. 2 the surface of the upper roll 15 is smooth whereas the surface of the lower roll 16 is profiled by the formation of circumferential grooves each adapted to receive an insulated conductor 11 in order to facilitate traction of the assembly through the rolls.

After passing through the laminating rolls 15,16 and while still being held in tension, the cable is heated to a temperature in excess of 320°C which allows the thermoplastic phase in the PTFE-containing tape to melt sufficiently to permit bonding between the carrier tapes 13,14 and the insulated conductors 11.

A section of the finished ribbon cable is illustrated in Fig. 3 and it will be seen that each conductor 11 is spaced from an adjacent conductor by a distance equivalent to the thickness of the insulating layer 12 around each of the conductors 11 together with the thickness of the interwoven serpentine layer 14 i.e. substantially three times the thickness of the insulating layer 12 around each conductor

After emerging from the rolls 15,16 the ribbon cable assembly is passed through a 0.5 metre molten salt bath at a temperature of 400°C and a line speed of 6 metres per minute. The line tension is 2 pounds per square inch (0.017 Nmm^{-2}). The ribbon cable thus formed is then cooled and washed in a water bath to remove excess salt.

A ribbon cable produced as described above was electrically tested and withstood 2.0 kV (AC) between conductors and 2.0 kV (AC) between the conductors and an electrode in contact with the outside of the cable.

The PTFE containing insulating layers described in the above embodiment may or may not be sintered prior to incorporation in the cable.

Fig. 4 illustrates a second embodiment of the present invention in which a ribbon cable is formed from a plurality of elongated electrical conductors 20 each having a surrounding insulating layer 21 formed as in the embodiment described above with reference to Figs. 1 to 3.

In this embodiment the individually insulated conductors are not provided with any carrier layers. In order to produce the finished ribbon cable, a plurality of individually insulated conductors are compressed slightly together to form abutting conductors to form flattened areas of contact. The compressed conductors are then heated at a temperature in excess of 320°C to allow the thermoplastic phase in the insulating layers to melt sufficiently to give a bond between the insulation of adjacent conductors 20. The cable thus formed is given a finishing treatment similar to that described in the embodiment of Figs. 1 to 3.

Fig. 5 illustrates a third embodiment of the present invention and is similar in product and process to that described in the first embodiment of Figs. 1 to 3 except that the planar layer or carrier tape 14 of that embodiment is omitted. The cable comprises individually insulated conductors 30 each having a surrounding individual insulating layer 31. Between the insulated conductors 30 is interwoven a serpentine insulating layer 32.

Fig. 6 illustrates a fourth embodiment identical in product and process to that of Figs. 1 to 3 except that a serpentine insulating layer 40 is interwoven be-

tween every second conductor 41 having individual insulating layers 42. The conductors are thereby divided into groups of two. A planar insulating layer 43 is provided on the lower face of the assembly.

Fig. 7 illustrates a fifth embodiment in which an array of non-insulated copper conductors 50 described in relation to the embodiment of Figs. 1 to 3 are provided with an interwoven serpentine insulating layer 51. Planar insulating layers 52,53 are then applied to both the upper and lower faces of the array of conductors 50. Otherwise the product and process are similar to that described in relation to the embodiment of Figs. 1 to 3.

It will be noted that in the embodiment of Fig. 7, each electrical conductor 50 is spaced from its adjacent conductor by a distance substantially equivalent to the thickness of the serpentine insulating layer 51.

Fig. 8 illustrates a sixth embodiment in which conductors 60 are provided with individual insulating layers 61 and a planar insulating layer 62 is superimposed on the upper face of the array of conductors in order to provide lateral stability.

In this case each electrical conductor 60 is spaced from its adjacent conductor by a distance substantially equivalent to twice the thickness of the insulating layer 61 surrounding each conductor.

Fig. 9 illustrates one form of pre-set shape into which ribbon cables according to the present invention can be formed. A ribbon tape 70 produced in accordance with the embodiment of Figs. 1 to 3 was laid in a channel of the shape illustrated in Fig. 9 formed in a metal block. Another metal block was laid on top of the cable to hold it in the channel. The whole assembly was heated to 350°C in a hydraulic press and maintained at that temperature for 5 minutes. After 5 minutes the assembly was removed from the press and cooled under water. After removal of the cable from the channel the cable remained in its moulded shape.

It will be clear to those of skill in the art that the above-described embodiments are merely exemplary of the present invention, and that various modifications and improvements may be made without departing from the scope of the present invention; for example, by introducing different strengths of carrier tapes as above described, the ease of separation of the conductors may be altered. Further, by introducing sections of higher strength tapes at different points along the cable then a cable can be made which has low strength and high strength sections along its length which will be useful when handling and terminating the cable.

Claims

1. An electrical ribbon cable comprising: a plurality of elongated electrical conductors (11) arranged in side-by-side array; and at least one insulating layer (12, 14) containing PTFE contiguous with and electrically insulating each conductor (11) from an adjacent conductor whereby each conductor (11) is spaced from an adjacent conductor by a distance not greater than substantially three times the thickness of the insulating layer (12, 14).

2. The electrical ribbon cable of claim 1, wherein the insulating layer (12) closely surrounds the periphery of each conductor.

3. The electrical ribbon cable of claim 1 or 2 wherein each conductor (11) is provided with an individual insulating layer (12) containing PTFE.

4. The electrical ribbon cable of claim 1, 2 or 3, including a serpentine insulating layer (32, 40) containing PTFE interwoven between adjacent conductors (30) or groups thereof (41).

5. The electrical ribbon cable of claim 1, 2, 3 or 4, wherein the array of conductors (11, 50, 60) has upper and lower faces and includes a planar insulating layer (13, 52, 53, 62) containing PTFE thermally bonded to at least one of said upper and lower faces.

6. The electrical ribbon cable of any one of claims 1 to 5, wherein the insulating layer comprises polytetrafluoroethylene modified by thermoplastic inclusion.

7. The electrical ribbon cable of claim 6, wherein the insulating layer comprises an admixture of a thermoplastic copolymer of polytetrafluoroethylene and propyl vinyl ether together with polytetrafluoroethylene.

8. A method of producing an electrical ribbon cable, comprising the steps of:

providing a plurality of elongated electrical conductors;

arranging the conductors in side-by-side array;

arranging at least one sheet of insulating material containing PTFE and a thermoplastic material to pass between and separate said conductors;

heating the insulating material to a level sufficient for the thermoplastic material to melt sufficiently for adjacent portions of said at least one sheet of insulating material to coalesce to form at least one insulating layer contiguous with and electrically insulating each conductor from an adjacent conductors.

9. The method of claim 8, wherein the insulating material is arranged between the conductors to space each conductor from an adjacent conductor by a distance not greater than substantially three times the thickness of the sheet of insulating material.

10. The method of claim 8 or 9, wherein each individual conductor is individually wrapped in PTFE containing insulating tape and is then heated sufficiently for the tape to form a homogeneous layer around the conductor.

11. The method of claim 8, 9, or 10, wherein the insulating material is provided in the form of a first sheet and the sheet is located between the conductors in a serpentine arrangement interwoven between adjacent conductors or groups thereof.

12. The method of claim 8, 9 10 or 11, wherein the insulating material is further provided in the form of a second sheet and the second sheet is located on a face of the array of conductors.

13. The method of claim 12, wherein the insulating layer is further provided in the form of a third sheet and the third sheet is located on the other face of the array of conductors.

14. The method of any one claims 8 to 13 wherein, prior to heating the insulating material, the insulating material and the array of conductors are passed in tension through the nip of co-operating pressure rolls.

15. The method of any one of claims 8 to 14, wherein during the heating of the insulating material the insulating material and the array of conductors are in tension.

16. The method of any one of the claims 8 to 15 and further comprising the steps of:

arranging the cable in a configuration with at least one bend in the plane of the width of the array of conductors; and

heating the cable sufficiently for the thermoplastic material to melt sufficiently for the insulating material to flow and assume said configuration.

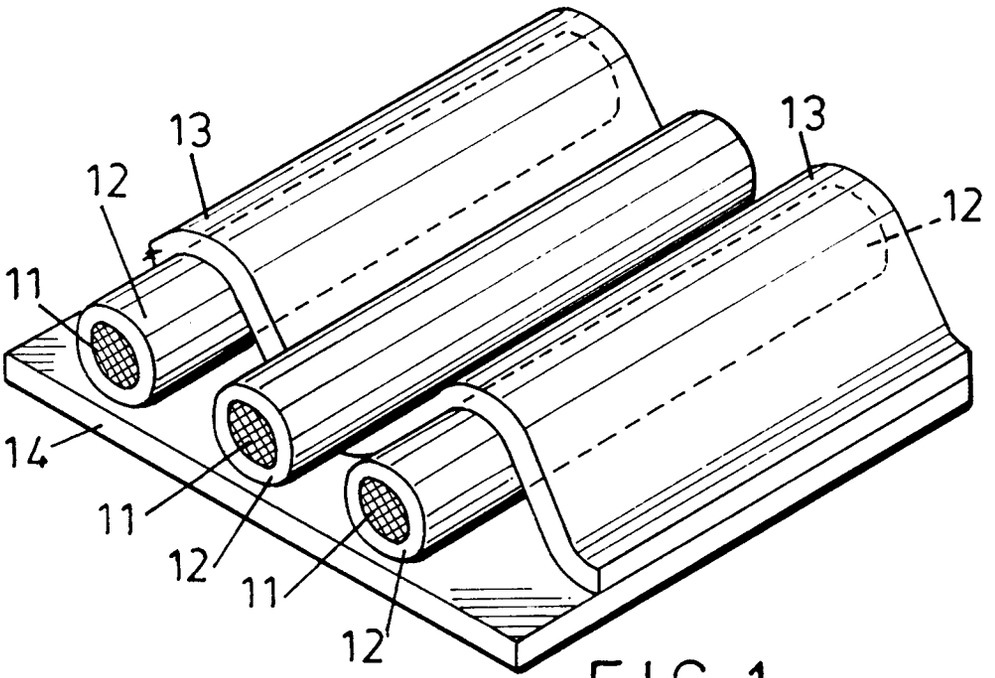

FIG. 1

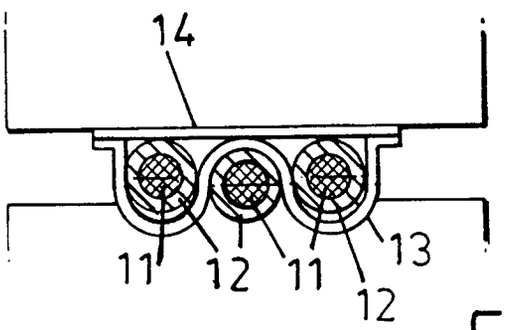

FIG. 2

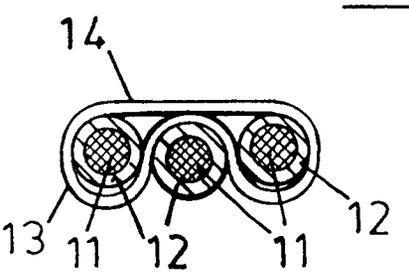

FIG. 3

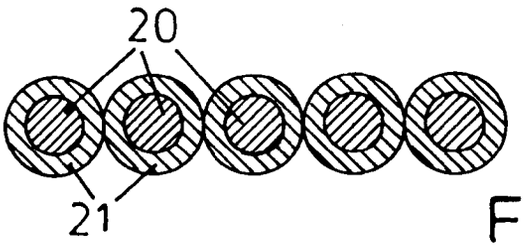

FIG 4

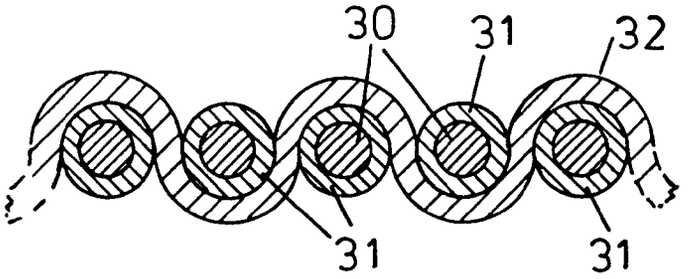

FIG 5

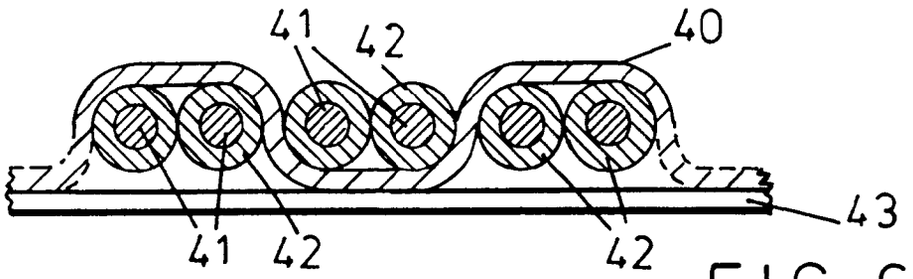

FIG 6

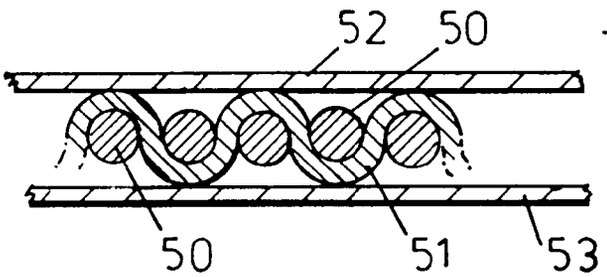

FIG 7

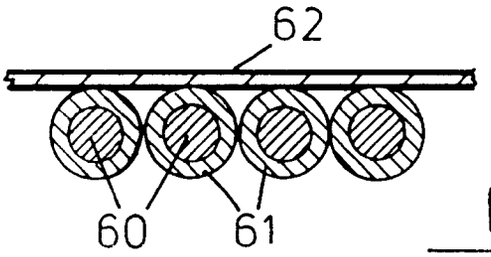

FIG 8

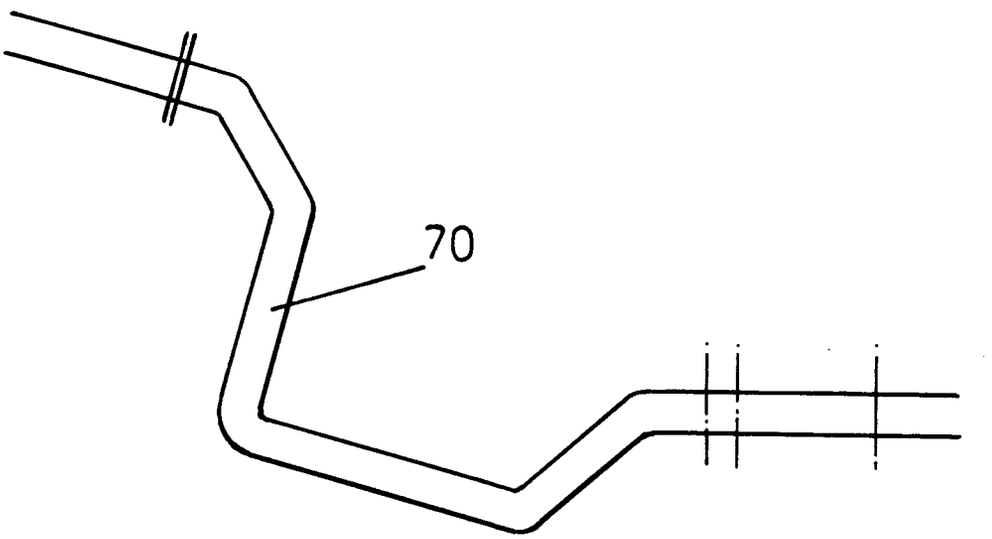

FIG. 9