

FIRE-RESISTANT WIRES

This invention relates to fire-resistant wires capable of maintaining electrical circuit integrity when the wires, or cables containing them, are exposed to fire.

Known examples of such wires are wrapped with inorganic fire-resistant material in order to continue to provide electrical insulation surrounding the electrical conductor where the usual layers of organic polymer insulation have been melted or burnt away. Of various known inorganic fire-resistant wrappings, mica "paper" is generally preferred, and for convenience the following description will therefore refer to mica wrapping while not restricting the present invention to that material.

Mica paper reinforced by a backing material of woven glass or of polyethylene film is produced as tape that can be spirally wrapped onto electrical conductors to give a degree of fire resistance. The mica wrapped conductor is then normally coated with a conventional polymer to impart the required electrical/mechanical properties. In a fire, the polymer is destroyed but the electrical integrity of the cable is maintained by the mica layer and the insulating char from the polymer. It is generally understood that the more mica the better from a fire performance point of view and tapes are available with different weights of mica (e.g. 80, 120, 160 g./sq m).

Conventionally mica tapes are applied by spiral wrapping with an overlap of typically 30% to 50% (of tape width) to maintain protection when the wrapped conductor is flexed, since the overlaps tend to open on flexing. High overlaps are preferred to achieve the required degree of fire resistance. It is a problem that the thicker, heavier tapes are harder to wrap successfully, especially on small diameter conductors, leading to tape damage, wrinkling and a poor wrapped surface making subsequent processing more difficult and final appearance and/or performance of the wire less satisfactory. Therefore, if a higher level of fire protection is needed, the options are normally to increase the weight of the mica tape and suffer a deterioration in the wrap quality, or to apply 2 layers of tape giving a greater diameter. It is also a problem that the overlapped tape tends to suffer from breakage of some of the glass weave reinforcement, causing glass fibre protrusions from the wrap. This problem gets worse the smaller the conductor diameter and

the thicker the tape, and is partly due to the low elongation to break (typically 3%) of these tapes. Geometrical calculations suggest that considerably higher elongation is needed to cope with the overlaps, but this may be compensated by some compression of the tapes in practice. This problem has resulted in the tape suppliers developing the polymer-film-backed alternatives, although the mica paper itself remains as inextensible as ever, and there is doubt as to the reliability of the tape not to delaminate during wrapping and the reduced fire performance that must be incurred by replacing glass and silicone binder tapes with polyethylene-backed tapes. These problems are exacerbated by the fact that the mica tape is supplied in discrete lengths requiring splicing every few hundred metres to allow continuous longer lengths of wrapped conductor to be produced. Splicing is normally done using a suitable adhesive tape applied to one side of the mica tape, which results in increased wrapping thickness where the splices occur.

These problems may be better understood from accompanying schematic sketches A to G, wherein

Sketch A indicates an "ideal" 50% overlap wrap on a wire;

Sketch B indicates a more realistic degree of overlap achieved in practice;

Sketch C indicates a wire having a single wrap with a typical 33% overlap;

Sketch D indicates a double layer of wraps similar to that shown in Sketch B;

Sketch E indicates a stranded wire having a double layer of wraps similar to that shown in Sketch C;

Sketch F indicates (exaggerated) imperfections in known wrappings; and

Sketch G indicates increases in wrap thickness caused by the aforementioned mica splicing tapes.

Ideally, as shown in Sketch A, the successive turns of mica wrap M of perceived width W would have an overlap of exactly 50%, giving a double thickness of mica tape over the entire surface of the wire conductor C from a single wrap. In practice, this ideal overlap is difficult to achieve, and Sketch B indicates a

more realistic result where gaps *G* occur, taking into account the finite thickness of the mica tape (*M*) which necessitates a lower degree of overlap to achieve a smooth wrap. Sketch *C* indicates a single wrap of mica tape *M* of perceived width *W* with an overlap (shaded) of about 33%. The perceived width *W* is slightly greater than the true width of the tape *M* owing to the spiral wrapping angle of the tape about the conductor axis. Because of the gaps *G* lowering the effectiveness of the wrapping, two mica tapes *M1* and *M2* are preferably used as indicated in Sketches *D* and *E* to ensure that at least two layers of the mica wrap are present at all points. Sketch *F* shows, with some exaggeration for clarity, the unevenness which occurs in these known wrappings of mica tape *M* on conductor *C*, and indicates the undesirable breakage of the brittle reinforcing fibres *F* (usually glass) which tends to occur due to stresses in the overlapped tapes.

These imperfections in the mica wraps, and even the aforementioned increases in thickness due to splices in the mica tape, can be tolerated when a thick coating (1 millimetre or more) of polymeric insulation is to be applied over the mica wraps, as shown in Sketch *G*. The mica tape *M* of width *W* is wrapped on the conductor *C* as before, but the splicing tape *S* is present on two or more adjacent turns, since the splicing tape *S* usually covers a length of the mica tape which is greater than that required to complete one turn around the conductor *C*, especially on conductors of small diameters. The resulting increase in wrapping thickness by one or two times the thickness of the splicing tape *S* (up to four times the thickness of *S* if splices of two tapes (Sketches *D* and *E*) overlap, so this is avoided in practice) can clearly be seen. This, and the roughness and fibre breakages indicated in Sketch *F*, tend to be swallowed up when thick coatings of insulating plastics *P*, of thickness 1 millimetre or more, are applied by known methods such as extrusion over the mica wraps, as indicated (not to scale) on the left-hand side of Sketch *G*. Such crude over-coating is undesirable, however, for wiring in situations where the weight and volume of the wire must be minimised.

In high-quality wires having thinner coatings of insulating plastics *P'*, as indicated on the right-hand side of Sketch *G*, all the aforementioned problems may have an increasingly significant effect on the appearance and/or performance and/or manufacturing efficiency of the mica-wrapped fire-resistant wire. The lumpy splice areas may even have to be cut out in some places, thus limiting the continuous lengths of wrapped wire which can be produced.

The present invention alleviates the aforementioned problems in surprisingly simple way.

The invention provides an electrical wire having a conductor carrying at least one under-layer of fire-resistant material over which is spirally wrapped a covering tape of inorganic fire-resistant material with adjacent turns of the tape overlapping one another by less than 10%, preferably less than 5%, more preferably less than 3%, of the tape width.

Preferably, the under-layer also comprises a tape of inorganic fire-resistant material spirally wrapped around (preferably in contact with) the conductor. The overlapping regions of the covering tape will preferably be positioned between the overlapping regions of the underlayer tape, so as to maintain protection on flexing of the wire which will tend to open the small overlaps of the covering tape.

It has been found, according to the present invention, that reducing the covering tape overlap as above, thus approaching or possibly even achieving a true "butt edge" wrapping with zero overlap, produces a very much smoother outer surface of the spiral wrap. A single layer of this spiral wrap with a continuous under-layer may be useful for some purposes, depending on what further materials are to be applied, but it is preferred to use an under-layer comprising a second tape of inorganic fire-resistant material spirally wrapped as aforesaid. Preferably, adjacent turns of the underlayer tape overlap one another by less than 20%, (more preferably less than 15%), of the second tape width.

For avoidance of doubt, it is to be noted that the term "spiral" is used herein in the sense of winding continually and advancing as if along a cylinder, the cylinder being in fact represented by the conductor in this invention, which is preferably of substantially circular cross-section although other cross-sections are not necessarily excluded.

The term "tape" is used herein to refer to any elongate body of material capable of being spirally wrapped around a wire conductor, without limitation to any particular format, construction or materials except as specifically stated herein.

This invention is especially useful for wires having a coating of organic polymer material of thickness less than 0.8 millimetre, preferably less than 0.6



mm, more preferably less than 5 mm, and especially less than 0.4 mm, overlying and preferably in contact with the outermost surface of the said wrapped tape(s).

Preferably, the adjacent turns of the underlayer tape overlap one another by not less than 2%, preferably not less than 4%, more preferably not less than 8%, of the respective tape width.

Although two or more tapes of different materials and/or widths and/or weights per unit area may be useful for some purposes, it is generally preferred to use two (or possibly more) tapes which are of similar width and thickness, preferably substantially identical. Preferably, the outer covering tape will have turns overlapping less than the turns of the underlayer tape(s).

The reasons for the clearly superior smoother wrapping of the present invention are not fully understood, but it appears (without limiting the invention to this theory) that the preferred fibrous support of the covering tapes may be able to enhance the smoothness by providing a degree of "play" or looseness which enables the reduced overlaps to partially amalgamate or settle closely against (or partially "into") each other, thus relieving some of the overlap tension and unevenness. The conventional larger overlaps extending nearer to the central portions of the tape are apparently unable to do this. The preferred fibrous backing appears to produce a greater smoothing effect than is obtained by similarly reduced overlapping of polymer-backed mica tapes. The aforementioned breakage of brittle fibres is also reduced, presumably due to reduction in tension in the overlaps according to the present invention.

In one preferred kind of tape for wrapping according to the present invention, the fibrous support of each tape is an open-weave cloth, preferably a square weave having the weft fibres or filaments substantially normal to the length of the tape. In such open weaves for the purposes of the present invention adjacent fibres in the weave are preferably spaced apart by a distance at least equal to the average fibre thickness, more preferably at least twice the average fibre thickness, and preferably not more than 20 times (more preferably not more than 10 times) the average fibre thickness. The preferred fibrous materials are woven glass cloths.

It is especially preferred that polymer-backed tapes of mica paper or other inorganic fire-resistant material be used as the covering tape, since they tend to produce a surprisingly smooth profile and may be superior to the cloth-backed tapes

in avoiding defects caused by loose or broken fibres. The covering tape backing preferably comprises a substantially continuous film of organic polymeric material, for example polyethylene or polyester film. Tapes having polymer coatings or films applied over the aforementioned fibrous (cloth) backings may be advantageous in combining the preferable qualities of the fibre or cloth and the polymeric (film) backings.

In the two-(or more)-layered wrappings according to this invention, it is preferred that the overlapping portions of the covering (outer) tape are positioned substantially mid-way between the overlapping portions of the underlayer tape.

The benefits of the present invention may be more clearly appreciated on referring to Figures 1 and 2 of the accompanying drawings, wherein

Figure 1 shows schematically in partial section a two-layered reduced-overlap construction according to this invention; and

Figure 2 indicates the smoother appearance of the wrapping in comparison with the known result indicated in Sketch F.

In Figure 1, the wire conductor 10 is shown carrying a first spiral wrap of glass-cloth-backed mica tape 20, the preferred open square weave of the glass cloth support of the tape being suggested by one illustrated strip 22. The tape is wrapped so that successive turns overlap by about 10% of the tape width (not to scale) and, as shown schematically, these overlaps 24 tend to flatten slightly as indicated to provide a somewhat smoother wrapping. Larger overlaps may also be acceptable in this under-layer. A second covering wrap of a similar mica tape 30 is shown having its overlaps of about 2% of tape width positioned in the preferred arrangement mid-way between those of the underlying tape 20. These minimal overlaps tend to produce noticeably smoother wrapping, as aforesaid.

It is a great and unexpected advantage of the smoother wrapping achieved by the present invention that heavier tapes can be used to achieve a given degree of fire resistance with effectively only two layers of the tape material, where four layers (two tapes at maximum possible overlap) were required before. For example, two glass-cloth-backed mica tapes of 80 g/m² weight wrapped as shown in Sketch D provides a coverage tending towards the theoretical 4-layer maximum of 320 g/m². This maximum level of coverage is actually achieved at points where

four layers of the tape material are superimposed, but the average coverage over the whole wire will be somewhat less due to the gaps which occur as hereinbefore described.

It has been found that two glass-cloth-backed mica tapes of 120 g/m² weight wrapped as shown in Figure 1 can advantageously achieve substantially the same level of fire protection with the coverage tending towards the theoretical minimum of only 240 g/m² (slightly more on average over the whole wire, due to the small overlaps). Furthermore, when a splicing tape 40 occurs on the mica tapes, it appears to benefit to some extent from the "amalgamation" effect of the reduced overlaps according to the present invention, as indicated schematically at splice overlaps 42 and 44, thus reducing substantially the problematic splice-tape-thickness-doubling effect illustrated in Sketch G.

As a result, a thin (0.35 mm) coating of polymeric insulation 50 can be extruded by methods known per se over the wrapped tapes 20 and 30 with only a relatively small and acceptable thickening 55 occurring at the splice. A thinner, smoother wire is thus produced according to this invention, with improved production efficiency, to meet the same fire-resistance standards which previously required much higher percentage overlaps of lighter tapes and/or thicker polymer coatings.

Fire resistance may be measured on fire test samples consisting of 2 of mica-wrapped wires with no additional polymer insulation twisted together with an overall copper braid applied. The fire tests are performed according to IEC331 (published by International Electrotechnical Commission, 1 rue de Varembe, Geneva) with the flame enhanced to 950°C ± 50°C. Voltage is applied to the conductors with the braid connected to earth. Tests are terminated if the cable maintains circuit integrity for more than 60 minutes.

The present invention may be practised using any of the known materials and production methods suitable for the production of insulated electrical wires, especially fire-resistant electrical wires. A preferred example will now be described by way of further illustration of the invention.

Example

Description of Production of 1.5 mm² fire resistant wire

- 1) Conductor = 7 strands of 0.52 mm tin plated copper conductors assembled into a round circular conductor to a nominal diameter of 1.50 mm.
- 2) Conductor wrapped with 2 layers of glass cloth backed mica tape with a mica content of 120 g/m². Total tape thickness 0.12 mm. Both tapes 5 mm overall width and applied in the same direction with the same nominal pitch (advance per revolution).
- 3) Wrapping performed on an industrial cable wrapping machine equipped with 2 concentrically mounted tape application heads.
- 4) Wrapping machine set up to give the same speed and direction of rotation to each application head of nominal 9.9 mm pitch and a left hand wrap direction.
- 5) Adjustment to be made between the two heads to ensure top tape is formed with the correct registration to the lower tape.
- 6) Overall diameter of the wrapped assembly is 1.93 mm.
- 7) Tapes applied to give an approximate butt edge to the top tape with a typical 10% overlap to the bottom tape.
- 8) Splices made in the tape to be performed using a suitable thin adhesive splicing tape applied to the glass side of the tape with care that the splicing tape does not protrude at the sides of the mica tape.
- 9) Splices in each tape to be staggered so as not to coincide.
- 10) Wrapped conductor so produced can then be insulated using standard wire insulating lines.
- 11) A tube extrusion or similar technique (known per se) is used to enable the slight diameter increase caused by splices in the wrapped product to be accepted.
- 12) Using above technique it is possible to insulate the wrapped conductor with a thermoplastic halogen free insulating compound (known per se).

13) Extrusion to a wall thickness of 0.35 mm is quite practical of such a material over such a wrapped conductor.

14) Diameter increases due to tape splices will produce an increase in insulation diameter of the same order as of the wrap itself. These splices need not be removed as fire resistant properties and insulation electrical and mechanical properties are not impaired.

15) Insulated wires so produced may be constructed by known methods into multicore electrical cables consisting of further extrusions and possibly steel armour layer as required.

16) Well designed cables so produced will be capable of withstanding fire resistance (circuit integrity) as defined by IEC331 with flame enhanced to 950°C.

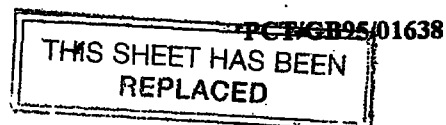
CLAIMS:

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1. An electrical wire having a conductor ~~carrying at least one under-layer~~ of fire-resistant material over which is spirally wrapped a covering tape of inorganic fire-resistant material with adjacent turns of the tape overlapping one another by less than 10%, preferably less than 5%, more preferably less than 3%, of the tape width.
2. A wire according to claim 1, wherein the under-layer comprises a tape of inorganic fire-resistant material spirally wrapped around the conductor and the overlapping regions of the covering tape are positioned between the overlapping regions of the under-layer tape.
3. A wire according to claim 2, wherein adjacent turns of the under-layer tape overlap one another by less than 20%, preferably less than 15% of the under-layer tape width.
4. A wire according to claim 2 or 3, wherein the two tapes have substantially the same width and thickness as each other.
5. A wire according to any of claims 2 to 4, wherein the adjacent turns of the covering tape overlap one another less than the adjacent turns of the under-layer tape overlap one another.
6. A wire according to any of claims 2 to 5, wherein the overlapping portions of the covering tape are positioned substantially mid-way between the overlapping portions of the under-layer tape.
7. A wire according to any preceding claim, wherein the adjacent turns of covering tape overlap one another by less than 2% of the covering tape width or have substantially zero overlap.
8. A wire according to any preceding claim, having a coating of organic polymer material of thickness less than 0.8 millimetre, preferably less than 0.6 mm, more preferably less than 5 mm, and especially less than 0.4 mm, overlying, and preferably in contact with, the outermost surface of the covering tape.

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9. A wire according to any preceding claim, wherein the covering tape incorporates a fibrous support, preferably formed of inorganic material.

10. A wire according to claim 9, wherein the fibrous support is an open weave cloth, preferably a square weave having the weft fibres or filaments substantially normal to the length of the tape.

11. A wire according to claim 10, wherein adjacent fibres in the weave are spaced apart by a distance at least equal to the average fibre thickness, preferably at least twice the average fibre thickness, and preferably not more than 20 times (more preferably not more than 10 times) the average fibre thickness.

12. A wire according to any preceding claim, wherein the covering tape has a backing of organic polymeric material, preferably a substantially continuous film of organic polymeric material.

13. A wire according to claim 12, wherein the said backing of organic material has been applied as a coating or film over a fibrous support according to any of claims 9 to 11.

14. A wire according to any preceding claim, wherein the covering tape has an elongation to break of less than 5%.

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