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METHOD AND APPARATUS FOR THE MANUFACTURE OF ELECTRIC CONDUCTORS

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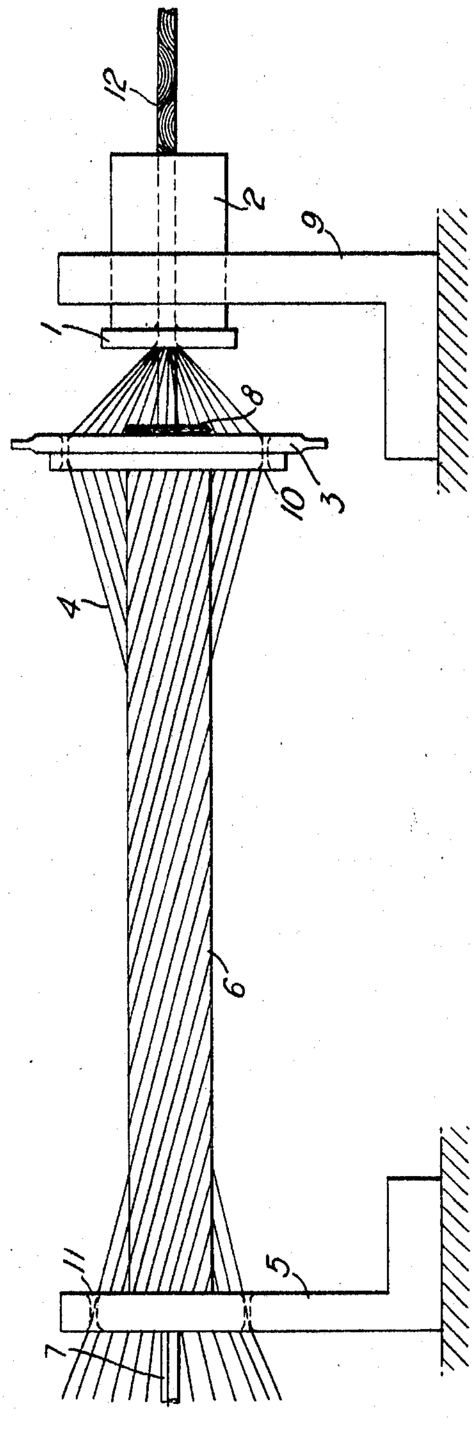

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METHOD AND APPARATUS FOR THE MANUFACTURE OF ELECTRIC CONDUCTORS

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ABSTRACT OF THE DISCLOSURE

In the method of forming an outer conductor or screen on a flexible core which comprises drawing a number of fine wires required to form the outer conductor or screen through an angularly reciprocating lay plate surrounding the core and, together with the core, through a forming die, the outer conductor or screen can be made self-retaining by the use of a forming die of certain forms and dimensions. Either the die is of uniform diameter equal to the core diameter plus twice the wire diameter and has a length exceeding the length between successive points of lay reversal, or a short bell-mouthed die having a bore of about 1.015 times the nominal core diameter plus twice the wire diameter is closely followed by a long bell-mouthed die having a bore of about 1.04 times that sum.

This invention relates to insulated electric conductors of the kind in which one or more than one insulated conductor is surrounded by an outer conductor or screen built up of fine wires, and to the manufacture of such conductors and screens. It is the practice to form such outer conductor or screen either as a tubular braid that is formed in situ on a core consisting of or comprising the insulated conductor or a group of insulated conductors or by laying the wires helically around the core in one or more layers, the wires in each layer all running helically in one and the same direction.

It has been suggested to form the outer conductor or screen of a plurality of fine wires which extend in a sinuous fashion along the core, each wire pursuing a helical path, first in one direction and then in a counter direction around the core and to secure the wires in position on the core by a binder or covering.

We have now discovered that we can obtain an outer conductor or screen consisting of or comprising a multiplicity of fine wires having a periodically reversing lay which requires no binder or covering to maintain the wires in position about the core by selecting for each size of core, wires of appropriate diameter and temper, an appropriate angular displacement between successive points of lay reversal and an appropriate longitudinal spacing of the points of lay reversal (which spacing depends on the angle of lay). Accordingly, our invention provides a core having on its surface an outer conductor consisting of or comprising a multiplicity of fine wires having a periodically reversing lay which is capable of maintaining itself in position on the core even during bending of the core, without the aid of a binder or covering. Examples of wires of appropriate temper are wires of annealed copper and aluminium wires.

Our invention includes a method of and apparatus for forming on an insulated conductor or other flexible core such a self-retaining outer conductor or screen.

One preferred method consists in drawing the wires required to form the outer conductor or screen through an angularly reciprocating lay plate surrounding the core and, together with the core, into and through a forming

die having a length exceeding the length between successive points of lay reversal of the wires of the outer conductor or screen and a diameter substantially equal to the core diameter plus twice the wire diameter. The forming die preferably has a bell-mouthed entrance.

Another preferred method consists in the same procedure modified by the use of a die arrangement comprising a first die having a land length of less than the core diameter and a bore approximately equal to 1.015×(nominal core diameter+2×wire diameter) and a second die having a land length not less than twelve times the core diameter and a bore approximately equal to 1.04×(nominal core diameter+2×wire diameter), the second die being co-axial with and contiguous with or in close proximity to the first die.

The first and second dies each have a bell-mouthed entrance of which the radius of curvature preferably approximates to the land length of the first die.

Arrangements of dies constructed in accordance with the above formulae have been successfully used to form self-sustaining outer conductors with a periodically reversing lay of which the distance between reversal points (measured along the core) may be of any desired value within a range extending from 2.5:1 to 15:1 relative to the core diameter. However in order to obtain cable attenuation values similar to those of a comparable cable having a braided screen formed of wires of the same size, a minimum ratio of the order of 12:1 is necessary.

The tension in the individual wires being laid on the core is preferably maintained at the lowest practical value compatible with snag-free running of the wire. It will normally be necessary to guide the wires towards the reciprocating lay plate by passing them through a fixed guide plate having a ring of spaced apertures, one for each wire, co-axial with the ring of apertures in the lay plate and hence co-axial with the core, which must also pass through the fixed guide plate. One important preferred feature of the apparatus in accordance with the invention that not only enables the tension in the wires to be kept to a small value but also inhibits any tendency of the wires to become entangled or to become longitudinally pre-shaped in their passage from the fixed guide plate to the reciprocating lay plate is the provision of rotatable spacing means for the wires located co-axially with the core between these two plates. An incidental function of the rotatable spacing means is that it prevents the wires from coming into contact with the cable core in its passage between the two plates.

The invention will be further illustrated by a description by way of example with reference to the accompanying drawing of examples of cables, methods of making them and apparatus for use in such methods. The drawing is a side elevation of a die arrangement in accordance with the invention showing a fixed guide plate and an oscillating lay plate by which the wires are fed into the die.

The method of the invention may be used to form a self-retaining layer of wires directly on the dielectric of a central conductor. In such case it will be appreciated that the term "nominal core diameter" is the nominal diameter of the dielectric wall of the central conductor. For example in the manufacture of TV downlead co-axial cable comprising a central conductor consisting of a 7/.010″ plain copper wire strand insulated with cellular polyethylene to a diameter of 0.128″, the outer conductor is formed of twenty-four plain annealed copper wires each of 0.010″ diameter applied with periodically reversing lay, the distance measured along the cable between successive points of reversal being within the range ⅜″ and 1⅛″ and preferably being about ½″ (if the lay length is considered to be the distance between alternate points of reversal, the lay length will be within the range ¾″ to

2¼"). The angular displacement between successive lay reversal points is between 270° and 360°.

The forming die used in the manufacture of these cables has a bell-mouthed entrance of radius 1/16", a length of 1½" and a bore of 0.140" and is positioned within ½" of the reciprocating lay plate. As so formed, the outer or co-axial conductor maintains its position on the core without any binder or other securing means even with repeated bending of the wire covered core to a radius of ten times its diameter.

Where, as will usually be the case, the wire covered core is to be given a seamless protective insulating covering of rubber or plastics material, this is preferably applied by an extrusion machine located at the outlet end of the closing die in which the outer conductor or screen is formed. The speed of travel of the core through the closing die and through the extruder may, in the case of the example above described, be from 6 to 70 feet per minute.

Where a higher degree of screening is required, the self-retaining layer of wires may constitute an outer component part of a composite outer conductor or screen and be applied on an insulated conductor enclosed in an envelope of thin metal, preferably copper or aluminium tape applied, preferably longitudinally, to the insulated conductor. In such case the term "nominal core diameter" means the nominal diameter over the metal envelope. Alternatively, as we have discovered, a composite outer conductor or screen may be formed of layers of wires applied with reversing lays, one layer directly on the other, providing the two layers of wires are out of phase with one another to a very substantial degree, they are preferably of equal period and out of phase by about 180°. In this case the term "nominal core diameter" means, insofar as it applies to the die used for the application of the inner layer of wires, the nominal diameter over the core on which the wires are applied and, insofar as it applies to the die used for the application of the outer layer of wires, the nominal diameter over the applied first layer.

An example of a cable having an outer conductor or screen constituted by an envelope of metal tape and a layer of wires applied with reversing lay will now be described together with a die arrangement for the application of the layer of wires.

The central conductor is a plain copper wire of 0.022" diameter and insulated with cellular polyethylene to a diameter of 0.105". To the insulated wire is longitudinally applied a copper tape having a width of 0.375" and a thickness of 0.0015". This is bent transversely round the conductor to form an envelope with overlapping edges. Over the metal tape covered core, whose maximum overall diameter is 0.110", are applied twenty-four plain annealed copper wires of 0.010" diameter with a distance between reversals of 1.3" and an angle between reversals of 360°. The wire covered core is subsequently provided with an extruded sheath of a polyvinyl chloride composition of a radial thickness of 0.025".

Electrical tests of this product showed that from the point of view of coupling impedance at frequencies above 50 mc./s. the cable constructed as above described by way of example is superior to that of a comparable cable having as its outer conductor a double braid.

The die arrangement by which the wires are applied is shown in the drawing. It comprises a first die **1** having a land length of 1/16" and a throat diameter of 0.132" and a second die **2** having a land length of 1½" and a throat diameter of 0.135". Both dies have a lead-in radius of 1/16". The first die is located with its rear face ⅝" in front of the front face of the oscillating lay plate and the front face of the first die and the rear face of the second die **2** are contiguous.

In the manufacture of the cable mentioned above the lay plate **3** is oscillated through 480° to give on the surface of the core an angle between reversals of 360°, as referred to in the description. The lay plate preferably moves with simple harmonic motion but we have found that deviations from pure simple harmonic motion do not substantially affect the product.

For example, the lay plate can be driven by a chain drive from the output shaft of a gear box, a pinion on the input shaft of which is driven by a straight toothed rack reciprocated rectilinearly by a crank. The diameter of the crank wheel and the length of the crank are such that the maximum annular velocity of the lay plate occurs 83° after one reversal and 97° after the other, thus making the curvature of the wires in the neighbourhood of alternate reversal points less than at the other reversal points.

Referring again to the drawing, it will be seen that the wires **4** pass through a fixed guide plate **5** spaced from the oscillating lay plate **3**. The oscillating lay plate **3** is supported on an outrigger bearing extending along the cable axis from the fixed guide plate **5** and inevitably the wires will wrap around this support as the lay plate **3** oscillates. To minimise the drag on the wires caused by this wrapping and unwrapping rotatable spacing means in the form of a freely rotatable sleeve **6** is mounted on the support for the bearing. In the present example, the sleeve is 5¾" in length, of outside diameter ⅝" and is of brass with a machine finished surface.

Although in the present example the sleeve is of uniform diameter and is equal in length to the spacing between the plates **3** and **5**, it will be appreciated that it can be of non-uniform diameter and need not extend over the whole distance between the plates, provided that it performs its essential functions of preventing the wires from coming into contact with the core and from becoming twisted together, and also preferably prevents them even from coming into contact with each other

The sleeve **6** is supported on roller bearings mounted on a rigid fixed tubular support, projecting from the guide plate **5**, through which support the cable core **7** passes freely. At its free end the tubular support carries a bearing for the lay plate **3** and from this bearing a threaded flange **8** projects. The flange **8** is adapted to carry a spreader (not shown) which is a smooth surfaced conical metal body shaped to make light contact with the wires **4** as they pass between the lay plate **3** and the first die **1** and formed with a central bore allowing free passage of the core **7**. The apex of the spreader is rounded to fit, with a small clearance, into the bell-mouthed entrance of the first die **1**, the minimum spacing between the spreader and the die mouth being slightly greater than the diameter of the wires **4**. The use of such a spreader is not essential.

Other forms of rotatable spacing means, than a freely rotatable sleeve such as the sleeve **6**, can be used. For example a number of freely rotatable guide plates, each with a ring of apertures for the wires, can be mounted at spaced intervals along the tubular outrigger support for the lay plate **3**. Instead of being freely rotatable, the additional guide plates can each be reciprocated in synchronism with the lay plate through an appropriate angle less than the angle through which the lay plate reciprocates, the angle of reciprocation being smaller the greater the distance of the reciprocating guide plate from the lay plate. A preferred method of reciprocating the additional guide plates is by means of one or more flexible members, for example steel wires or strands, each extending, through apertures in the guide plates, parallel to the wires **4** and each flexible member being attached directly or indirectly at one end to the fixed guide plate and at the other end to the lay plate. The flexible members are made extensible, for example by attaching them at one or both ends to the lay plate and/or the fixed guide plate by means of a tension spring or springs. When the lay plate runs in external bearings instead of on an internal bearing, the rotatable guide plates can also run in external bearings.

The die **2** is mounted on a fixed support **9** in such a way that it cannot rotate about its axis and the die **1** is attached to and supported by the die **2**. The apertures **10** and **11** for the wires **4** in the plates **3** and **5** are each bell-mouthed at both ends to a radius of 1/16″.

In order to keep the tension in the wires **4** to the minimum, they are preferably supplied from spools driven in accordance with the wire tension or drawn off fixed supply spools through a light flyer rotated about the spool axis by the wire and comprising a curved tube through which the wire passes.

Suitable apparatus is the subject of United States of America Patent No. 3,233,397.

The wire covered core **12** passes from the die **2** to an extrusion machine for applying the PVC sheath referred to above.

The apparatus described by way of example is in general, without major modification, suitable also for applying a conductor or screen of fine aluminium wires but when the softer grades of aluminium are used we prefer to use dies less liable to be contaminated and hence clogged by the aluminium than are metal dies suitable for use with copper. A suitable material for such dies is filled polytetrafluorethylene.

Our improved method of manufacture has the advantage over methods which involve continuous rotation in space of either the wire supply bobbin or the take-up reel, of permitting manufacture of the outer conductor and its covering in one continuous operation at high production speeds. As compared with the manufacture of co-axial conductors having a braided outer conductor or screen it has the added advantage of eliminating the operation of winding the wire upon braiding spindles.

What we claim as our invention is:

1. A method of forming on a flexible core a self-retaining outer conductor which comprises the steps of drawing a multiplicity of fine wires of appropriate temper to form the self-retaining outer conductor through a lay plate surrounding the core, bringing the wires into engagement with the core, angularly reciprocating the lay plate to lay the wires about the core with reversals of lay at successive points along the core and passing the core with the wires thereon into and through a forming die having a length exceeding the length between successive points of lay reversal of the wires of the outer conductor and a diameter substantially equal to the core diameter plus twice the wire diameter.

2. A method as claimed in claim **1** in which the angle of reciprocation of the lay plate is such that the angle of displacement between reversal points of the wires is at least 270°.

3. A method as claimed in claim **1** in which the motion of the lay plate approximates to simple harmonic.

4. A method of forming on a flexible core a self-retaining outer conductor which comprises the steps of drawing a multiplicity of fine wires of appropriate temper to form the self-retaining outer conductor at the lowest practical tension compatible with snag-free running through a lay plate surrounding the core, bringing the wires into engagement with the core, angularly reciprocating the lay plate to lay the wires about the core with reversals of lay at successive points along the core and passing the core with the wires thereon into and through a forming die having a length exceeding the length between successive points of lay reversal of the wires of the outer conductor and a diameter substantially equal to the core diameter plus twice the wire diameter.

5. A method as claimed in claim **4** in which the angle of reciprocation of the lay plate is such that the angle of displacement between reversal points of the wires is at least 270°.

6. In apparatus for forming a self-retaining outer conductor comprising a multiplicity of fine wires on a flexible

core comprising a forming die means for guiding the wires into the forming die comprising a lay plate and a fixed guide plate spaced from each other with the lay plate nearer the die, rotatable spacing means located between the guide plate and the lay plate, means for drawing the wires and the core individually through the guide plate, the rotatable spacing means and the lay plate and together through the forming die, and means for angularly reciprocating the lay plate to lay the wires about the core with reversals of lay at successive points along the core, a forming die having a length exceeding the distance by which the core and the wires are drawn forward between successive changes in direction of the lay plate.

7. Apparatus as claimed in claim **6** in which the spacing means is in the form of a freely rotatable sleeve.

8. Apparatus as claimed in claim **7** in which the sleeve is of uniform diameter.

9. A method of forming on a flexible core a self-retaining outer conductor which comprises the steps of drawing a multiplicity of fine wires of appropriate temper to form the self-retaining outer conductor through a lay plate surrounding the core, bringing the wires into engagement with the core, angularly reciprocating the lay plate to lay the wires about the core with reversals of lay at successive points along the core and passing the core with the wires thereon into and through a forming die arrangement comprising a first die having a land length of less than the core diameter and a bore approximately equal to 1.015×(nominal core diameter+2×wire diameter) and a second die having a land length not less than twelve times the core diameter and a bore approximately equal to 1.04×(nominal core diameter+2×wire diameter), the second die being co-axial with and in close proximity to the first die, the first and second dies each having a bell-mouthed entrance.

10. A method as claimed in claim **9** comprising maintaining in the fine wires the lowest practical tension compatible with snag-free running.

11. A method as claimed in claim **9** in which the radius of curvature of the bell-mouth of each of the first and second dies approximates to the land length of the first die.

12. A method as claimed in claim **9** in which the angle of reciprocation of the lay plate is such that the angle of displacement between reversal points of the wires is at least 270°.

13. A method as claimed in claim **9** in which the rate of reciprocation of the lay plate relative to the axial speed of the core is such that the ratio of the axial distance between points of reversal to the core diameter is between 2.5:1 and 15:1.

14. A method as claimed in claim **9** in which the motion of the lay plate approximates to simple harmonic.

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