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(54) Heating cable

(57) A heating cable (10) and a method of manufacturing a heating cable (10). The heating cable (10) comprises at least one conductor (12a,12b) extending along the cable (10), a conductive shield extending along the cable (10), and surrounding said at least one conductor (12a,12b); and at least one insulating separation layer (14a,14b) separating the conductive shield from said at least one conductor (12a,12b). At least a portion of said conductive shield comprises a shielding conductor (16) extending in a spiral around said at least one conductor (12a,12b), the spiral comprising a plurality of turns (16a-e), each turn (16a-e) being physically separated from a corresponding portion of an adjacent turn (16a-e).

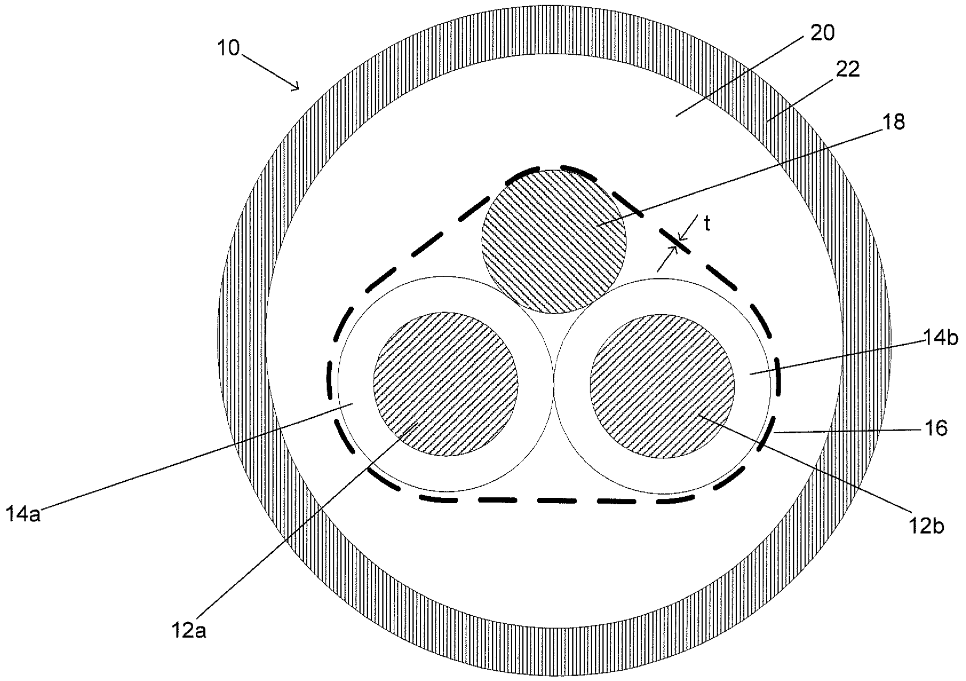

FIGURE 1

EP 2 026 629 A2

Description

[0001] The present invention relates to heating cables, and methods of manufacture and use of heating cables. Embodiments of the present invention are particularly suitable for, but not limited to, use in underfloor heating cables.

[0002] A wide variety of heating cables are known. A typical heating cable includes one or more conductors extending longitudinally along the cable. In some types of heating cable, the conductors act as resistive heating elements. In other types of heating cable, the conductors are arranged to provide power to an electrical heating element for instance a semi-conductive polymeric matrix extruded between the conductors. A controller may be connected to the heating cable, so as to control the supply of electrical power to the heating cable. The controller can also act as a safety device, so as to ensure that the electrical power stops if the temperature of the heating cable exceeds a predetermined threshold or if an electrical fault is detected. Heating cables can also be self-regulating, for instance formed of material that limits the temperature reached by the cables and/or prevents operation of the cable if a fault occurs. Such self-regulating cables typically comprise materials having a negative temperature coefficient of resistance and/or materials having a positive temperature coefficient of resistance.

[0003] Safety standards often require that the electrical heating cable is surrounded by an electrical earth or ground shield such as a metallic shield for connection to electrical earth/ground. Sharp conductive objects (such as pins) that penetrate such heating cables will thus first penetrate the metallic shielding connected to earth, before contacting the electrical conductors. One electrical safety standard requires the cable to accommodate penetration by a 1mm diameter pin in this way. Thus, the sharp object would be grounded prior to contacting the electrical conductors that carry the electrical power to reduce the chance of an electrical shock, or at least reduce the effect of an electrical shock that might occur, to a person or device in electrical contact with the sharp object.

[0004] One known type of earth shielding takes the form of metallic braiding forming a close-knit mesh of metal wires, surrounding the electrical conductor(s). An advantage of braiding is that the shielding is relatively flexible. However, the braiding is relatively expensive and time consuming to form around the electrical conductors. Known electrical safety standards require a minimum conductance to earth. For example, one requirement is that the earth/ground shield has a current carrying capacity equivalent to a 0.5mm diameter round copper wire

[0005] An alternative solution of earth shielding is to provide a continuous metal sheath that completely encapsulates the conductor(s) of the heating cable. A known material for forming such a shield is aluminium. The encapsulation technique tends to be cheaper than metallic braiding, but provides poor flexibility.

[0006] In many applications, it is desirable that the heating cable is relatively flexible, for instance within electrical blankets, or for underfloor heating, or indeed for many other applications in which it may be desirable or necessary for the heating cable to flex during use or during installation.

[0007] US-5558794 discloses a coaxial heating cable comprising a central electrically conductive heating core, an electrically insulating polymeric sheath surrounding the core and an outer electrically conductive ground shield enclosing the polymeric sheath. Complete coverage of the core is provided by means of helically wound wire strands. This allows the cable to earth a pin which pierces the outer sheath before contact is made with the core. The preferred embodiment specifies using 24 strands of tin plated copper of diameter of approximately 0.1mm diameter. This is insufficient to meet known safety standards requiring that a ground shield has a current carrying capacity equivalent to a 0.5mm diameter round copper wire. Due to the large amount of metal within the braid and limited space for movement within the cable itself, the cables disclosed in US-5558794 are inflexible and expensive.

[0008] US-2005/0167134 describes a heating cable substantially free from electromagnetic fields comprising a pair or spirally twisted heating wire elements and a tubular sheath made of an electrically conductive material covering the pair of spirally twisted heating wire elements. The tubular sheath may be constructed of a plurality of small-diameter electrically-conductive metal wires braided together to form a tubular shielding. It is stated that a function of the metal sheath is to mechanically resist impacts as strong as 1001bs. In the preferred embodiment the metal sheath is a constructed by braiding together a plurality of small-diameter wires. It is well known that the braiding process uses both a relatively large amount of metal and is a very slow process in terms of throughput. Therefore, while the preferred embodiment would offer a good degree of protection with regards to earthing a pin of 1mm diameter if it pierced the outer sheath, it is relatively expensive and is a bottleneck in the manufacture of a cable requiring braiding.

[0009] Another embodiment of US-2005/0167134 provides a metal tape spirally wound or longitudinally applied to the pair of spirally twisted heating wire elements as an alternative or addition to the braided metal wires. Such a metal tape would have to be substantial in order to resist impacts of 1001bs and therefore would be brittle and have poor flexibility adversely affecting the final product characteristics and increasing the complexity of manufacture. Furthermore, in order to meet the requirement that the tubular sheath covers the pair of spirally twisted heating wire elements, it is clear that for embodiments in which the tubular sheath comprises only a spirally wound metal tape adjacent turns of the spiral must overlap.

[0010] The two primary requirements of a heating cable to be used in an underfloor heating application are thus:

1. A pin of 1mm diameter, if pierced the outer sheath, must be earthed before the touching the live parts - i.e. the core conductor.
2. The ground conductor must have a current carrying capacity equivalent to a 0.5mm diameter round copper wire.

[0011] A secondary requirement is the cable should be able to withstand an impact of approximately 50kgs without destroying the integrity of any electrical or mechanical insulation within the cable.

[0012] It is apparent from the prior art discussed above that individual requirements may be fulfilled adequately however meeting the all of the above requirements results in a cable which is expensive in terms of material cost, troublesome to manufacture and suffers from poor flexibility.

[0013] It is an aim of embodiments of the present invention to address one or more problems of the prior art, whether referred to herein or otherwise. It is an aim of an embodiment of the present invention to provide a heating cable that includes a relatively flexible but cost effective conductive shield for earthing. In particular, it is an aim of an embodiment of the present invention to provide such a heating cable able to meet the above discussed requirements for underfloor heating applications.

[0014] In a first aspect, the present invention provides a heating cable comprising: at least one conductor extending along the cable; a conductive shield extending along the cable, and surrounding said at least one conductor; and at least one insulating separation layer separating the conductive shield from said at least one conductor, wherein at least a portion of said conductive shield comprises a shielding conductor extending in a spiral around said at least one conductor, the spiral comprising a plurality of turns, each turn being physically separated from a corresponding portion of an adjacent turn.

[0015] Formation of the conductive shield in the form of a spiral allows the provision of a heating cable having earth shielding that is relatively flexible. Further, as spiralling is a relatively simple process compared to braiding, such a conductive shield can be formed faster and more easily than a prior art braid shield, and hence generally at a lower cost. The configuration of the spiral can be controlled such that adjacent turns on the spiral have a predetermined separation arranged to meet a predetermined safety regulation such as any predetermined safety regulation relating to intrusion by sharp objects. In many instances, a spiral can be formed that includes less material than a braided shield meeting the same regulation (for instance having the same minimum separation between adjacent portions), hence reducing cost. In particular, spacing adjacent turns of the spiral apart significantly reduces the amount of material within the shielding conductor. Providing the spacing between adjacent turns is controlled, the cable retains the ability to meet regulations requiring a sharp conductive object penetrating the cable to be earthed before contacting a conductor.

[0016] The heating cable may further comprise a conductive conduit extending along the cable, in electrical contact with said shielding conductor.

[0017] Said conductive conduit may have a cross-sectional area greater than the cross-sectional area of the shielding conductor.

[0018] Said conductive conduit may comprise a plurality of conductive fibres extending along the cable.

[0019] Said plurality of conductive fibres may be intertwined.

[0020] Said at least one insulating separation layer may separate the conductive conduit from said at least one conductor.

[0021] Said conductive conduit may be helically wrapped with said at least one conductor.

[0022] Said portion of said conductive shield may comprise a shielding conductor extends in a spiral around both said at least one conductor and said conductive conduit.

[0023] Said at least one insulating separation layer may comprise a respective insulating separation layer extending around each of said at least one conductor.

[0024] Said at least one conductor may comprise a first conductor and a second conductor, each extending along the cable, and connected at one end of the cable in series such that if the first and second conductors are connected at the other end of the cable to respective poles of a power supply, equal currents flow in opposite directions through adjacent portions of the conductors.

[0025] The separation between adjacent turns may be less than 2mm.

[0026] The separation between adjacent turns may be at least 0.1mm.

[0027] The shielding conductor may have a tensile strength of at least 500N/mm^2.

[0028] Said shielding conductor may be formed in the shape of a tape.

[0029] Said portion of said conductive shield may extend along the complete length of the cable.

[0030] Said conductive shield may be for connection to electrical earth when in use.

[0031] In a second aspect, the present invention provides a method of installing a heating cable as herein described, comprising the step of connecting said shielding conductor to an electrical earth.

[0032] In a third aspect, the present invention provides a method of manufacturing a heating cable comprising: providing at least one conductor extending along the cable; providing a conductive shield extending along the cable and surrounding said at least one conductor; and providing at least one insulating separation layer separating the conductive shield from said at least one conductor, wherein at least a portion of said conductive shield comprises a shielding conductor extending in a spiral around said at least one conductor, the spiral comprising a plurality of turns, each turn being physically separated from a corresponding portion of an adjacent turn.

[0033] Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view through a heating cable in accordance with an embodiment of the present invention;
Figure 2 is a close-up side view of the heating cable of Figure 1, with both the protective outer jacket and insulating membrane removed; and
Figure 3 is a schematic diagram of the heating cable of Figure 1 connected to an electrical power supply.

[0034] As discussed above, the two primary requirements of a heating cable to be used in an underfloor heating application are thus:

1. A pin of 1mm diameter, if pierced the outer sheath, must be earthed before the touching the live parts - i.e. the core conductor.
2. The ground conductor must have a current carrying capacity equivalent to a 0.5mm diameter round copper wire.

[0035] A secondary requirement is the cable should be able to withstand an impact of approximately 50kgs without destroying the integrity of any electrical or mechanical insulation within the cable.

[0036] By recognising the two primary requirements as separate and hence incorporating two separate means for meeting these requirements, a low cost, yet flexible, cable may be achieved which is relatively straightforward to manufacture.

[0037] To meet the requirement of earthing a pin of 1mm diameter, a conductive shield in the form of a shielding conductor is helically wound around insulated core conductors. A flattened round wire may be used, which is advantageous over a round wire in that it has increased strength by work hardening of the metal during the flattening process. Additionally, a flattened round wire has a reduced profile therefore decreasing the overall diameter of the cable. If the cable is helically wound such that the gap between adjacent turns is less than 1mm, ideally approximately 0.8mm, it is impossible to penetrate the cable to contact the core conductor without touching at least one turn of the conductive shield.

[0038] In order to meet the second primary requirement, a conductive conduit may extend along the cable, in electrical contact with the said shielding conductor. Such a conductive conduit may comprise a plurality of conductive fibres and have a cross sectional area equivalent to at least the cross sectional area of a 0.5mm diameter round wire. Due to the conductive conduit being in electrical contact with the helically wound shielding conductor, the shielding conductor resistance is now in parallel with the conductive conduit resulting in a low overall electrical resistance satisfying the requirement that the shielding conductor (connected to earth) must have a certain minimum current carrying capability. Preferably, the combined cross sectional area of both the helically wound conductive shield and conductive conduit may be equivalent to the cross sectional area of a 0.5mm diameter round copper wire.

[0039] Embodiments of the present invention therefore provide a low cost solution to providing an underfloor heating cable because a minimal amount of metal may be used in order to satisfy both primary requirements. A further advantage is the minimal impact on flexibility due to the helically wound conductive shield. Finally the manufacturing throughput does not suffer because the conductive conduit and two conductive heating cores may all be introduced at the same stage, i.e. during spiralling of the conductive shield which operates at a much greater speed than certain known braiding operations.

[0040] In order to meet the secondary requirement that the cable should be able to withstand an impact of approximately 50kgs without damage to any insulation, specific polymers for use as the separation layer of the core conductors and the outer protective sheath may be chosen to augment the cable properties. Such polymers should have a high hardness (preferably over 70 on the Rockwell R hardness scale), a high tensile modulus (preferably over 1000 MPa) and a high impact strength (preferably over 50kJ/m2 at 23°C). An advantage to using specialised polymers to increase the mechanical strength of the cable is the extrusion of plastic offers throughputs in excess of 50m/min in comparison to braiding as disclosed in the prior art which typically operates at 0.5m/min, that is two orders of magnitude slower.

[0041] As illustrated in Figures 1 & 2, a heating cable 10 comprises two conductors 12a, 12b extending longitudinally along the full length of the cable. In this particular embodiment, the conductors 12a, 12b act as heating elements. Each conductor 12a, 12b is surrounded by a respective insulating layer 14a, 14b. A conductive conduit 18 also extends along the full length of the cable 10. The conductor conduit 18 can extend parallel to the conductors 12a, 12b.

[0042] The conductive conduit 18 can be formed of a single piece of material for instance of a wire such as copper. However, more preferably, for increased flexibility, the conductive conduit 18 is formed of a plurality of intertwined conductive fibres. For example, the conduit could be a stranded core, or could be braided. In preferred embodiments the conduit is a stranded wire comprising approximately seven bunched wires. As such a conduit can be pre-formed, a cable including such a stranded conduit can be formed relatively quickly and cheaply. Figure 2 illustrates a braided conduit 18, with the conduit 18 being seen to comprise a plurality of intertwined conductive fibres. In the example illustrated in Figure 2, the conductive fibres take the form of thin copper wires, braided together.

[0043] A conductive shield is provided by a shielding conductor 16 extending in a spiral or helix around the conductors 12a, 12b. In the example shown in Figures 1

& 2, the shielding conductor 16 extends in a spiral around both the conductors 12a, 12b and the conductive conduit 18. The shielding conductor 16 binds or holds together the conductive conduit 18 and the conductors 12a, 12b.

[0044] Figure 2 illustrates the individual turns 16a, 16b, 16c, 16d, 16e of a section of the spiral formed by the shielding conductor 16. Each turn, wrap or round 16a-16e of the shielding conductor 16 is in electrical contact with the conductive conduit 18. As will be explained further below, such an electrical connection ensures a good grounding path.

[0045] To prevent electrical shorting, the insulating layers 14a, 14b separate the conductors 12a, 12b from the adjacent conductive conduit 18, and also from the shielding conductor 16.

[0046] At least one further electrically insulating layer extends around the shielding conductor 16. In the example shown in Figure 1, an electrically insulating membrane 20 surrounds the shielding conductor 16 (and the conductors 12a, 12b and conductive conduit 18). The insulating membrane 20 is preferably waterproof. That insulating membrane 20 is further surrounded by a protective outer jacket 22 for instance formed of nylon, so as to form a sheath around the cable 10.

[0047] For ease of manufacturing, the spiral of the shielding conductor 16 is formed to be a regular shape, such that a uniform separation d exists between adjacent turns 16a-16e of the shielding conductor. The separation d can be any predetermined separation suitable for meeting the desired use of the heating cable. Typically, each turn 16a-16e is separated by a non-zero amount from the adjacent turn 16a-16e. Typically, d is greater than 0.1mm.

[0048] The shielding conductor 16 is of predetermined width w and predetermined thickness t. Preferably, as indicated within the Figures, the shielding conductor is formed as a tape, that is as a relatively long piece of conductive material, with a width w greater than the thickness t. For example, during manufacture, the shielding conductor could be formed into a tape structure from a wire for instance by flattening of a wire. Preferably, the thickness t is one tenth or less of the width w. Formation of the shielding conductor 16 as a tape facilitates the wrapping of the shielding conductor 16 in a spiral around the conductors 12a, 12b, in the manufacturing process. Further, by providing a relatively thin tape, the overall size of the heating cable (for instance the total external diameter of the heating cable) is minimised. For example, typically the overall diameter of the heating cable 10 would be less than 5mm, for instance the cable 10 may have a diameter of around 3.5mm or less.

[0049] The shielding conductor can be formed of any conductive material, including a metal such as copper. To facilitate the winding of the shielding conductor during the manufacturing process, preferably the shielding conductor is formed of a material having a higher tensile strength than copper. For example, copper typically has a tensile strength of around 330N/mm^2, whilst preferably the material of the shielding conductor has a tensile strength of 500N/mm^2 or greater, and more preferably a tensile strength of 750N/mm^2 or greater. For example, the shielding conductor could be formed of a copper alloy, such as a copper tin alloy.

[0050] Typically, the conductive conduit will have a cross-sectional area larger than the cross-sectional area of the conductive conduit. The cross-sectional area of the conductive conduit is preferably at least double, and more preferably at least four times the cross-sectional area of the shielding conductor.

[0051] The precise dimensions t, w of the shielding conductor 16, the cross-sectional area (or at least the effective cross-sectional area) of the conductive conduit 18, and the separation d between adjacent turns 16a-16e of the shielding conductor can have any predetermined value, depending upon the use of the heating cable. Such values can be selected to meet appropriate safety standards.

[0052] As illustrated in Figure 3, in use the heating cable 10 will be connected to a power supply 30. The electrical conductors 12a, 12b of the heating cable 10 are connected to corresponding electrodes 32a, 32b of the power supply 30. The power supply 30 may comprise a controller, for controlling delivery of the electrical power to the conductors 12a, 12b. In the particular example shown, the opposite ends of the conductors 12a, 12b from the electrodes 32a, 32b are connected in series, such that equal currents flow in opposite directions through adjacent portions of the conductors 12a, 12b (in both directions along each conductor, when the power supply 30 provides an AC supply).

[0053] The shielding conductor 16 is connected to an electrical earth connection 34. In the schematic diagram of Figure 3, the shielding conductor 16 is represented by a dotted box. In the particular embodiment illustrated in Figures 1 & 2, the shielding conductor 16 is in electrical contact with the conductive conduit 18, and hence the shielding conductor is actually connected to the electrical earth 34 via the conductive conduit 18.

[0054] Thus, in use, if an object having a diameter greater than the separation d between the turns 15a-16e attempts to penetrate the heating cable 10, the object will first contact the shielding conductor 16. As the shielding conductor 16 is in electrical contact (on each turn) with the conductive conduit 18, the penetrating object will be electrically earthed prior to it touching/penetrating through to the electrical conductors 12a, 12b. Thus, the shielding conductor provides an earthing shield.

[0055] It should be appreciated that the above embodiment is described by way of example only, and that various alternatives will be apparent to the skilled person as falling within the scope of the claims.

[0056] For example, the use of the shielding conductor has been described in conjunction with one particular type of heating cable. However, it should be appreciated that such a conductor is equally applicable to other types of heating cable having different configurations of conductors.

[0057] Within the preferred embodiment, the shielding conductor 16 is described as being in electrical contact with a conductive conduit 18, with that conduit 18 being connected to an electrical earth in use.

[0058] It should be appreciated that the shielding conductor need not provide an electrical earth shield, but could be used in other electrical shielding requirements. Equally, the heating cable need not comprise the conductive conduit 18, but instead the shielding conductor 16 could be connected directly to an electrical earth connection 34.

[0059] However, by providing both the conductive conduit 18, and the shielding conductor 16, a flexible, relatively compact heating cable can be formed.

[0060] The size (cross-sectional areas) of the shielding conductor and the conductive conduits can be selected in dependence upon the relevant application. The cross-sectional areas, in combination with the conductivity of the materials of the shielding conductor and the conductive conduit, will determine the current that may be safely carried by the shielding conductor/the conductive conduit. Typically, in many applications the standard, or intended use of the heating cable, will set a minimum conductance to earth. For example, one requirement is that the earth/ground shield has a current carrying capacity equivalent to a 0.5mm diameter round copper wire, whilst a US standard relates to the current carrying capacity being equivalent to that of a 0.75mm diameter wire. Depending upon the intended use, the conductive conduit could have a cross-sectional area at least equivalent to that of either a 0.5mm diameter wire, or a 0.75mm diameter wire.

[0061] Typically, the shielding conductor would have a smaller cross-sectional area than the conduit for instance the shielding conductor could be formed having a cross-sectional area equivalent to that of a wire having a diameter less than 0.2mm. For example, it could be formed from a wire having a diameter of 0.2mm or less, which is then subsequently flattened into a tape. The thickness of the tape could be approximately 0.05mm, with the width w of the tape being around 1mm. Typically, the width w of the tape would be of the same order of magnitude as (or indeed, have a value within 50% of, or more preferably 20% of) the value of the separation d between adjacent rounds of the tape.

[0062] The separation d between adjacent rounds of 16a-16e of the shielding conductor 16 can be selected depending upon the desired application. In most instances, it will be desirable to maximise the separation d, whilst still keeping within the desired safety criteria. The greater the separation d between adjacent turns, the less material that is required to form the shielding conductor along a predetermined length of cable. However, the separation d must also meet the requisite safety criteria. Thus, typically, d will be less than 2mm.

[0063] One known safety test is that the earth shielding must result in earthing a pin of diameter 1mm that pierces the electrical cable. In such an instance, the separation d will be less than the width of the pin. For example, an appropriate separation d to meet such a safety criteria would be to provide a separation of approximately 0.8mm or less.

Claims

1. A heating cable comprising:

at least one conductor extending along the cable;

a conductive shield extending along the cable, and surrounding said at least one conductor; and

at least one insulating separation layer separating the conductive shield from said at least one conductor,

wherein at least a portion of said conductive shield comprises a shielding conductor extending in a spiral around said at least one conductor, the spiral comprising a plurality of turns, each turn being physically separated from a corresponding portion of an adjacent turn.

2. A cable as claimed in claim 1, further comprising a conductive conduit extending along the cable, in electrical contact with said shielding conductor.

3. A cable as claimed in claim 2, wherein said conductive conduit has a cross-sectional area greater than the cross-sectional area of the shielding conductor.

4. A cable as claimed in claim 2 or claim 3, wherein said conductive conduit comprises a plurality of intertwined conductive fibres extending along the cable.

5. A cable as claimed in any one of claims 2 to 4, wherein said at least one insulating separation layer separates the conductive conduit from said at least one conductor.

6. A cable as claimed in any one of claims 2 to 5, wherein said conductive conduit is helically wrapped with said at least one conductor.

7. A cable as claimed in any one of claims 2 to 6, wherein said portion of said conductive shield comprising a shielding conductor extends in a spiral around both said at least one conductor and said conductive conduit.

8. A heating cable as claimed in any one of the above claims, wherein said at least one insulating separation layer comprises a respective insulating separation layer extending around each of said at least one conductor.

9. A heating cable as claimed in any one of the above claims, wherein said at least one conductor comprises a first conductor and a second conductor, each extending along the cable, and connected at one end of the cable in series such that if the first and second conductors are connected at the other end of the cable to respective poles of a power supply, equal currents flow in opposite directions through adjacent portions of the conductors.

10. A cable as claimed in any one of the above claims, wherein the separation between adjacent turns is less than 2mm.

11. A cable as claimed in claim any one of the above claims, wherein the separation between adjacent turns is at least 0.1mm.

12. A cable as claimed in any one of the above claims, wherein the shielding conductor has a tensile strength of at least 500N/mm^2.

13. A cable as claimed in any one of the above claims, wherein said shielding conductor is formed in the shape of a tape.

14. A cable as claimed in any one of the above claims, wherein said portion of said conductive shield extends along the complete length of the cable.

15. A method of manufacturing a heating cable comprising:

providing at least one conductor extending along the cable;
providing a conductive shield extending along the cable and surrounding said at least one conductor; and
providing at least one insulating separation layer separating the conductive shield from said at least one conductor,
wherein at least a portion of said conductive shield comprises a shielding conductor extending in a spiral around said at least one conductor, the spiral comprising a plurality of turns, each turn being physically separated from a corresponding portion of an adjacent turn.

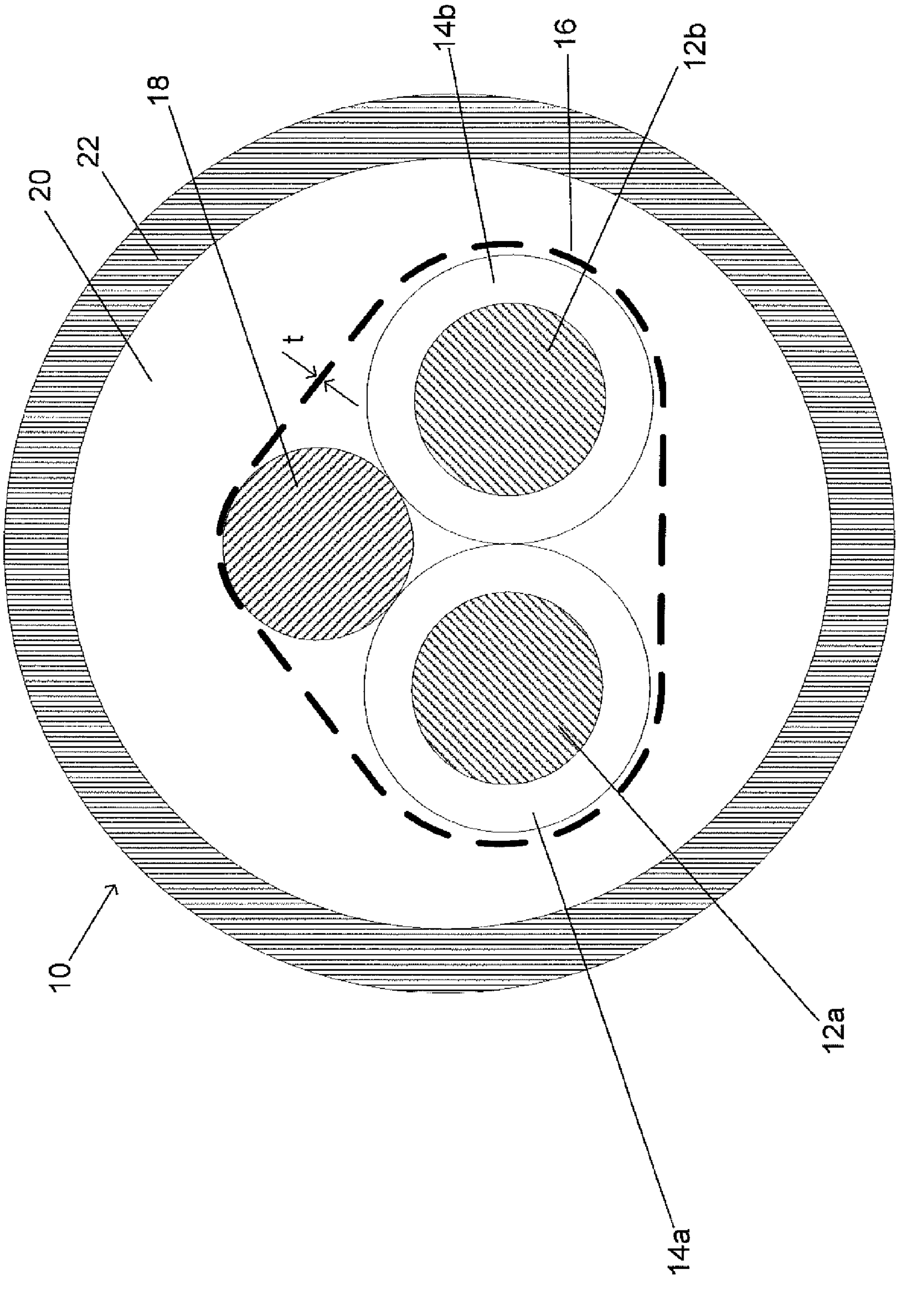

FIGURE 1

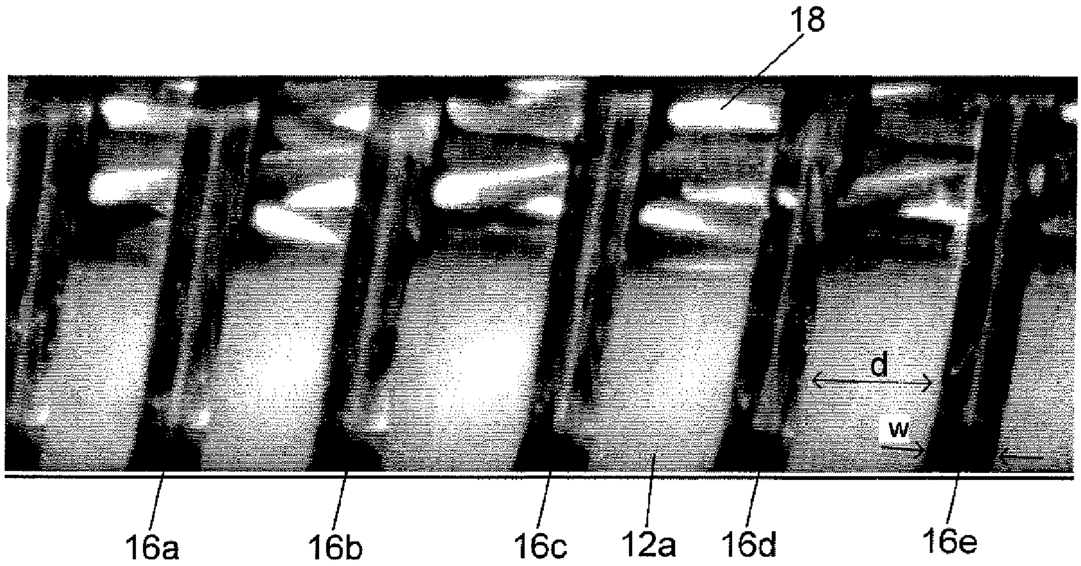

FIGURE 2

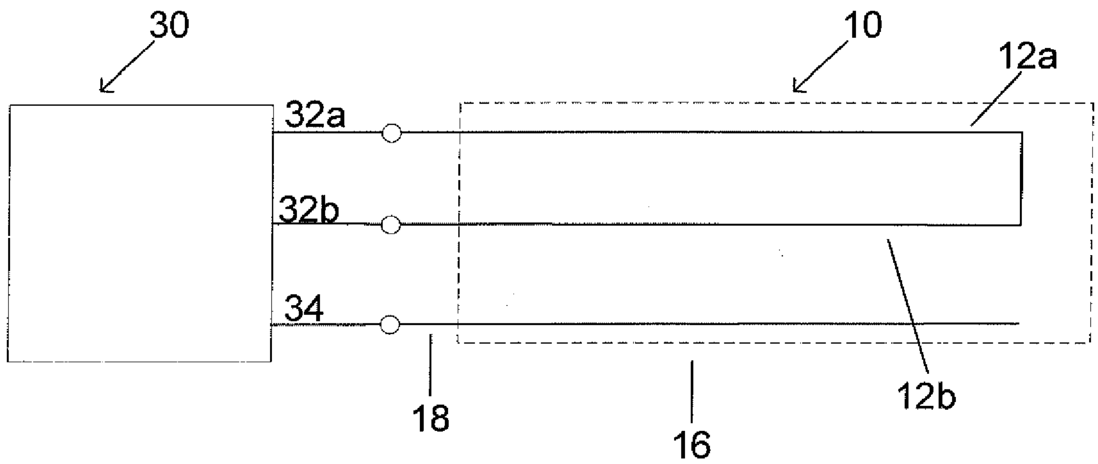

FIGURE 3

REFERENCES CITED IN THE DESCRIPTION

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