Oct. 13, 1936. R. MAUTSCH 2,057,242

PROCESS OF MAKING ELECTRIC CONDUCTORS

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Fig. 1.

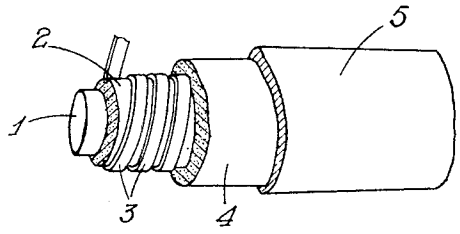


Fig. 2.

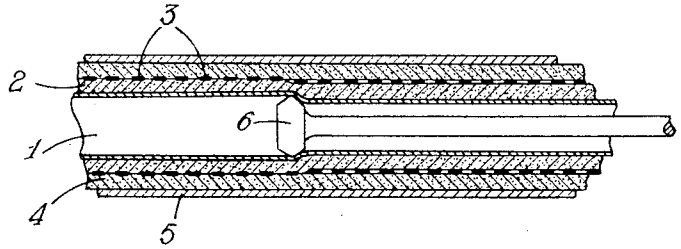


Fig. 3.

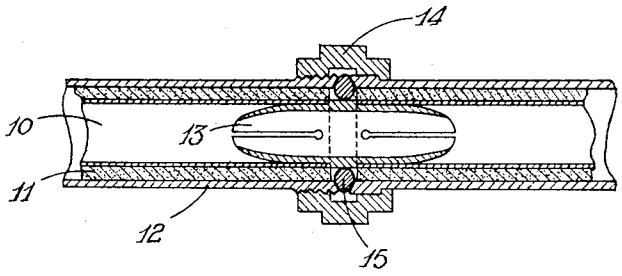


Fig. 4.

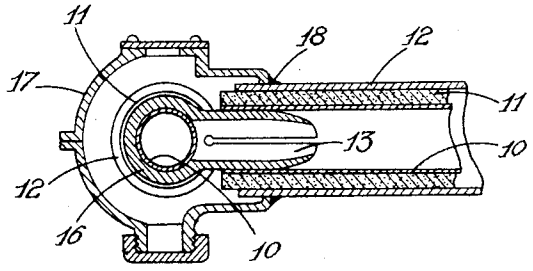


Fig. 5.

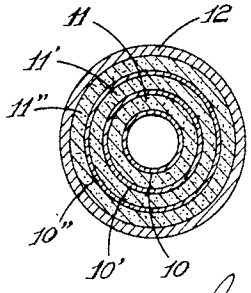


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Fig. 6.

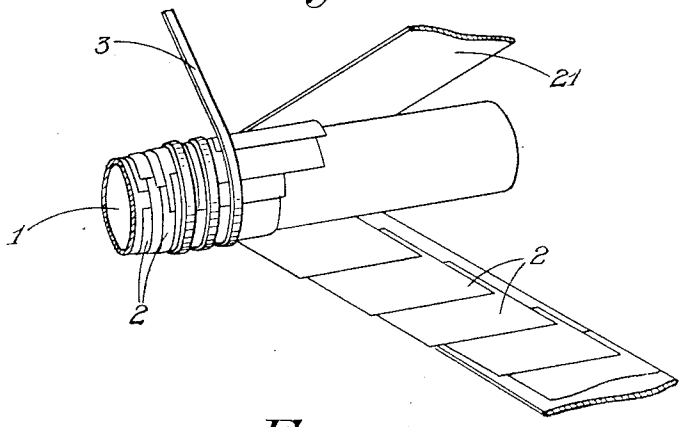



Fig. 7.

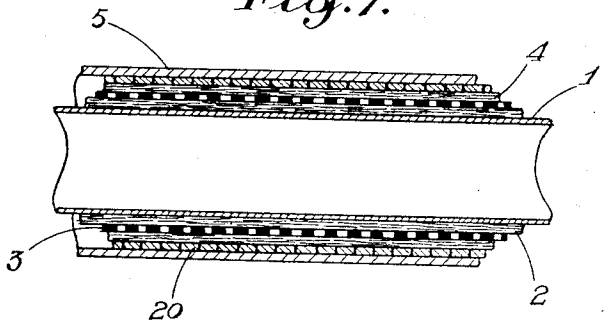



Fig. 8.

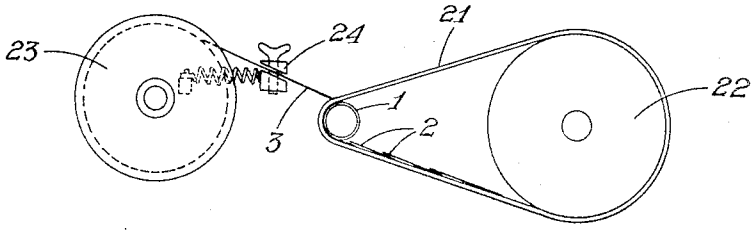
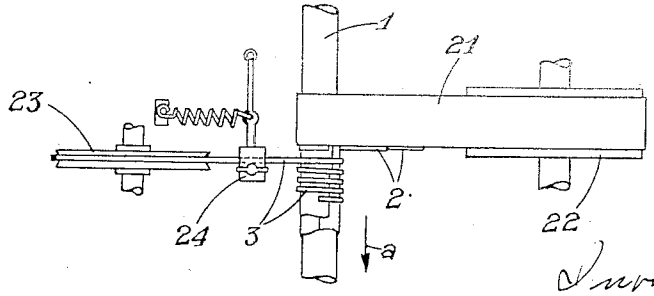



Fig. 9.

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# UNITED STATES PATENT OFFICE

2,057,242

## PROCESS OF MAKING ELECTRIC CONDUCTORS

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Application May 29, 1935, Serial No. 24,112
In Belgium June 9, 1934

8 Claims. (Cl. 201—67)

This invention refers to the manufacture of insulated electric conductors, such as heating resistances, and of cables for power transmission, which comprise a core and a sheath or sleeve, both of concentric tubular shape, separated by one or more annular layers of non-conductive material, in which the heating wire is embedded in the case of a heating resistance. It is very important that the insulating material of these conductors should be well compressed between the core and the sleeve, especially in the case of heating resistances in which the insulating material is exposed to disaggregation under the action of high temperatures and to the strains of expansion and contraction of the heating wire. It has already been suggested that the insulating material could be compressed by causing the conductor to be drawn out or laminated, which process has for effect, the re-tightening of the sleeve, but only at the price of lengthening it, which causes the displacement of the insulating material, and is only practicable when such material is in pulverulent or plastic form.

In accordance with the present invention, the "in situ" compression of the insulating material of the conductor is assured by expanding the tubular core by a mandrel, by hydraulic pressure, or by any other suitable means.

The expanded tubular core presses the insulating material forcefully between it and the sleeve, without causing any appreciable deformation in the aggregation of the conductor. If this latter be composed of a heating wire wound in the insulating material, this wire will be firmly held by the compressed insulating material, and there can be no play, even under the effect of vibration or violent shocks. In addition, the di-electric coefficient and the thermal conductivity of the insulating material are increased by the compression. If the insulated conductor is intended to be used as a cable for power transmission, the compression of the insulating material will give to it, qualities of water-tightness and of di-electric rigidity, which are very favourable to perfect insulation of the core through which the electric current is passed.

According to a preferred method of carrying out my invention, I avoid the use of binding agents or other materials capable of giving combustion products liable to soil and lower the quality of the insulating material. To this end, I apply the insulating material in sheet form and I subject said sheets, without binding agent, to a preliminary compression while it is being applied, i. e. before the tubular core is expanded. To effect this preliminary compression I use the conductor itself, while it is being wound. I then surround the winding with a further insulating layer which in turn is tightly compressed by winding around it a metal wire or strip forming a tight wrapper band.

When there are a plurality of concentric conductors, each conductor is used for compressing the underlaying insulating layer, and an encircling band or wire is tightly wound around the whole element. This encircling band is intended not only to compress the parts enclosed thereby, but also to expel the air from the superposed insulating layer.

The encircling winding being completed, the composite element is introduced into a tubular metal sheath of a diameter just sufficient to receive it. A relatively slight expansion of the inner tube then is sufficient to firmly clamp the insulating material between the concentric parts of the element, without the insulating material being damaged or subjected to excessive mechanical stresses.

The accompanying drawings illustrate, by way of example, some embodiments of my invention.

Fig. 1 shows in perspective, a section of an electric heating resistance partially stripped in order to show the concentric elements.

Fig. 2 is a view of a longitudinal section of a portion of resistance, illustrating the process of expansion.

Fig. 3 represents, in longitudinal section, two portions of a tubular cable joined end to end.

Fig. 4 shows a cable joining at right angles,

Fig. 5 is a cross-section of a cable with several conductors.

Fig. 6 illustrates the winding of insulating material in sheet form.

Fig. 7 is a longitudinal section of a complete element with sheet insulation.

Figs. 8 and 9 are respectively an elevation and a corresponding plan view, on a smaller scale, showing the winding of the insulating sheets and of the wire for compressing same.

In Figs. 1 and 2, the heating resistance consists of a tubular core 1 of malleable metal, as for example, a copper tube, on which is placed an insulating sleeve 2, for example of mica or mica composition, around which the resistance wire 3 is wound helically. A second insulating sleeve 4 surrounds the wire 3 and the whole is placed in a tubular sheath or sleeve 5, advan-

tageously composed of a harder metal than the core 1, for example, of steel.

As these various elements may be readily slid one into the other, the process of manufacture is very easy. In order firmly to unite the elements and to compress the insulating body on to the resistance wire, the malleable inner tube is expanded. For this purpose, a fluid may be introduced under pressure, or, as is shown in Fig. 2, an expanding tool 6 may be drawn through the tube 1, the diameter of the tool being greater than the original diameter of the tube. It will be understood that the expansion of the core 1 compresses the insulating bodies 2 and 4 against the internal wall of the sleeve 5. The insulating material is forced between the turns of the resistance wire 3, which are thus definitely locked in position. Neither the disaggregation of the insulating material through heat, nor the expansion or contraction stresses of the heating wire, nor vibrations nor exterior shocks can cause any loosening, so that all risk of over-heating or of fusion by "hot points", or by contact of the convolutions of the wire, is eliminated.

The tubular resistance may be used to heat a circulating liquid, as well outside of the sleeve 5 as inside of the core 1. It may be fitted with fins or arranged in any suitable manner in a heating apparatus.

In Figs. 3 and 4, which show an electric cable in accordance with the invention, 10 is the tubular core of the cable, for example a copper tube, 11 is an insulating sleeve placed over the core, and 12 is the tubular metal sheath or sleeve, which surrounds the whole. As in the case of the resistance described above, the tubular core 10, which, in this case, serves as the conductor, in the proper sense of the word, is suitably expanded to compress the insulating material 11 between it and the sleeve 12. The compression of the insulating material prevents the presence of empty spaces or of air pockets in the insulation of the cable and assures absolute water-tightness.

Two portions of cable manufactured in this manner may be electrically connected end to end in a very simple way, by means of pins 13 fitted into their cores 10, and the joining may be tightened by means of a ring 14 screwed on the joined extremities of the sleeves 12. A water-tight fitting 15 completes the joint.

In the case of an angle joint, as is shown in Fig. 4, a pin 13 fitted into the core 1 of one of the portions of the cable is made with an eye 16 clamped around the stripped core of the other portion, and the whole is placed in a junction box 17 welded at 18 to the sleeve 12.

Fig. 5, shows a cable with a plurality of concentric tubular conductors 10, 10' and 10'', which is made by expanding, in the first place, the tube 10'' in the sleeve 12, then the tube 10' in the tube 10'' and finally, the tube 10 in the tube 10'.

Referring to Figs. 6 and 7, 1 is the tubular core, of copper or other malleable metal, 2 the first layer of insulating material, 3 the conductor, for example a resistance wire or strip tightly wound around the layer 2, and 4 is the second insulating layer. 20 is an encircling wire or strip which is tightly wound around the insulating layer 4, and 5 is the outer tube which forms a protecting sheath for the whole element.

In order to compress the successive layers of insulating material I may advantageously operate as follows.

The tubular core 1 being rotated and being simultaneously moved longitudinally in the direction of the arrow *a* (Fig. 9) on a suitable support (not shown), I apply thereon the first insulating layer which comprises sheets 2, for example of mica, fed by a belt 21 which is rotated by a pulley 22.

In immediate proximity to the belt 21, I feed the resistance wire from a spool 23 situated on the side of the core 1 remote from the pulley 22. As shown in Fig. 6, the wire 3 is wound on the core 1 in overlapping relation to the sheets 2, in such manner that as soon as a sheet is applied on the core it is caught by the wire 3 which holds it in place and presses it with a pressure that may be adjusted by means of a stretching device 24.

The insulating layer 2 and the resistance wire 3 being wound, the same operation is repeated with the outer insulating layer 4 and the encircling band 20. The whole then is forcibly introduced into the sheath 5 and subjected to internal pressure, for example by means of a mandrel, which tightens all the parts together and uniformly distributes the stresses in each layer. The concentric layers then can no longer become loosened under the action of vibrations or jars. Moreover the dielectric coefficient and the thermal conductivity of the insulating material are increased by the compression.

It will be understood that these qualities are also preserved when the element comprises more than two insulating layers and that the advantages of the invention obtain, whether it be applied to heating resistances or to cables for power transmission.

I claim:

1. A process of producing insulated electric conductors, comprising surrounding an expansible tubular core with insulating material, tightly winding an electric conductor around said material, thereby subjecting said material to permanent pressure, surrounding the wound conductor with more insulating material, surrounding the whole with a sheath and expanding said core by an internal pressure.

2. A process of producing insulated electric conductors, comprising surrounding a malleable tubular core with a layer of insulating material, winding an electric conductor around said insulating layer thereby compressing same, surrounding the wound conductor with an outer layer of insulating material, winding a band around said outer layer to compress same, surrounding the whole with an outer sheath, and passing a mandrel through said core to expand same and compress the parts comprised between said core and said sheath.

3. A process of producing insulated electric conductors, comprising an expansible tubular core with a plurality of superposed insulating layers, tightly winding an electric conductor between every two successive insulating layers thereby successively subjecting each said layer to preliminary pressure, inserting the whole in an outer sheath and subjecting said tubular core to internal pressure to expand same and compress the parts comprised between said core and said sheath.

4. A process of producing insulated electric conductors, comprising surrounding an expansible tubular core with an insulating layer, sub-

jecting said layer to compression by winding an electric conductor therearound, surrounding the wound conductor with a further insulating layer, subjecting said further layer to compression by winding an encircling band therearound, inserting the whole in an outer sheath and subjecting said tubular core to internal pressure.

5. A process of producing insulated electric conductors, comprising winding sheets of insulating material on an expansible core, pressing said sheets into position by tightly winding an electric conductor therearound, winding sheets of insulating material around the wound conductor, pressing said sheets in position by tightly winding therearound a compressing band, surrounding the whole with a sheath, and expanding said core by internal pressure.

6. A process of producing insulated electric heating resistances, comprising winding sheets of insulating material on an expansible tubular core and simultaneously winding an electric resistance wire in overlapping relation to said sheets, thereby encircling said insulating sheets with the winding of said wire and subjecting said sheets to compression, then again winding sheets of insulating material on the resulting product and simultaneously winding under tension a pressure resisting band in overlapping relation to said last mentioned sheets, inserting the whole in a sheath and expanding said core by internal pressure.

7. A process of producing insulated electric heating resistances, comprising rotating an expansible tubular core and simultaneously moving said core longitudinally, winding sheets of insulating material on said rotating core and simultaneously winding under tension a resistance wire in overlapping relation to said sheets, then winding around the resulting product sheets of insulating material and simultaneously winding under tension a metal strip in overlapping relation to the last mentioned band, inserting the whole in a sheath and expanding said core by internal pressure.

8. A process of making insulated heating resistances comprising winding sheets of insulating material on an expansible tubular core, tightly winding a resistance wire around said sheets, thereby subjecting said sheets to inward pressure and causing any air entrapped therebetween to escape, winding sheets of insulating material around the resulting product, tightly winding encircling wire around the last mentioned sheets, thereby subjecting them to inward pressure and causing any air entrapped therebetween to escape, inserting the whole in a sheath and passing a mandrel through said tubular core, thereby subjecting the whole to an outward pressure and securing the previously compressed parts within said outer sheath.

ROBERT MAUTSCH.