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METHODS OF CURING VULCANIZABLE COMPOUNDS

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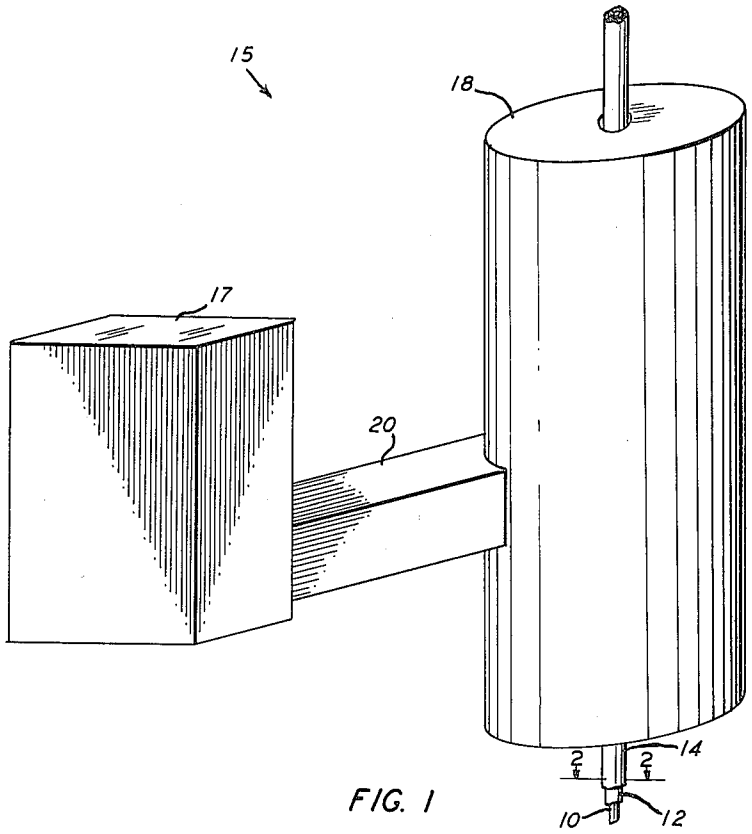


FIG. 1

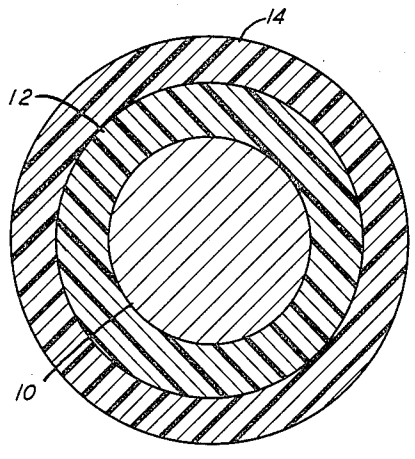


FIG. 2

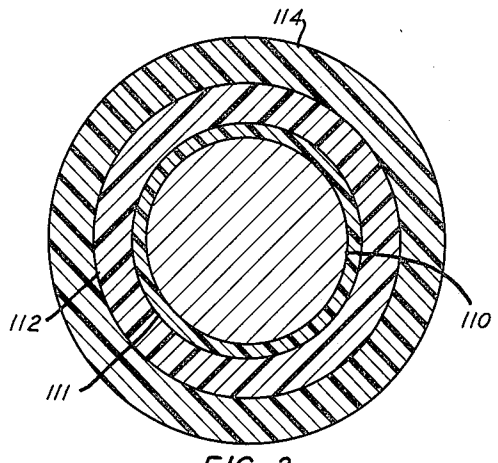


FIG. 3

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METHODS OF CURING VULCANIZABLE COMPOUNDS

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This invention pertains to methods of curing vuclanizable compounds, and more particularly to methods of curing vulcanizable compounds by dielectric heating.

One of the recent developments pertaining to the curing of vulcanizable compounds is the application of microwave dielectric heating. The use of energy at microwave frequencies facilitates a rapid heating of dielectric material and affords a suitable method for uniformly and rapidly heating and curing continuous lengths of vulcanizable compounds.

The above method is particularly well suited for curing vulcanizable compounds which serve as insulating coverings on continuous lengths of electric conductors. It has been found, however, that in order to produce a tight, smooth-skinned insulating covering upon a conductor, the vulcanizable compound must be confined and subjected to pressure during the curing operation.

Various means have been suggested to fulfill the above requirements. These means have not proved entirely satisfactory when applied to vulcanization processes utilizing microwave dielectric heating because of the problems peculiar to this type of heating. At the present stage of development, microwave dielectric heating applications are sharply restricted by the limitation in the available sources of microwave frequency power. Any commercially feasible process involving microwave frequencies must have a minimum of energy losses.

It is an object of this invention to provide new and improved methods of curing vulcanizable compounds.

It is another object of this invention to provide new and improved methods of curing vulcanizable compounds by dielectric heating.

Other objects of this invention will become apparent as the specification proceeds.

In one method illustrating certain features of this invention, a conductor is covered with an extruded layer of uncured vulcanizable insulating compound. The insulated conductor is then provided with a sheath of dielectric material which has substantially lower dielectric losses than that of the insulating covering on the conductor. The sheathed and insulated conductor is next subjected to a high frequency electric field wherein the vulcanizable insulating compound is cured.

A clear understanding of the invention will be had from the following detailed description of a specific embodiment thereof, when read in conjunction with the appended drawing, in which:

Fig. 1 is a schematic view of a microwave frequency dielectric heating apparatus suitable for use in practicing the invention and illustrating one method embodying the invention;

Fig. 2 is a section taken along line 2—2 of Fig. 1, and

Fig. 3 is a section similar to Fig. 2, illustrating how another method embodying the invention may be practiced.

In a specific embodiment of the invention a filamentary conductor 10 of indefinite length is covered with an insulating layer 12 of uncured vulcanizable compound, such as a neoprene compound, which has relatively high di-

electric losses when subjected to a high frequency alternating electric field. The uncured vulcanizable insulating layer 12 is applied to the conductor 10 by a suitable conventional extruding operation. It is well known that such a vulcanizable layer 12 of neoprene compound must be cured by the application of heat and pressure in order to produce a high quality covering upon the conductor 10.

An outer sheath 14 of a low dielectric loss thermoplastic material, such as high molecular weight, normally solid polyethylene is extruded over the uncured vulcanizable layer 12 in a subsequent conventional extruding operation. In this operation the conductor 10 with its uncured vulcanizable layer 12 is enveloped by the outer sheath 14 of polyethylene. The sheathed and insulated conductor 10 is then advanced through a suitable microwave frequency heating apparatus, which is shown generally at 15.

The microwave frequency heating apparatus 15 includes a high frequency generator 17, capable of generating energy at microwave frequencies, which is coupled to a cylindrical cavity resonator 18 by a wave guide 20. The microwave frequency heating apparatus 15 is similar to apparatus shown and described in "Microwaves and Their Possible Use in High Frequency Heating," a pamphlet distributed by Westinghouse Electric Corp., Industrial Electronics Division, Baltimore, Maryland.

The cylindrical cavity resonator 18 is provided with apertures at both ends which permit the passage of the sheathed and covered conductor therethrough. Within the cavity resonator 18, the advancing sheathed and insulated conductor 10 is subjected to a high frequency electric field which causes a rapid heating of the layer 12, which has high dielectric loss characteristics. The sheathed and covered conductor 10 is advanced at such a rate that the layer 12 reaches an optimum temperature at which the neoprene compound becomes cured during its passage through the cavity resonator 18.

Since the outer polyethylene sheath 14 has relatively low dielectric losses as compared to the relatively high dielectric losses of the layer 12 of neoprene compound, the temperature of the sheath 14, except for portions thereof adjacent to the layer 12, remains substantially unchanged during the transit of the sheathed and covered conductor 10 through the cavity resonator 18. As a result, the properties of the sheath 14 remain substantially unchanged and the sheath, which envelopes the neoprene compound layer 12 entirely, serves to confine the layer 12 and prevents expansion of the residual gases during the curing process.

It is important that the polyethylene sheath 14 be of such thickness that it will have sufficient strength to contain the resultant high internal pressure caused by the swelling neoprene compound layer 12. The polyethylene sheath 14 holds the neoprene compound against swelling during the curing operation and provides the necessary static pressure to prevent sponging, which would normally occur if the compound were cured in an unconfined condition. In addition, the sheath 14 prevents surface oxidation which would normally occur on the surface of the neoprene compound layer 12 if it were exposed to the atmosphere at a high temperature.

After passing through the cavity resonator 18, the sheathed and covered conductor 10 is passed through a suitable cooling means, such as a bath of water (not shown), to reduce the temperatures of the polyethylene sheath 14 and the layer 12 of neoprene compound. The cooled outer sheath 14 of polyethylene then is removed by a suitable stripping device (not shown) leaving the conductor 10 with a smooth, high quality layer 12 of cured neoprene compound substantially free from surface defects, such as sponging and oxidation. The polyethylene from the sheath 14, which has been stripped from

the insulated conductor 10, is suitable for reuse in the extruder which applies the polyethylene sheath 14 upon the uncured neoprene compound layer 12. In this manner, the polyethylene may be used repeatedly with resulting economic benefits.

The use of a low loss dielectric material, such as polyethylene reduces energy losses, since very little energy is absorbed thereby. Such material has substantially no effect on the electric field within the cavity resonator. Conservation of energy is of prime importance in microwave frequency dielectric heating apparatus because of the limitations in available power. The heretofore described method has been expressly developed to make the continuous curing of vulcanizable compounds economically feasible.

Alternate embodiment

An alternative embodiment of the invention is illustrated in Fig. 3 of the drawing. In this embodiment, a conductor 110 is provided with an insulating covering 111 of polyethylene, which is extruded thereupon by conventional means. A jacket 112 of uncured neoprene compound is extruded over the polyethylene covering by a subsequent conventional extruding operation. A sheath 114 of polyethylene is applied upon the jacketed and insulated conductor 110 as in the preferred embodiment.

The conductor 110, with the insulating covering 111, jacket 112 and sheath 114 thereon, is advanced by suitable means through the resonant cavity 18 of the dielectric heating apparatus 15 where it is subjected to a microwave frequency alternating electric field. During the transit through the resonant cavity 18 sufficient time is allowed for the layer 114 of neoprene compound to become heated and cured. However, as previously described, the polyethylene insulating covering 111 and the polyethylene sheath 114 are substantially unaffected by the high frequency field due to the low dielectric loss characteristics of polyethylene. After cooling, the polyethylene sheath 114 is stripped from the insulated and jacketed conductor 110 and may be used as sheathing in subsequent operations.

Heretofore, standard methods of curing the neoprene compound jacket 112 (e. g. continuous steam vulcanization) have caused injury to an inner polyethylene insulating covering, such as the covering 111. Any method wherein the polyethylene covering 111 is heated is unsatisfactory, since the covering tends to become nonconcentric, thereby destroying the uniform electrical properties of the finished cable.

It will be understood that the methods and materials utilized in the heretofore described embodiments are merely illustrative. It is manifest that various methods utilizing various materials may be practiced within the scope of the invention.

For example, a neoprene compound has been chosen as representative of vulcanizable compounds, which may be cured in accordance with the teachings of this invention. Other suitable compounds, such as those containing rubber, Buna-S (a rubbery copolymer of butadiene and styrene) or the like, may be used instead of the neoprene compound.

Also, polyethylene has been selected as a compound representative of low dielectric loss compounds. Other materials, such as polystyrene, or the like, which possess dielectric loss characteristics of the order of those exhibited by polyethylene, are suitable materials for the outer sheath. Such materials possess dielectric power factors which are negligible in comparison to those of vulcanizable materials, such as compounds of neoprene, rubber, Buna-S, or the like. Since the dielectric energy loss is directly proportional to the power factor, the reasons for the radical differences in heat developed within the materials, such as polyethylene and that developed within the vulcanizable compounds, such as the neoprene compound, are readily apparent.

What is claimed is:

1. The method of curing vulcanizable compounds, which comprises covering a continuous length of filamentary conductor with a layer of an uncured, vulcanizable compound, extruding a sheath of low loss dielectric material having dielectric losses of the order of those of polyethylene over the layer of vulcanizable compound, and advancing the continuous length of sheathed and covered conductor continuously through a microwave frequency alternating electric field whereby the vulcanizable compound is heated and cured during its transit therethrough.

2. The method of curing vulcanizable compounds, which comprises covering a continuous length of filamentary conductor with a layer of an uncurved, vulcanizable compound, extruding a sheath of low loss dielectric material having dielectric losses of the order of those of polyethylene over the layer of vulcanizable compound, advancing the continuous length of sheathed and covered conductor continuously through a microwave frequency alternating electric field whereby the vulcanizable compound is heated and cured during its transit therethrough, and stripping the outer sheath of low loss dielectric material from the vulcanized layer.

3. The method of curing vulcanizable materials by microwave frequency dielectric heating, which comprises covering a continuous length of filamentary conductor with a layer of material of the group consisting of vulcanizable compounds of rubber, neoprene and rubbery copolymers of butadiene and styrene, extruding a sheath of a material of the group consisting of polyethylene and polystyrene over the vulcanizable layer, and advancing the continuous length of sheathed and covered conductor continuously through a microwave frequency alternating electric field whereby the vulcanizable layer is heated and vulcanized while the sheath is substantially unaffected.

4. The method of curing vulcanizable materials by dielectric heating, which comprises extruding an insulating layer of a material of the group consisting of polyethylene and polystyrene upon a filamentary conductor, applying a jacket of material of the group consisting of vulcanizable compounds of rubber, neoprene and rubbery copolymers of butadiene and styrene over the insulating layer, extruding an outer sheath of a material of the group consisting of polyethylene and polystyrene over the jacketed and insulated conductor, advancing the resulting assembly continuously through a high frequency alternating electric field whereby the vulcanizable material is heated and cured while the insulating layer and the sheath are substantially unaffected, and stripping the outer sheath from the jacketed and insulated conductor.

5. The method of curing vulcanizable materials by dielectric heating, which comprises extruding an insulating layer of a material of the group consisting of polyethylene and polystyrene upon a filamentary conductor, applying a jacket of material of the group consisting of vulcanizable compounds of rubber, neoprene and rubbery copolymers of butadiene and styrene over the insulating layer, extruding a sheath of a material of the group consisting of polyethylene and polystyrene over the jacketed and insulated conductor, and advancing the resulting assembly continuously through a high frequency alternating electric field whereby the vulcanizable material is heated and cured while the insulating layer and the sheath are substantially unaffected.

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