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(54) **Method for providing an insulated electric cable or termination or joint**

Verfahren zur Bereitstellung von isoliertem elektrischem Kabel oder Anschluss oder Verbindung

Procédé pour fournir un câble, une terminaison ou une jonction électrique isolé

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EP 2 950 313 B1

Description

[0001] The present invention relates generally to electrical power equipment, and particularly to high voltage electrical power equipment. More particularly, the invention relates to a method for providing an insulated electric cable or termination or joint. The purpose of the method is to increase the dielectric withstand strength of the cable/termination/joint. The method applies to both a (high voltage) DC cable or DC termination/joint and (high voltage) AC cable or AC termination/joint.

[0002] Extruded solid insulation based on a polyethylene, or a cross linked polyethylene (XLPE), has for almost 40 years been used for AC transmission and distribution cable insulation.

[0003] Therefore the possibility of the use of XLPE for cable insulation has been under investigation for many years. Cables with such insulations have the same advantage as the mass impregnated cable in that for transmission there are no restrictions on circuit length and they also have a potential for being operated at higher temperatures, thus offering a possibility to increase the transmission load.

[0004] It is well known that the level of crystallinity of extruded XLPE used for cable insulation is correlated to the electric withstand strength both for AC and impulse voltages and it is expected to improve the long term properties of extruded DC cables as well. A high level of crystallinity is also desirable as it will decrease the diffusivity of the material making the electric properties more stable over time. By applying high temperature after the crosslinking process the crystallinity can be increased as well as evenly distributed. However, the surface of a XLPE cable must be protected from oxygen to avoid degradation of the insulation material, which in turn affects the electric properties negatively.

[0005] It is known from document US 8,398,803 a heat treatment that aims at equally distributing the byproducts in the cables rather than improving the dielectric properties based on morphology changes. The purpose is therefore completely different and it is not disclosed how to achieve higher crystallinity and the same morphology profile across the insulation thickness.

[0006] It is an object of the present invention to provide a method for providing an insulated electric (high voltage) DC or AC cable as specified in the foregoing. It is also an object of the invention to provide a (high voltage) DC or AC termination or joint having similar properties.

[0007] The object mentioned above is accomplished by a method of providing an insulated electric cable or termination or joint, the method comprising :

- providing a polymer based insulation system comprising a cross-linked polymer composition, wherein providing the polymer based insulation system comprises exposing the polymer based insulation system to a heat treatment procedure while the outer surface of the polymer based insulation system is covered by a cover impermeable to at least one substance present in the polymer based insulation system in a non-homogenous distribution.

[0008] The method according to the invention comprises after the heat treatment procedure a controlled cooling step while the outer surface of the polymer based insulation system is covered by the impermeable cover, thereby achieving a high crystallinity of the cross-linked polymer composition.

[0009] The cross-linked polymer composition is typically a cross-linked polyethylene, but could also be applied to other polyolefins, such as LDPE, HDPE, PP or copolymer of those.

[0010] The heat treatment can be performed at a heating temperature of between 80 and 120°C, and preferably at a temperature of between 85 and 105°C.

[0011] The heating temperature can be maintained for a time between 1 and 20 days, and preferably between 4 and 10 days.

[0012] The controlled cooling step can include a controlled decrease of the temperature of between 1 and 20 °C/hour.

[0013] The controlled decrease of the temperature can be performed from the heating temperature and until a cooling temperature of between 60 and 70°C, and preferably of between 63 and 67°C. Under this cooling temperature, no more or very limited crystallization takes place. Slow cooling is needed as not to freeze some morphological structures that have not yet crystallized at the heat treatment temperature. That is, some crystallization takes place during cooling, and these crystals should be as "perfect" as possible.

[0014] The substances present in the polymer based insulation system in a non-homogenous distribution can include at least one rest or byproduct from the cross-linking.

[0015] The substance present in the polymer based insulation system in a non-homogenous distribution can include at least one peroxide decomposition product.

[0016] The polymer based insulation system can comprise a first semi-conducting shield, the cross-linked polymer composition, and a second semi-conducting shield.

[0017] The method can be a method for production of insulated electric AC or DC cable and :

- the cable can be exposed to a heat treatment while the outer surface of the polymer based insulation system is not covered by the impermeable cover to remove a second substance present in the polymer based insulation system after cross-linking; and
- said exposure of the polymer based insulation system to the heat treatment procedure and controlled cooling step while the outer surface of the extruded polymer based insulation system is covered by the cover can be performed after removal of said second substance to thereby achieve a high crystallinity of the cross-linked polymer composition.

[0018] Said second substance is typically methane.

[0019] The impermeable cover can be a lead sheet, a metal cover such as a metal laminate and/or an outer covering or sheath provided that this layer is impermeable to the at least one substance present in the extruded insulation system.

[0020] Further characteristics of the invention and advantages thereof will be evident from the following detailed description of embodiments of the invention:

- FIG. 1 is a flow scheme of a method for production of an insulated electric high voltage DC cable according to an embodiment of the present invention,
- FIG. 2 illustrates schematically in a perspective view a high voltage DC cable as manufactured according to the flow scheme of FIG. 1, and
- FIG. 3 is a diagram that is useful for understanding the method according to the invention.

[0021] A method for production of an insulated electric high voltage cable according to an embodiment of the present invention will now be described with reference to FIGS. 1 and 2. The latter Figure shows the insulated electric high voltage cable in a section view. The cable comprises from the center and outwards: a stranded multi-wire conductor 10, a first extruded semi-conducting shield 11 disposed around and outside the conductor 10, an extruded polyethylene based conductor insulation 12 with an extruded, cross-linked composition as further described below, a second extruded semi-conducting shield 13 disposed outside the conductor insulation 12, and an outer covering or sheath 15 arranged outside the polymer based insulation system.

[0022] The cable can when found appropriate be further complemented in various ways with various functional layers or other features. It can for example be complemented with a reinforcement in form of metallic wires outside the outer extruded shield 13, a sealing compound or a water swelling powder introduced in metal/polymer interfaces or a system achieved by e.g. a corrosion resistant metal polyethylene laminate and longitudinal water sealing achieved by water swelling material, e.g. tape or powder beneath the sheath 15. The conductor need not be stranded but can be of any desired shape and constitution, such as a stranded multi-wire conductor, a solid conductor or a segmental conductor.

[0023] According to the method for production of the insulated electric high voltage cable, a polymer based insulation system is, in a step 21, extruded around the conductor 10, wherein the polymer based insulation system comprises the semi-conducting shield 11, the polyethylene based conductor insulation 12, and the second semi-conducting shield 13. In an alternative embodiment the polyethylene based conductor insulation 12 is exchanged for other polymer based conductor insulation.

[0024] Below is a short description of one exemplary method of performing the extrusion. A person skilled in the art realizes that there are other extrusion techniques that can be used with the present invention.

[0025] In the exemplary method the conductor is fed from a conductor pay-off through the extruder equipment and other processing and conditioning devices and is finally taken up on a cable core take-up. The conductor pay-off and cable core take-up may be reels or drums suitable for discrete lengths but can be of any suitable type including devices for essentially continuous handling of the supplied conductor and produced cable. The conductor is passed over a first wheel through a conductor preheater wherein it is preheated for a suitable temperature before the insulation system is applied by extrusion. The process is suitable for true triple extrusion where a triple head extruder is used. The inner and outer semi-conductive layers are applied using two separate extruders and a further third extruder is used for the main insulation.

[0026] After the extrusion operation the extruded polyethylene based conductor insulation 12 is advantageously, in a step 22, cross-linked. To this end the insulated DC cable is passed through a pressurized curing and cooling chamber, wherein the conditions is controlled to ensure the desired cross-linking degree and other structural characteristics that can be effected by this controlled conditioning and cooling of the extruded insulation system. Typically, the extruded polyethylene based conductor insulation 12 includes a number of additives, among them dicumylperoxide and additives. Thereafter the cable is hauled through a haul-off caterpillar and over a second wheel before being taken up for further processing.

[0027] The above approach offers the possibility of an essentially continuous or semi-continuous process for the application and processing of the extruded insulation system.

[0028] As a result of the process, however, methane may be created in the cross-linked polyethylene based conductor insulation 12. Any methane may be removed by exposing, in a step 23, the extruded DC cable to a heat treatment while the outer surface of the extruded polymer based insulation system is kept free from any covering to thereby allow the methane to leave.

[0029] Next, in a step 24, the outer surface of the extruded polymer based insulation system is covered by a cover 14 impermeable to one or more substances present in the extruded insulation system in a non-homogenous distribution.

[0030] The one or more substances include preferably one or more rest or byproducts from the cross-linking and/or one or more additives. The rest products include typically peroxide decomposition products, such as acetophenone and cumyl alcohol, and the additives include typically one or more antioxidants and scorch retarders. However, other additives may be of equal or even higher importance.

[0031] Next, after having covered the extruded DC cable with the impermeable cover, the extruded DC cable is, in a step 25, exposed for a heat treatment procedure in order to achieve a high crystallinity of the cross-linked polymer composition.

[0032] The heat treatment procedure is preferably performed at a temperature of between 80 and 120°C, and more preferably between 85 and 105°C, and for a time that is shorter the higher the temperature is, preferably between 4 and 10 days.

[0033] For instance, as shown in Figure 3, the recrystalisation process can consist of heating in the order of 95ºC (step a) for a length of time appropriate for the cable thickness (step b) followed by a controlled cooling down to 60ºC (step c). During this cooling sequence the temperature distribution inside the cable insulation should be as even as possible. This thermal conditioning (recrystalisation process) will be performed at temperatures where the XLPE can be oxidized which leads to ageing of the polymer material, causing the dielectric properties to degrade and it is therefore imperative that the extruded insulation is protected with a barrier layer which is impermeable to oxygen. This barrier would preferably be the lead sheath of a submarine cable but could also be another externally applied layer.

Claims

1. A method of providing an insulated electric cable or termination or joint, the method comprising :

- providing a polymer based insulation system (11,12,13) comprising a cross-linked polymer composition (12), wherein providing the polymer based insulation system comprises exposing the polymer based insulation system (11,12,13) to a heat treatment procedure (a,b) while the outer surface of the polymer based insulation system (11,12,13) is covered by a cover (14) impermeable to at least one substance present in the polymer based insulation system (11,12,13) in a non-homogenous distribution, the method being **characterized in that**:
    - the cover is impermeable to oxygen,
    - it comprises after the heat treatment procedure a controlled cooling step (c) while the outer surface of the polymer based insulation system (11,12,13) is covered by the impermeable cover (14), thereby achieving a high crystallinity of the cross-linked polymer composition (12), said controlled cooling step (c) including a controlled decrease of the temperature of between 1 and 20°C/hour, and
    - the heat treatment procedure (a,b) and the controlled cooling step (c) represent a recrystallization process.

2. The method according to claim 1, **characterized in that** the cross-linked polymer composition (12) is a cross-linked polyethylene.

3. The method according to claim 1 or 2, **characterized in that** the heat treatment is performed at a heating temperature of between 80 and 120°C.

4. The method according to claim 3, **characterized in that** the heating temperature is maintained for a time between 1 and 20 days.

5. The method according to claim 1, **characterized in that** the controlled decrease of the temperature is performed from the heating temperature and until a cooling temperature of between 60 and 70°C.

6. The method according to any of claims 1 to 5, **characterized in that** the substances present in the polymer based insulation system (11,12,13) in a non-homogenous distribution include at least one rest or byproduct from the cross-linking.

7. The method according to claim 6, **characterized in that** the substances present in the polymer based insulation system (11,12,13) in a non-homogenous distribution include at least one peroxide decomposition product.

8. The method according to any claims 1 to 7, **characterized in that** the polymer based insulation system (11,12,13) comprises a first semi-conducting shield (11), the cross-linked polymer composition (12), and a second semi-conducting shield (13).

9. The method according to any of claims 1 to 8, **characterized in that** the method is a method for production of insulated electric AC or DC cable and that :

- the cable is exposed to a heat treatment while the outer surface of the polymer based insulation system (11,12,13) is not covered by the impermeable cover (14) to remove methane present in the polymer based insulation system (11,12,13) after cross-linking; and
- said exposure of the polymer based insulation system (11,12,13) to the heat treatment procedure (a,b) and controlled cooling step (c) while the outer surface of the extruded polymer based insulation system (11,12,13) is covered by the cover (14) is performed after removal of methane to thereby achieve a high crystallinity of the cross-linked polymer composition (12).

10. The method according to any of claims 1 to 9, **characterized in that** said impermeable cover is a lead sheet or a metal cover.

Patentansprüche

1. Verfahren zur Bereitstellung eines isolierten elektrischen Kabels oder Abschlusses oder einer isolierten elektrischen Verbindung, wobei das Verfahren Folgendes umfasst:

- Bereitstellen eines Polymer-basierten Isolierungssystems (11, 12, 13), umfassend eine vernetzte Polymerzusammensetzung (12), wobei das Bereitstellen des Polymer-basierten Isolierungssystems das Aussetzen des Polymer-basierten Isolierungssystems (11, 12, 13) an einen Hitzebehandlungsprozess (a, b) umfasst, während die äußere Oberfläche des Polymer-basierten Isolierungssystems (11, 12, 13) mit einer Abdeckung (14) bedeckt ist, die undurchlässig für mindestens eine Substanz ist, die im Polymer-basierten Isolierungssystem (11, 12, 13) in einer nicht homogenen Verteilung vorhanden ist,

wobei das Verfahren **dadurch gekennzeichnet ist, dass**

- die Abdeckung undurchlässig für Sauerstoff ist,
- es nach dem Hitzebehandlungsprozess einen gesteuerten Schritt des Abkühlens (c) umfasst, während die äußere Oberfläche des Polymer-basierten Isolierungssystems (11, 12, 13) durch die undurchlässige Abdeckung (14) bedeckt ist, wodurch eine hohe Kristallinität der vernetzten Polymerzusammensetzung (12) erzielt wird, wobei der gesteuerte Schritt des Abkühlens (c) eine gesteuerte Abnahme der Temperatur von zwischen 1 und 20 °C/Stunde einschließt, und
- der Hitzebehandlungsprozess (a, b) und der gesteuerte Schritt des Abkühlens (c) einen Rekristallisierungsprozess darstellen.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die vernetzte Polymerzusammensetzung (12) ein vernetztes Polyethylen ist.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Hitzebehandlung bei einer Erhitzungstemperatur von zwischen 80 und 120 ºC durchgeführt wird.

4. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, dass** die Erhitzungstemperatur für eine Zeit zwischen 1 und 20 Tagen beibehalten wird.

5. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die gesteuerte Abnahme der Temperatur von der Erhitzungstemperatur und bis zu einer Abkühlungstemperatur zwischen 60 und 70 °C durchgeführt wird.

6. Verfahren nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** die Substanzen, vorhanden im Polymer-basierten Isolierungssystem (11, 12, 13) in einer nicht homogenen Verteilung mindestens einen Rest oder ein Nebenprodukt aus der Vernetzung einschließen.

7. Verfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** die Substanzen, vorhanden im Polymer-basierten Isolierungssystem (11, 12, 13), in einer nicht homogenen Verteilung mindestens ein Peroxid-Abbauprodukt einschließen.

8. Verfahren nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, dass** das Polymer-basierte Isolierungssystem (11, 12, 13) einen ersten halbleitenden Schirm (11), die vernetzte Polymerzusammensetzung (12) und einen zweiten halbleitenden Schirm (13) umfasst.

9. Verfahren nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet, dass** das Verfahren ein Verfahren zur Herstellung eines isolierten elektrischen Wechselstrom- oder Gleichstromkabels ist, und dass:

- das Kabel einer Hitzebehandlung ausgesetzt wird, während die äußere Oberfläche des Polymer-basierten Isolierungssystems (11, 12, 13) nicht durch die undurchlässige Abdeckung (14) bedeckt ist, um Methan zu entfernen, das im Polymer-basierten Isolierungssystem (11, 12, 13) nach der Vernetzung vorhanden ist; und
- die Aussetzung des Polymer-basierten Isolierungssystems (11, 12, 13) an den Hitzebehandlungsprozess (a, b) und den gesteuerten Schritt des Abkühlens (c), während die äußere Oberfläche des extrudierten Polymer-basierten Isolierungssystems (11, 12, 13) von der Abdeckung (14) bedeckt ist, nach der Entfernung von Methan durchgeführt wird, um dadurch eine hohe Kristallinität der vernetzten Polymerzusammensetzung (12) zu erzielen.

10. Verfahren nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet, dass** die undurchlässige Abdeckung ein Bleiblech oder eine Metallabdeckung ist.

Revendications

1. Procédé pour réaliser un raccordement ou une connexion de sortie ou un câble électrique isolé, lequel procédé comprend :

- l'obtention d'un système isolant à base d'un polymère (11, 12, 13) comprenant une composition de polymère réticulé (12), laquelle obtention du système isolant à base d'un polymère comprend l'exposition du système d'isolation à base d'un polymère (11, 12, 13) à une procédure de traitement à la chaleur (a, b) cependant que la surface extérieure du système d'isolation à base d'un polymère (11, 12, 13) est recouverte d'un recouvrement (14) imperméable à au moins une substance présente dans le système d'isolation à base d'un polymère (11, 12, 13) selon une distribution non homogène,

lequel procédé est **caractérisé en ce que** :

- le recouvrement est imperméable à l'oxygène,
- il comprend, après la procédure de traitement à la chaleur, une étape de refroidissement contrôlé (c) cependant que la surface extérieure du système d'isolation à base d'un polymère (11, 12, 13) est recouverte du recouvrement imperméable (14), permettant ainsi l'obtention d'une cristallinité élevée de la composition de polymère réticulé (12), ladite étape de refroidissement contrôlé (c) comprenant un abaissement contrôlé de la température, compris entre 1 et 20°C/heure, et
- la procédure de traitement à la chaleur (a, b) et l'étape de refroidissement contrôlé (c) constituent un traitement de recristallisation.

2. Procédé selon la revendication 1, **caractérisé en ce que** la composition de polymère réticulé (12) est un polyéthylène réticulé.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** le traitement à la chaleur est effectué à une température de chauffage comprise entre 80 et 120°C.

4. Procédé selon la revendication 3, **caractérisé en ce que** la température de chauffage est maintenue pendant un temps compris entre 1 et 20 jours.

5. Procédé selon la revendication 1, **caractérisé en ce que** l'abaissement contrôlé de la température est effectué à partir de la température de chauffage et jusqu'à une température de refroidissement comprise entre 60 et 70°C.

6. Procédé selon l'une quelconque des revendications 1 à 5, **caractérisé en ce que** les substances présentes dans le système d'isolation à base d'un polymère (11, 12, 13) selon une distribution non homogène comprennent au moins un reste ou un sous-produit issu de la réticulation.

7. Procédé selon la revendication 6, **caractérisé en ce que** les substances présentes dans le système d'isolation à base d'un polymère (11, 12, 13) selon une distribution non homogène comprennent aussi un produit de décomposition de peroxyde.

8. Procédé selon l'une quelconque des revendications 1 à 7, **caractérisé en ce que** le système d'isolation à base d'un polymère (11, 12, 13) comprend un premier blindage semi-conducteur (11), la composition de polymère réticulé (12), et un deuxième blindage semi-conducteur (13).

9. Procédé selon l'une quelconque des revendications 1 à 8, **caractérisé en ce que** le procédé est un procédé pour la production d'un câble électrique isolé pour courant continu ou courant alternatif, et **en ce que** :

- le câble est exposé à un traitement à la chaleur cependant que la surface extérieure du système d'isolation à base d'un polymère (11, 12, 13) n'est pas recouverte du recouvrement imperméable (14) pour que soit éliminé le méthane présent dans le système d'isolation à base d'un polymère (11, 12, 13) après la réticulation ; et
- ladite exposition du système d'isolation à base d'un polymère (11, 12, 13) à la procédure de traitement à la chaleur (a, b) et à l'étape de refroidissement contrôlé (c) cependant que la surface extérieure du système d'isolation à base d'un polymère extrudé (11, 12, 13) est recouverte du recouvrement (14) est effectuée après l'élimination du méthane de façon que soit ainsi obtenue une cristallinité élevée de la composition de polymère réticulé (12).

10. Procédé selon l'une quelconque des revendications 1 à 9, **caractérisé en ce que** ledit recouvrement imperméable est une tôle de plomb ou un recouvrement métallique.

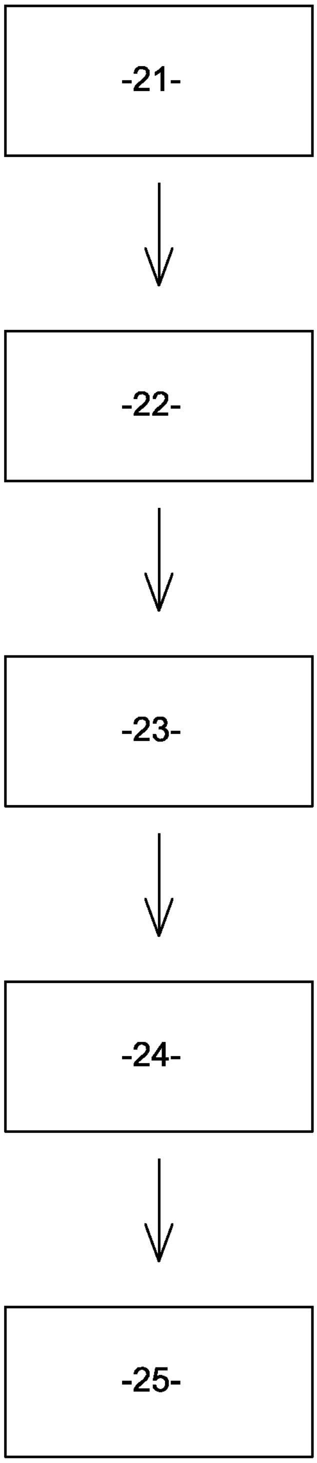

Fig. 1

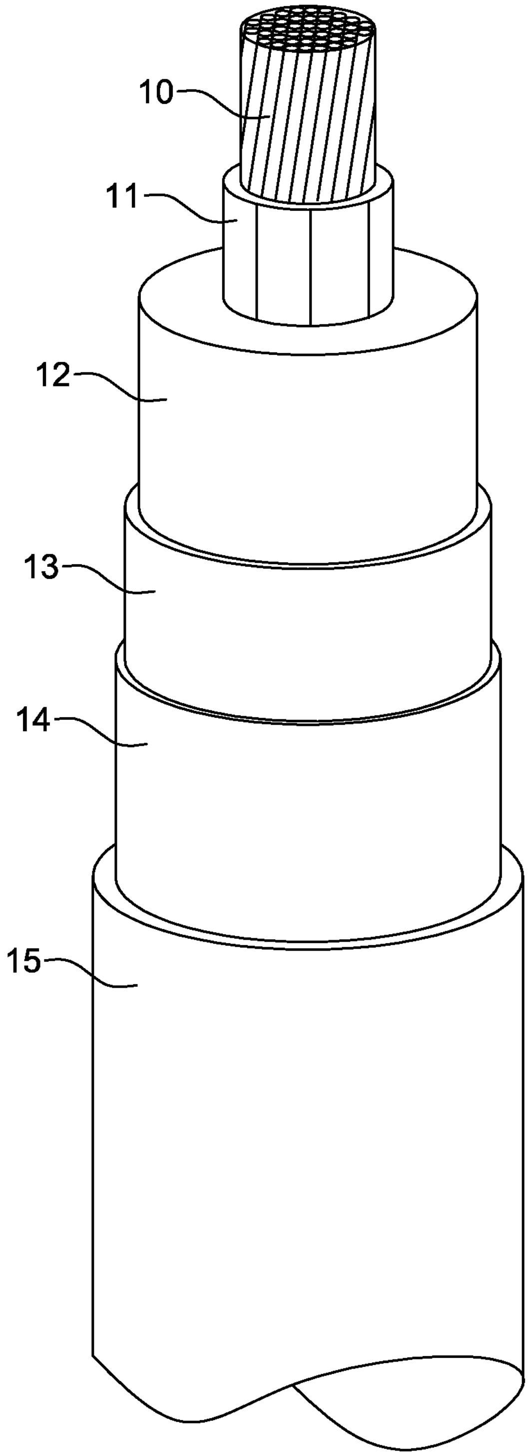

Fig. 2

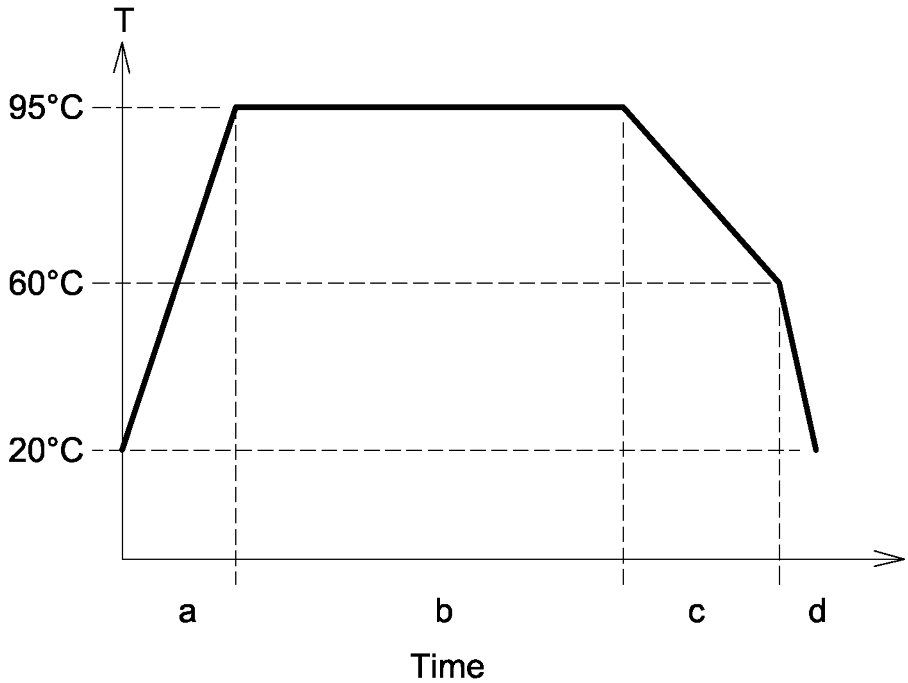

Fig. 3

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