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(71) Applicant: **ABB Technology Ltd**
8050 Zürich (CH)

(72) Inventors:
- **Johansson, Lars**
  771 90 Ludvika (SE)
- **Stahl, Robert**
  771 92 Ludvika (SE)
- **Wang, Lu**
  770 13 Grangärde (SE)
- **Kaufmann, Patrik**
  5400 Baden (CH)
- **Birgerson, Jonas**
  784 41 Borlänge (SE)

(74) Representative: **Savela, Reino Aleksi**
ABB AB
Intellectual Property
Ingenjör Bååths Gata 11
721 83 Västerås (SE)

(54) **Electrical insulator bushing**

(57) The present invention relates to an electrical insulator bushing (1) comprising: an electrically insulating sleeve (2) having a central longitudinal through hole (4) surrounding a central longitudinal axis (5) of the bushing; and an electrical conductor (3) positioned through the central longitudinal through hole of the sleeve; wherein the conductor comprises a cavity (6) extending longitudinally along the conductor and having an opening at one end; wherein the cavity is arranged for accommodating a heat-pipe, the heat-pipe comprising a fluid being contained in a closed system arranged for transferring heat along the bushing, and wherein the cavity is arranged for allowing the heat-pipe to be introduced into and removed from said cavity via its opening.

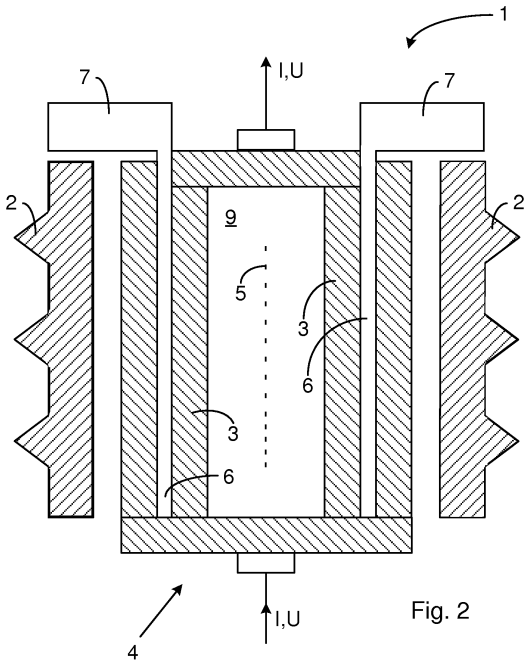

Fig. 2

EP 2 704 157 A1

Description

TECHNICAL FIELD

[0001] The invention relates to an electrical insulator bushing comprising an electrically insulating sleeve having a central longitudinal through hole, and an electrical conductor positioned through the central longitudinal through hole of the sleeve.

BACKGROUND

[0002] A bushing is a hollow electrical insulator through which a conductor may pass. Bushings are used where high voltage lines must pass through a wall or other surface, on switchgear, transformers, circuit breakers and other high voltage equipment. A bushing is used for passing a high voltage line from an oil-filled transformer, whereby the bushing is an oil-to-air bushing with a part in oil in the transformer and a part in air outside of the transformer. Other bushings are air-to-air bushings e.g. passing high voltage lines through a wall.

[0003] Resistive heat losses in a bushing arise evenly along the conductor. The heat is primarily dissipated to the environment at the upper and lower ends of the bushing. The heat is transported from the central part to the ends by conduction and sometimes by convection. Even though it is rarely used, it is also known that the heat can be transported by an evaporating medium, a so called heat pipe. In order to prevent high temperature rise of the conductive rod, a thicker conductive rod can be used to reduce the current density and thereby reduce the heat generated. However a thicker rod leads to increased material consumption and cost.

[0004] A heat pipe or heat pin is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between a hot interface and a cooler interface. The function of a heat pipe is to evaporate a liquid at the hot interface of the pipe and to condense it at the cooler interface where the heat is to be dissipated.

[0005] A given bushing with a defined central space for a conductor has different current carrying capacity due to heat generation depending on what size conductor it is provided with. Typically a flexible conductor gives comparatively low current carrying capacity and a solid rod or tube conductor gives higher capacity. In the same way copper conductors give higher capacity than aluminium. The same basic bushing can be given various current ratings depending on which conductor it is equipped with. If the bushing is provided with a heat-pipe, the rating can also be increased. Thus, a bushing can handle a higher current, without the need to use a larger conductor, if the conductor is equipped with a heat-pipe. However, a heat-pipe renders the bushing more expensive to produce and maintain and may not be needed for regular bushings. Instead, special bushings with heat pipes are produced especially for applications where such improved heat transfer is needed.

[0006] CN 101369483 (application number CN 2008 10115462.2) discloses a heat pipe bushing for transformers, comprising a conductive pipe, a radiator, a main insulating layer, an insulating sleeve and a connecting bushing. The conductive pipe is a hollow metal pipe that is connected to the radiator at one end and filled with environmentally-friendly, non-combustible cooling liquid. The exterior of the conductive pipe is wrapped with the main insulating layer, and the insulating sleeve and the connecting flange are installed on the exterior of the main insulating layer. The radiator is a hollow metal cavity whose internal cavity is connected to hollow cavity of the conductive pipe. The cooling liquid absorbs the heat generated by the conductive pipe and evaporates into gas, which rises to the radiator for external heat discharge; following this, it is condensed upon cooling and reflows to the conductive pipe.

[0007] WO 2007/107119 discloses a current carrier combined with heat-pipe which comprises a fluid with low boiling point. The current carrier can be used for the bushing of electrical equipment, the primary winding of a current transformer, a great current bus and so on.

SUMMARY

[0008] It is an objective of the present invention to improve the flexibility and usability of a bushing by allowing it to be used over a wider range of currents, being adjustable for different current ratings depending on the need.

[0009] According to an aspect of the present invention, there is provided an electrical insulator bushing comprising: an electrically insulating sleeve having a central longitudinal through hole surrounding a central longitudinal axis of the bushing; and an electrical conductor positioned through the central longitudinal through hole of the sleeve; wherein the conductor comprises a cavity extending longitudinally along the conductor and having an opening at one end; wherein the cavity is arranged for accommodating a heat-pipe, the heat-pipe comprising a fluid being contained in a closed system arranged for transferring heat along the bushing, and wherein the cavity is arranged for allowing the heat-pipe to be introduced into and removed from said cavity via its opening.

[0010] According to another aspect of the present invention, there is provided a detachable heat pipe comprising: a heat conducting tube; and a fluid partly filling the tube; wherein the heat conducting tube at least partly forms a closed system containing the fluid; and wherein the heat pipe is configured for being detachably inserted into a longitudinally extending cavity of an electrical conductor positioned through the central longitudinal through hole of an electrical insulator bushing.

[0011] By designing the bushing and its electrical conductor such that a heat pipe can be optionally added or removed, the bushing is made more flexible in respect of the currents it can be used for, and the bushing can

be provided with an additional rating for when a heat pipe is used. At the same time, the same bushing can be used without a heat pipe if the current is such that no heat pipe is required.

[0012] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic side view of a transformer with an embodiment of a bushing of the present invention.

Fig 2 is a schematic longitudinal section of an embodiment of a bushing of the present invention.

Fig 3 is a schematic longitudinal section of an embodiment of a detachable heat pipe in accordance with the present invention.

Fig 4 is a schematic longitudinal section of another embodiment of a detachable heat pipe in accordance with the present invention.

Fig 5 is a schematic cross-sectional view of an embodiment of a conductor in accordance with the present invention.

Fig 6 is a schematic cross-sectional view of another embodiment of a conductor in accordance with the present invention.

Fig 7 is a schematic cross-sectional view of another embodiment of a conductor in accordance with the present invention.

DETAILED DESCRIPTION

[0014] The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

[0015] The conductor is configured for conducting electrical current through the bushing. Thus, at least a part of the conductor is made of an electrically conducting material, e.g. a metal such as cupper. In high-voltage applications, especially for alternating current (AC), the conductor conveniently comprises an electrically conducting tube since the skin effect results in the current only travelling at the surface of a conductor whereby a tube can be used to save conducting material. According to embodiments of the present invention, the heat pipe cavity or cavities is defined by wall surfaces of such conducting material, e.g. between conducting tubes, between a conducting tube and another structure, or inside a wall of such a conducting tube whereby the cavity or cavities can form longitudinal pipes in the wall of the tube.

[0016] The cavity is a through or blind hole or space extending along the conductor longitudinal axis and having an opening at at least one longitudinal end of the hole, via which opening the heat pipe can be arranged into the cavity.

[0017] The fluid can be any suitable fluid which has a boiling point at a desired operating temperature of the electrical conductor. The fluid can e.g. be water or a fluorocarbon.

[0018] It should be noted that the bushing may be configured for accommodating any number of heat-pipes, according to different embodiments of the present invention.

[0019] The sleeve is made of an electrically insulating material, e.g. rubber such as silicon rubber, plastic, glass or a ceramic such as porcelain, or combinations thereof. The function of the sleeve is to insulate the conductor from e.g. a wall which the bushing is intended to pass through. In some embodiments, the sleeve may comprise an insulating condenser core which may be formed by a an insulating material or material combination e.g. including plastics, paper, oil etc. Such a condenser core may extend along and in parallel with the cavity (or the heat-pipe formed therein) at least partly, where other parts of the longitudinal extension of the cavity (or the heat-pipe formed therein) may be covered/insulated by another media e.g. a gas. The sleeve has a longitudinal through hole or opening along the central longitudinal axis of the bushing, the sleeve thus surrounding but not intersecting said central longitudinal axis of the bushing.

[0020] The bushing of the present invention can be beneficial in both direct current (DC) and alternating current (AC) applications.

[0021] In some embodiments the cavity is arranged for accommodating the heat-pipe by said cavity being arranged for allowing the fluid to be introduced into the

cavity via its opening and for allowing the opening to be blocked to form the closed system. According to these embodiments, the heat-pipe is formed by the liquid fluid being poured, or otherwise introduced directly into the cavity. The opening of the cavity is then blocked e.g. by means of a cap or plug, or by means of a condenser (discussed below) being attached over the opening. Thus the closed system of the heat-pipe can be formed by the cavity itself and the blocking of its opening. This can be an easy and inexpensive way of forming a heat pipe in the conductor of the bushing. The present invention also covers the bushing further comprising the fluid, after it has been introduced into the cavity, and wherein the opening has been blocked to form the closed system.

[0022] In some embodiments, the cavity is arranged for accommodating the heat-pipe by said cavity being arranged for receiving a heat conducting tube partly filled with the fluid. According to these embodiments, the fluid is not introduced directly into the cavity. Rather, the fluid is already contained in a heat conducting tube, i.e. a tube made from a heat conducting material, and the heat conducting tube can be positioned in the cavity. This may be a more simple way of introducing the heat pipe into the conductor where the heat pipe may be easily introduced and/or removed from the cavity without having the risk of spilling the fluid etc. It also makes the fluid more easily reusable. Also, the heat pipe may have been prepared as a permanent closed system, reducing the risk of leakage at e.g. a cavity blockage. The present invention covers the bushing being arranged to receive such a heat pipe and also covers the bushing further comprising the heat conducting tube partly filled with the fluid, detachably having been inserted into the cavity through/via its opening.

[0023] In some embodiments, the bushing also comprises comprising a heat conducting condenser (i.e. a condenser made from a heat conducting material) which is part of the heat-pipe closed system and extends outside of the cavity via the opening. By using a condenser, the heat transfer from the conductor to the outside of the bushing can be improved. The fluid can thus vaporize down inside the cavity where the conductor may have a hot spot, and rise to the condenser where it can be cooled and condensed, dissipating the heat, more efficiently than if the heat pipe was completely contained in the conductor. It is noted, however, that in some embodiments, a condenser may not be needed and in those embodiments the heat pipe can be used for transporting heat from a hot spot of the conductor to a cooler part of the conductor.

[0024] In some embodiments, the cavity is eccentrically located in the conductor such that said cavity does not intersect the central longitudinal axis of the bushing. It may be an advantage to use an eccentrically located cavity for forming a heat pipe in a bushing since this allows the central space of the solid pipe-formed conductor (the space along the central longitudinal axis of the bushing) to be free for other use. An example of a convenient use of the central space includes a centric draw rod arranged for connecting an electricity line/cable to an end of the bushing conductor at a first end of the bushing from the side of the opposite second end of the bushing. It is also possible to use a solid rod conductor instead of a tube, or to draw a flexible conductor (a cable) through the central space. To use a heat pipe is an efficient way of cooling a bushing by transferring heat formed by resistance within the bushing, from the bushing to an ambient medium. However, in other embodiments, it may be convenient to use the central space of the conductor for accommodating a heat pipe, whereby it may not be needed to e.g. drill additional hole(s) in the pipe conductor for accommodating the heat-pipe. That the cavity is eccentric means that it is not positioned in or along the central longitudinal axis of the bushing. Thus, the cavity does not intersect the central longitudinal axis of the bushing. The cavity extends longitudinally along at least a part of the longitudinal extension of the bushing, such that the heat pipe can transfer heat from one longitudinal position where it is desired to lower the temperature (typically an inner position of the bushing) to another longitudinal position (typically an outer position of the bushing, possibly even beyond an end of the sleeve since the sleeve also insulates heat). A problem with using the hollow cavity of the conductive pipe as a heat pipe is that this cavity then cannot be used for other parts of, or associated with, the bushing. This central cavity is often needed for other purposes, e.g. to locate a flexible or solid rod conductor which carries the bushing current or to arrange a draw rod which holds a bottom contact connected to the bushing end, electrically connecting the winding of the transformer with the bushing conductor.

[0025] Figure 1 is a schematic illustration of a transformer 8 where a bushing 1 is used for conducting an electrical current (I, U) through the casing of the transformer 8. The transformer may be an oil-filled transformer. The transformer may be a high-voltage transformer, whereby a high-voltage current is passed from the transformer through the conductor of the bushing 1. The bushing 1 may thus have an inner oil-immersed part at a lower end of the bushing inside the transformer 8, and an outer part in air at an upper end of the bushing outside of the transformer, whereby the bushing, by means of its conductor, may conduct current from e.g. a winding of the transformer, through the casing of the transformer and to e.g. an air-borne line of a power distribution network, the bushing 1 insulating the current from the casing and any other external structures.

[0026] Figure 2 schematically illustrates an embodiment of a bushing 1 of the present invention. The bushing 1 is schematically shown in a longitudinal section along the central longitudinal axis 5 of the bushing. The bushing 1 of figure 1 is a tubular or essentially cylindrical device wherein a electrically insulating sleeve 2 forms an envelope surface surrounding the bushing in its longitudinal direction in parallel with the longitudinal axis 5. The sleeve insulates an electrical conductor 3 from external

structures, such as a wall through which the bushing is to be arranged. The conductor 3 is arranged within and through a longitudinal central through hole 4 of the sleeve, through which hole 4 also the central longitudinal axis 5 runs. The conductor 3 is configured to conduct an electrical current (AC or DC) through the bushing 1 (in the figure this is schematically illustrated by a current (I, U) entering at the lower end of the bushing and exiting at the upper end of said bushing, but the opposite direction, or alternating current, is of course equally possible). In the embodiment of the figure, the conductor 3 is in the form of a hollow tube or cylinder, forming a central space or cavity 9 through which the central longitudinal axis 5 passes. As discussed above, this central space 9 can be used for different things, such as a draw rod or the like, or for accommodating a heat-pipe. Alternatively, a solid conductor 3, without a central space 9, can be used. Within the conductor 3, there may be formed at least one (two are shown in the figure) eccentrically located cavity 6 extending longitudinally along the conductor 3. The cavities of the embodiment of figure 2 are eccentric and do not intersect the central longitudinal axis 5. The cavities 6 can accommodate a heat pipe e.g. by being at least partly filled with a fluid or a heat conducting pipe partly filled with a fluid, forming a heat pipe for transporting heat from within the bushing out towards at least one of the ends of the bushing. The cavities 6 can e.g. comprise longitudinal pipes formed within the wall of the conductor 3 tube or cylinder. In the embodiment of the figure, the heat pipes of the cavities 6 also comprise one or more condensers 7. There may be a condenser 7 at an end of the bushing 1, preferably extending longitudinally beyond the sleeve 2 in order to improve heat dissipation. If the condenser 7 is positioned at an upper end of the bushing 7, condensed fluid may flow back into the cavity part of the heat pipe (to once again be evaporated) by act of gravity. In some embodiments, each condenser 7 is comprised exclusively in one heat pipe, but it is also contemplated that a condenser 7 may be comprised in a plurality of heat pipes. In view of gravity, as mentioned above, the condensers 7 are conveniently positioned at the end of the bushing 1 intended to be an upper end of the bushing when in use. However, in some embodiments, it may be convenient to arrange condensers 7 at both ends of the bushing, e.g. allowing a heat pipe to be connected to a condenser 7 at each end of the bushing, or allowing one heat pipe to be connected to a condenser at an end of the bushing and another heat pipe to be connected to a condenser at another (opposite) end of said bushing.

[0027] Figure 3 illustrates an embodiment of a detachable heat pipe configured for being inserted and/or withdrawn from a cavity 6 or 9 of the conductor 3. A heat conducting pipe 10 forms a closed system enclosing the fluid 11 therein.

[0028] Figure 4 illustrates another embodiment of a detachable heat pipe configured for being inserted and/or withdrawn from a cavity 6 or 9 of the conductor 3. A heat conducting pipe 10 forms a closed system together with a condenser 7, enclosing the fluid 11 therein.

[0029] Figure 5 schematically illustrates an embodiment of a conductor 3. The conductor is shown in a cross-section perpendicular to the longitudinal axis 5. According to the embodiment of figure 5, the conductor 3 comprises a hollow tube or cylinder of an electrically conducting material. The hollow tube conductor 3 forms the central space 9 discussed above in relation to figure 2. In the longitudinal envelope wall of the conductor tube 3, a plurality of pipe shaped cavities 6 are defined. The number of cavities 6 may vary greatly depending on design of the bushing/conductor and the need for heat exchange. Here, four cavities are shown as an example. Each of the cavities 6 are configures for accommodating a heat-pipe, as discussed herein. The cavities may conveniently be essentially equidistantly distributed along the circumference of the tube 3, within the wall of said tube 3, in order to achieve heat exchange relatively evenly around the conductor 3. Additionally or alternatively, the central space 9 can be used for accommodating a heat pipe.

[0030] Figure 6 schematically illustrates another embodiment of a conductor 3. The conductor is shown in a cross-section perpendicular to the longitudinal axis 5. According to the embodiment of figure 6, the conductor 3 comprises a hollow tube or cylinder of an electrically conducting material. The hollow tube conductor 3 forms the central space 9 discussed above in relation to figure 2. In the longitudinal envelope wall of the conductor 3, at least one (here a plurality are shown) cavity 6 is defined. According to the embodiment of figure 6, the cavity or cavities 6 has an elongated cross-section extending along the conductor 3 wall, following the curving of the wall. The number of cavities 6 may vary greatly depending on design of the bushing/conductor and the need for heat exchange. Here, two cavities are shown as an example. Each of the cavities 6 are configures for accommodating a heat-pipe, as discussed herein. The cavities 6 (of there is more than one) may conveniently be essentially equidistantly distributed along the circumference of the tube 3, within the wall of said tube 3, in order to achieve heat exchange relatively evenly around the conductor 3. Additionally or alternatively, the central space 9 can be used for accommodating a heat pipe.

[0031] Figure 7 schematically illustrates another embodiment of a conductor 3. The conductor is shown in a cross-section perpendicular to the longitudinal axis 5. According to the embodiment of figure 7, the conductor 3 comprises two concentrically arranged hollow tubes or cylinders of an electrically conducting material. The inner hollow tube 3a of the conductor 3 forms the central space 9 through which the central longitudinal axis 5 of the bushing runs. The eccentrically located cavity 6 is formed between the inner tube 3a and the outer tube 3b of the conductor 3. The cavity 6 is configured for accommodating a heat-pipe, as discussed herein. In this embodiment, the cavity 6 extends, in the transvers plane, 360° around the central space 9 within the conductor 3, allowing the

heat to be exchanged more evenly in the conductor 3. Additionally or alternatively, the central space 9 can be used for accommodating a heat pipe.

[0032] The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

Claims

1. An electrical insulator bushing (1) comprising:

an electrically insulating sleeve (2) having a central longitudinal through hole (4) surrounding a central longitudinal axis (5) of the bushing; and an electrical conductor (3) positioned through the central longitudinal through hole (4) of the sleeve;
wherein the conductor (3) comprises a cavity (6; 9) extending longitudinally along the conductor (3) and having an opening at one end;
wherein the cavity (6; 9) is arranged for accommodating a heat-pipe, the heat-pipe comprising a fluid being contained in a closed system arranged for transferring heat along the bushing (1), and
wherein the cavity (6; 9) is arranged for allowing the heat-pipe to be introduced into and removed from said cavity via its opening.

2. The bushing of claim 1, wherein the cavity (6; 9) is arranged for accommodating the heat-pipe by said cavity being arranged for allowing the fluid to be introduced into the cavity via its opening and for allowing the opening to be blocked to form the closed system.

3. The bushing of claim 2, further comprising the fluid (11), having been introduced into the cavity (6; 9), wherein the opening is blocked to form the closed system.

4. The bushing of claim 1, wherein the cavity (6; 9) is arranged for accommodating the heat-pipe by said cavity being arranged for receiving a heat conducting tube (10) partly filled with the fluid (11).

5. The bushing of claim 4, further comprising the heat conducting tube (10) partly filled with the fluid (11), detachably inserted into the cavity (6; 9) through its opening.

6. The bushing of claim 3 or 5, further comprising a heat conducting condenser (7) which is part of the heat-pipe closed system and extends outside of the cavity (6; 9) via the opening.

7. The bushing of any preceding claim, wherein the cavity (6; 9) is eccentrically located in the conductor (3) such that said cavity does not intersect the central longitudinal axis (5) of the bushing.

8. A detachable heat pipe comprising:

a heat conducting tube (10); and
a fluid (11) partly filling the tube;
wherein the heat conducting tube (10) at least partly forms a closed system containing the fluid (11); and
wherein the heat pipe is configured for being detachably inserted into a longitudinally extending cavity (6; 9) of an electrical conductor (3) positioned through the central longitudinal through hole (4) of an electrical insulator bushing (1).

9. The detachable heat pipe of claim 8, further comprising:

a heat conducting condenser (7) which is part of the heat-pipe closed system and is configured for extending outside of the cavity (6; 9).

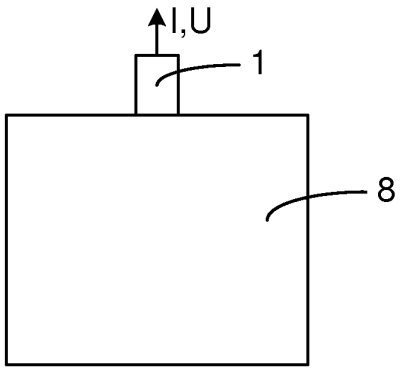

Fig. 1

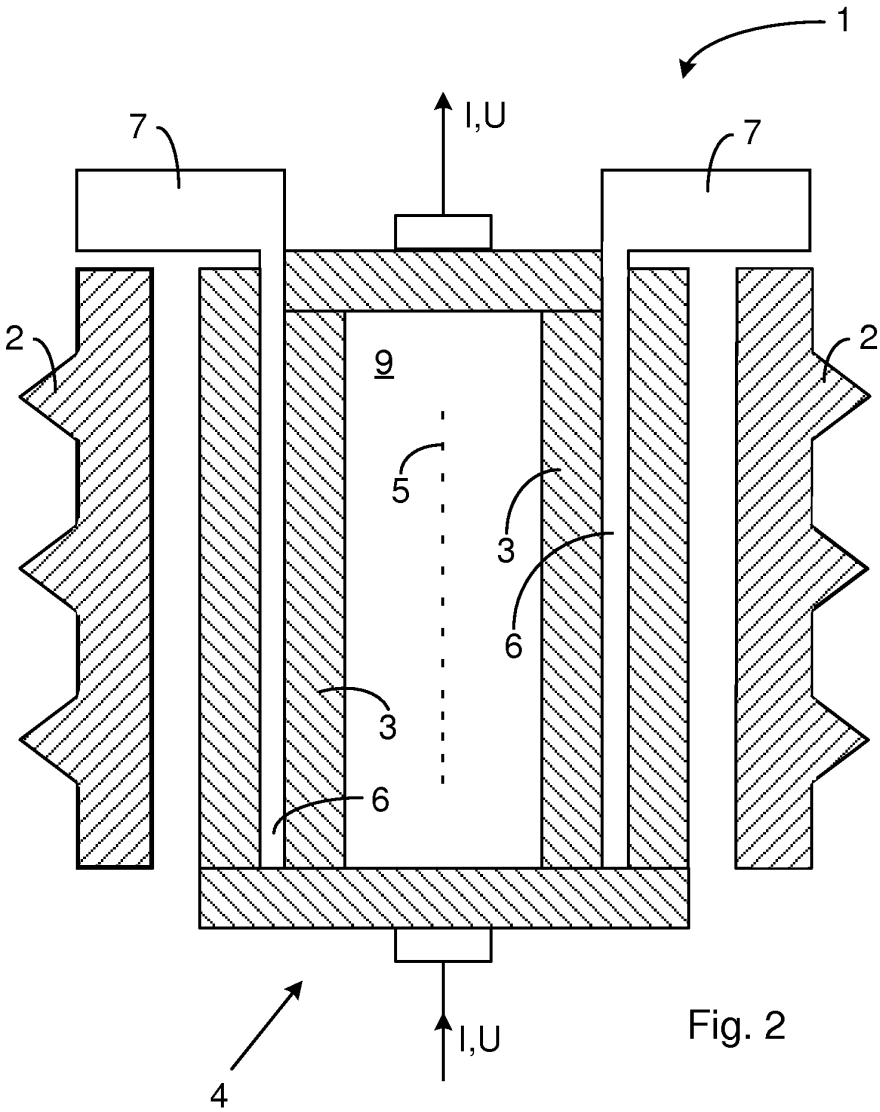

Fig. 2

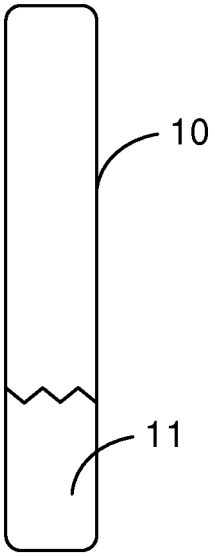

Fig. 3

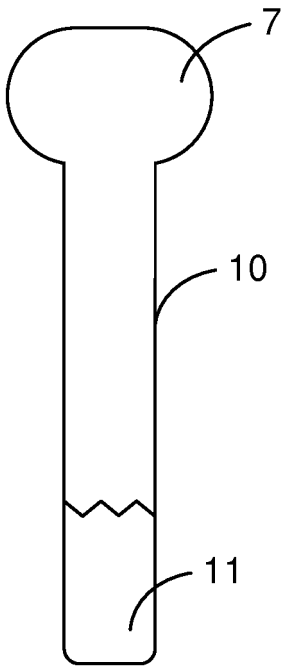

Fig. 4

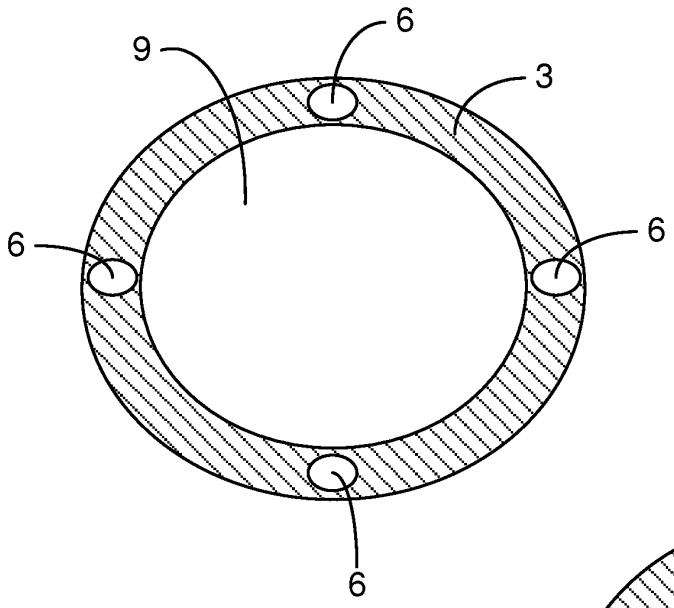

Fig. 5

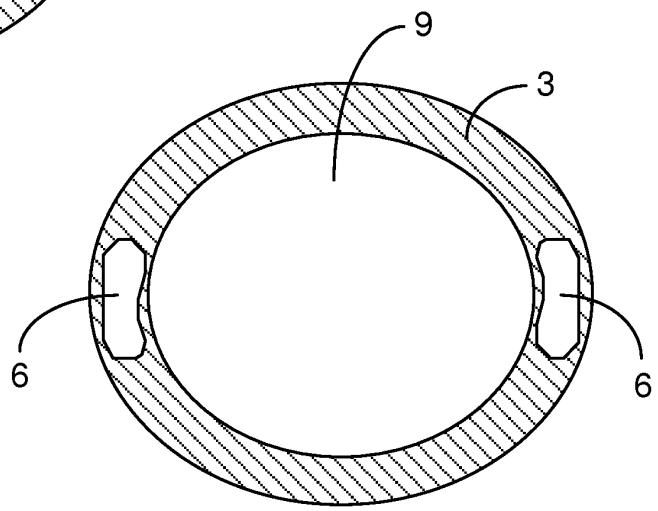

Fig. 6

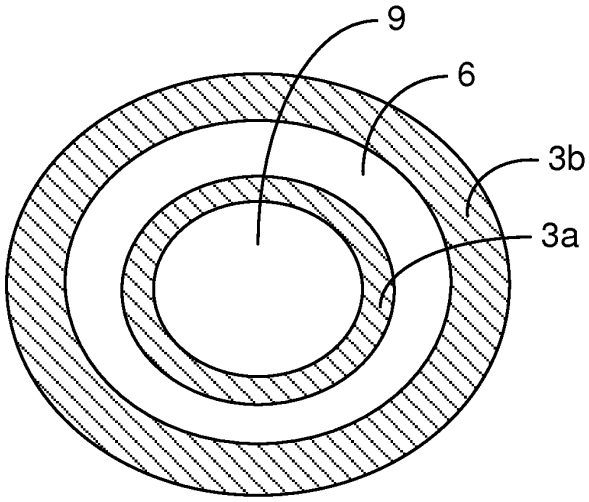

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 8209

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2012/161930 A1 (ABB TECHNOLOGY AG [CH]; KAUFMANN PATRIK [CH]; BUEHLER TILO [CH]; KARAN) 29 November 2012 (2012-11-29) * paragraphs [0010], [0039], [0042] - [0048], [0052] - [0053], [0072] - [0073], [0076]; figures 3A-3C, 4A-4C, 6A, 10 *	1-9	INV. H01B17/54 ADD. H01B17/26 F28D15/02
X	JP H06 231636 A (NGK INSULATORS LTD) 19 August 1994 (1994-08-19) * abstract; figure 4 *	1-3	
A	US 3 627 899 A (MOORE CURTIS L) 14 December 1971 (1971-12-14) * column 1, line 33 - column 2, line 22; figure 1 *	7	
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TECHNICAL FIELDS SEARCHED (IPC)
H01B
F28D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 May 2013	Hillmayr, Heinrich

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 19 8209

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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10-05-2013

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 101369483 **[0006]**
- CN 200810115462 **[0006]**
- WO 2007107119 A **[0007]**