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(54) ELECTRICAL INSULATOR BUSHING

(57) The present disclosure relates to an electrical insulator bushing (1) comprising an electrically insulating sleeve (5) having a central longitudinal through hole surrounding a central longitudinal axis of the bushing. The bushing also comprises an electrical conductor (2) positioned through the central longitudinal through hole of the sleeve. The bushing also comprises an electrically insulating gas (4) filling at least a part of the central longitudinal through hole between the conductor and the sleeve. The bushing also comprises a gas cooler (6) mounted at a first end (7a) of the bushing, around the conductor and axially beyond the sleeve. The gas cooler is arranged for cooling the electrically insulating gas.

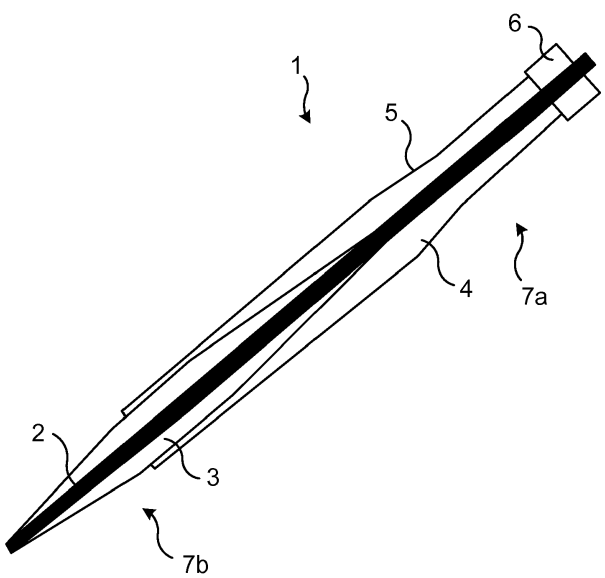

Fig. 2

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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] A bushing can comprise an oil impregnated capacitor body surrounding the conductor for controlling the electrical field in the bushing. Further, the bushing is filled with an insulating fluid, e.g. oil or a gas such as sulphur hexafluoride (SF6).

[0004] 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.

[0005] 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.

[0006] 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.

SUMMARY

[0007] It is an objective of the present invention to provide improved heat transfer and cooling in an electrical bushing which is at least partly filled with an electrically insulating gas.

[0008] 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. The bushing also comprises an electrical conductor positioned through the central longitudinal through hole of the sleeve. The bushing also comprises an electrically insulating gas filling at least a part of the central longitudinal through hole between the conductor and the sleeve. The bushing also comprises a gas cooler mounted at a first end of the bushing, around the conductor and axially beyond the sleeve. The gas cooler is arranged for cooling the electrically insulating gas, e.g. by allowing the gas to enter, or otherwise contact, the cooler for exchanging heat, for instance with a medium surrounding the first end of the bushing (typically air or water) or with a cooling medium connected to the gas cooler.

[0009] According to another aspect of the present invention, there is provided an electrical device, e.g. a power transformer which may be liquid-filled. The device comprises an embodiment of the bushing of the present disclosure.

[0010] The use of a gas cooler improves the voltage/current rating of a gas-filled bushing by cooling the gas which in its turn cools the conductor. Heat-pipe(s) may also be used to cool the conductor, but for a heat-pipe to be efficient, it needs to be able to at the (top) end of the bushing exchange its heat, e.g. from a fluid filled (such as an oil-filled capacitor body) part of the bushing. In a gas-filled bushing, the heat-exchange between a heat-pipe and the gas is also improved by means of the gas cooler in accordance with the present invention. The gas is thus cooled, allowing the gas to more efficiently cool the conductor and any heat-pipe.

[0011] It is to be noted that any feature of any of the aspects may be applied to any other aspect, wherever appropriate. Likewise, any advantage of any of the aspects may apply to any of the other aspects. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following detailed disclosure, from the attached dependent claims as well as from the drawings.

[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] Embodiments will be 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 side view of an embodiment of a bushing of the present invention.

Fig 4a is a schematic cross-sectional view of an embodiment of a conductor in accordance with the present invention.

Fig 4b is a schematic cross-sectional view of another embodiment of a conductor in accordance with the present invention.

Fig 4c is a schematic cross-sectional view of another embodiment of a conductor in accordance with the present invention.

Fig 4d is a schematic cross-sectional view of another embodiment of a conductor in accordance with the present invention.

Fig 5a is a schematic longitudinal section of an embodiment of a heat pipe in accordance with the present invention.

Fig 5b is a schematic longitudinal section of another embodiment of a heat pipe in accordance with the present invention.

DETAILED DESCRIPTION

[0014] Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments are shown. However, other embodiments in many different forms are possible within the scope of the present disclosure. Rather, the following embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Like numbers refer to like elements throughout the description.

[0015] The bushing of the present invention may be used for a transformer, as exemplified herein, but the inventive bushing may alternatively be used for other electrical devices, especially fluid-filled (e.g. oil) electrical devices, such as electrical motors or switches.

[0016] 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, e.g. filled with mineral oil or an ester-based oil. The transformer may be a high-voltage power 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. 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.

[0017] Figure 2 illustrates a longitudinal section of an embodiment of an embodiment of a bushing 1. The bushing comprises an electrically insulating sleeve 5 having a central longitudinal through hole surrounding a central longitudinal axis of the bushing. Along the central longitudinal axis of the bushing, an electrical conductor 2, e.g. of copper or aluminium, is positioned and configured to carry a current/voltage through the bushing 1. At a second (typically lower) end 7b of the bushing, an capacitor body 3 is arranged around the conductor 2 in order to control the electrical field formed by the conductor. The use of a capacitor body is common practice in the field and the capacitor body is typically impregnated with oil or epoxy, or other insulating material. The capacitor body 3 may be encapsulated in a shell, e.g. of epoxy, which contains the insulating material and separates it from the insulating gas 4 in the first (typically upper) end 7a of the bushing 1. The insulating gas 4 fills a part of the bushing, typically at the first end 7a and surrounds the conductor 2 and separates it from the sleeve 5. In addition to insulating the conductor, the gas 4 also acts as a cooling fluid for transferring heat from the conductor. In some embodiments of the present invention, the electrically insulating gas 4 comprises or consists of sulphur hexafluoride, carbon dioxide or nitrogen, or a combination thereof. Sulphur hexafluoride (SF6) may be preferred due to its excellent insulating properties, but SF6 is also a potent greenhouse gas why it may in some applications be less preferred. Carbon dioxide (CO_2) and nitrogen (N_2) may be suitable alternatives to SF6, e.g. a mixture of CO_2 and N_2.

[0018] In accordance with the present invention, a gas cooler 6 is mounted at the first end (7a) of the bushing, around the conductor 2 and axially beyond the sleeve 5, i.e. outside of the sleeve 5 longitudinally extending the bushing in order to make heat exchange with the surrounding medium (typically air, or possibly water in case of e.g. a sub-sea application). The cooler 6 is arranged such that the gas 4 can flow into the cooler to exchange heat via a heat exchanger of the cooler, e.g. a heat sink such as a heat sink with cooling fins for increasing the interface with the surrounding medium for increased cooling capacity. The gas 4 may thus circulate in and out of the cooler 6, e.g. by means of convection. Since the first end 7a with the cooler 6 is usually the upper end of the bushing 1, and hot gas 4 typically is lighter than cooled gas, hot gas 4 rises in the bushing, enters the cooler 6, is cooled down in the cooler, and sinks back down in the bushing where the cooled gas 4 can take up heat from the hot conductor 2 as well as from any heat-pipes transporting heat from the liquid-filled capacitor body 3 surrounded part of the conductor 2. Thus, by combining cooling of the gas 4 by means of the gas cooler 6, with the use of heat-pipes in order to transport heat to the gas-filled part of the bushing, the gas cooler 6 may, via the cooled gas and the heat-pipe(s), act to cool down both the gas-filled and the liquid-filled parts of the bushing 1.

[0019] The gas cooler 6 may have any suitable shape and position at the first end 7a, but it may be convenient if the cooler has a substantially cylindrical shape with a central longitudinal through hole through which the conductor can pass directly outside of (on top of) the sleeve 5, as shown in figure 2. For additional cooling, the electrically conducting solid material of the cooler, e.g. copper or aluminium, may directly contact the conductor 2 as it passes through the conductor. However, since this may cause a problem with the cooler carrying a current/voltage, it may be preferred that the cooler solid material is insulated from the conductor whereby the conductor is only cooled indirectly by the cooler 6 via the gas 4.

[0020] To further increase the cooling efficiency of the gas cooler 6, the cooler may comprise a fan for agitating the surrounding medium (typically blowing the medium passed the cooler, or the fins of the cooler) for improving the heat exchange with the surrounding medium. Additionally or alternatively, the bushing 1 may comprise an internal fan for circulating the insulating gas 4 for improving the heat exchange, e.g. if convection is not enough for sufficiently circulating the gas 4 within the sleeve 5. Du to the harsh electrical environment inside the bushing 1, it may not be desirable to introduce electrical wires for running the fan inside the bushing. However, the current passing through the conductor 2 may provide an electrical field which may by way of electrical induction run the fan.

[0021] Figure 3 is a schematic side view of an embodiment of a bushing 1, e.g. the bushing shown in figure 2. The gas cooler 6 is shown as a heat sink with a multitude of longitudinal parallel running cooling fins for cooling the gas within the sleeve 5.

[0022] Figure 4a schematically illustrates an embodiment of a conductor 2. The conductor is shown in a cross-section perpendicular to the longitudinal axis of the bushing 1. According to the embodiment of figure 4a, the conductor 2 comprises a hollow tube or cylinder of an electrically conducting material. The hollow tube conductor 2 forms a central longitudinal space 9. In the longitudinal envelope wall of the conductor tube 2, a plurality of pipe shaped cavities are defined for accommodating heat-pipes 10. The number of cavities may vary greatly depending on design of the bushing/conductor and the need for heat exchange. Here, four cavities are shown as an example. The cavities may conveniently be essentially equidistantly distributed along the circumference of the tube 2, within the wall of said tube, in order to achieve heat exchange relatively evenly around the conductor 2. Additionally or alternatively, the central space 9 can be used for accommodating a heat pipe. According to some embodiments, the cavity or cavities has an elongated cross-section extending along the conductor 2 wall, following the curving of the wall. Thus, in some embodiments of the present invention, the conductor 2 comprises a cavity extending longitudinally along the conductor and having an opening at one end. The cavity is arranged for accommodating a heat-pipe 10, the heat-pipe comprising a fluid 11 being contained in a closed system arranged for transferring heat along the bushing 1. In some embodiments, the cavity accommodates a heat-pipe 10 by said cavity containing the fluid 11 having been introduced into the cavity via its opening, which opening has been blocked to form the closed system. Additionally or alternatively, in some other embodiments, the cavity accommodates a heat-pipe 10 by said cavity containing a heat conducting tube partly filled with the fluid 11.

[0023] Figure 4b schematically illustrates another embodiment of a conductor 2. The conductor is shown in a cross-section perpendicular to the longitudinal axis of the bushing 1. According to the embodiment of figure 4b, the conductor 2 comprises two concentrically arranged hollow tubes or cylinders of an electrically conducting material. The inner hollow tube 2a of the conductor 2 forms the central space 9 through which the central longitudinal axis of the bushing 1 runs. An eccentrically located cavity for accommodating a heat-pipe 10 is formed between the inner tube 2a and the outer tube 2b of the conductor 2. In this embodiment, the cavity extends, in the transvers plane, 360° around the central space 9 within the conductor 2, allowing the heat to be exchanged more evenly in the conductor 2. Additionally or alternatively, the central space 9 can be used for accommodating an additional heat pipe. Thus, in some embodiments of the present invention, the cavity is an annular cavity formed between the tubular conductor part 2b and an inner conductor part 2a which is longitudinally concentrically positioned within the tubular conductor part 2b.

[0024] Figure 4c schematically illustrates another embodiment of a conductor 2. The conductor is shown in a cross-section perpendicular to the longitudinal axis of the bushing 1. According to the embodiment of figure 4c, the conductor 2 is a pipe of an electrically conducting material having a longitudinal central cavity/space, e.g. a through hole, 9. In the longitudinal cavity 9 of the conductor tube 2, a plurality of longitudinally arranged heat-pipes 10 are positioned. It should be noted that the bushing 1 may be configured for accommodating any number of heat-pipes 10, according to different embodiments of the present invention. The central cavity 9 is typically at least partly liquid-filled, e.g. with a conventional transformer oil, and the heat-pipe 10 may be at least partly immersed in said liquid. The heat-pipes 10 may thus cool the conductor 2 by heat transfer via the liquid in the central cavity 9. Additionally, if a heat-pipe 10 is positioned in direct contact with the inside surface of the conductor tube 3, at least some of the cooling may be done also by direct heat transfer via the heat conducting pipe of the heat-pipe 10 and the conductor tube 2. The number of heat-pipes 10 may vary greatly depending on design of the bushing/conductor and the need for heat exchange. Here, four heat-pipes 10 are shown as an example. Each of the heat-pipes 10 may be detachable, allowing the number of heat-pipes used to be adjusted in view of the cooling need of the bushing 1. The heat-pipes 10 may conveniently be essentially equidistantly distributed along the circumference of the conductor tube 2, along the inner wall of said tube 2, in order to achieve heat exchange relatively evenly around the conductor 2.

[0025] Thus, in some embodiments of the present invention, the bushing comprises at least one heat-pipe 10 comprising a heat transfer fluid 11 enclosed in a heat conducting pipe for transferring heat along the bushing 1, the heat-pipe 10 being longitudinally arranged and positioned in a central longitudinal cavity 9 formed within a tubular conductor part 2b of the conductor 2.

[0026] Figure 4d schematically illustrates another embodiment of a conductor 2. The conductor is shown in a cross-section perpendicular to the longitudinal axis of the bushing 1. According to the embodiment of figure 4d, the conductor 2 is a pipe of an electrically conducting material having a longitudinal central cavity/space, e.g. as the through hole 9 in figure 4c. However, according to the embodiment of figure 4d, the heat-pipe 10 is formed within the central cavity, substantially filling the central cavity over its entire cross-section. This may e.g. be achieved by fitting a heat-pipe 10 (formed in its own, separate heat conducting pipe), in the central cavity 9, or by simply forming the heat-pipe 10 directly inside the conductor 2 by blocking the central cavity at a lower end of the bushing 1, partly filling the central cavity with the heat-pipe fluid 11, and blocking the central cavity at an upper end of the bushing, whereby a heat-pipe 10 is formed in the central cavity, with the inner wall of the conductor functioning as the cylinder wall of the heat-pipe 10.

[0027] The embodiments of figures 4a, 4b and 4c are only examples of how one or more heat-pipes may be formed or otherwise included in a bushing 1 of the present invention. The heat-pipes may be used to transport heat within the bushing 1 to where it may be exchanged by heating the gas 4 which is in its turn cooled by means of the gas cooler 6. The heat-pipes may be permanently formed in the bushing, or may be detachably inserted e.g. in the cavities of figure 4a.

[0028] Figure 5a illustrates an embodiment of a heat pipe 10, e.g. a detachable heat-pipe configured for being inserted and/or withdrawn from a cavity or from the central through hole 9 of the pipe-formed conductor 2. A heat conducting pipe forms a closed system enclosing the heat transfer fluid 11 therein.

[0029] Figure 5b illustrates another embodiment of a heat pipe 10, e.g. a detachable heat-pipe configured for being inserted and/or withdrawn from a cavity or from the central through hole 9 of the pipe-formed conductor 2. A heat conducting pipe forms a closed system together with a condenser 12, enclosing the heat transfer fluid 11 therein.

[0030] The heat transfer fluid 11 may be any suitable fluid which has a boiling point at a desired operating temperature of the electrical conductor 3. The fluid may e.g. be water, an alcohol, a fluorinated alcohol or a fluorocarbon.

[0031] In some embodiments of the present invention, the heat-pipe 10 is detachable. The power-rating of the bushing 1 may thus be changed depending on need and the heat-pipe may more easily be serviced or exchanged as needed.

[0032] In some embodiments of the present invention, the at least one heat-pipe 10 is eccentrically positioned in the central cavity 9 such that it does not intersect the central axis of the bushing. Thus, a central space within a tubular conductor 2 may be used for other purposes, e.g. a draw rod, without the heat-pipe being in the way.

[0033] In some embodiments of the present invention, the heat-pipe 10 comprises a condenser 12 extending beyond the sleeve 5. Thus, the heat-pipe may extend at one (typically upper) end, beyond (above) the sleeve 5 in order to more easily cool down and condense the heat transfer fluid away from the heat insulating effect of the sleeve. Alternatively, the condenser 12 may be formed inside the central space 9 in a cooler part of the bushing 1.

[0034] The present disclosure 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 present disclosure, as defined by the appended claims.

Claims

1. An electrical insulator bushing (1) comprising:

an electrically insulating sleeve (5) having a central longitudinal through hole surrounding a cen-

tral longitudinal axis of the bushing;
an electrical conductor (2) positioned through the central longitudinal through hole of the sleeve (5);
an electrically insulating gas (4) filling at least a part of the central longitudinal through hole between the conductor (2) and the sleeve (5); and
a gas cooler (6) mounted at a first end (7a) of the bushing, around the conductor (2) and axially beyond the sleeve (5);
wherein the gas cooler (6) is arranged for cooling the electrically insulating gas (4).

2. The bushing of claim 1, wherein the cooler (6) comprises a heat sink, e.g. comprising cooling fins.

3. The bushing of any preceding claim, further comprising:

an internal fan for circulating the insulating gas (4) for improving the heat exchange.

4. The bushing of claim 3, wherein the internal fan is an electrical fan powered by electrical fields within the bushing (1).

5. The bushing of any preceding claim, wherein the gas cooler is cylindrical with a longitudinal through hole through which the conductor (2) passes.

6. The bushing of any preceding claim, wherein the electrically insulating gas (4) comprises or consists of sulphur hexafluoride, carbon dioxide or nitrogen, or a combination thereof.

7. The bushing of any preceding claim, wherein the conductor (2) 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 (10), the heat-pipe comprising a fluid (11) being contained in a closed system arranged for transferring heat along the bushing (1).

8. The bushing of claim 7, wherein the cavity accommodates the heat-pipe (10) by said cavity containing the fluid (11) having been introduced into the cavity via its opening, which opening has been blocked to form the closed system.

9. The bushing of claim 7, wherein the cavity accommodates the heat-pipe (10) by said cavity containing a heat conducting tube partly filled with the fluid (11).

10. The bushing of claim 9, wherein the heat conducting tube is detachably contained in the cavity.

11. The bushing of any preceding claim 7-10, wherein the cavity is eccentrically located in the conductor (2) such that said cavity does not intersect the central longitudinal axis of the bushing (1).

12. The bushing of any preceding claim 7-10, wherein the cavity is formed in a central longitudinal cavity formed within a tubular conductor part (2b) of the conductor (2).

13. The bushing of claim 12, wherein the cavity is an annular cavity formed between the tubular conductor part (2b) and an inner conductor part (2a) which is longitudinally concentrically positioned within the tubular conductor part (2b).

14. The bushing of any preceding claim, further comprising:

at least one heat-pipe (10) comprising a heat transfer fluid (11) enclosed in a heat conducting pipe for transferring heat along the bushing (1), the heat-pipe (10) being longitudinally arranged and positioned in a central longitudinal cavity formed within a tubular conductor part (2b) of the conductor (2).

15. An electrical device (8), e.g. a power transformer, comprising the bushing (1) of any preceding claim.

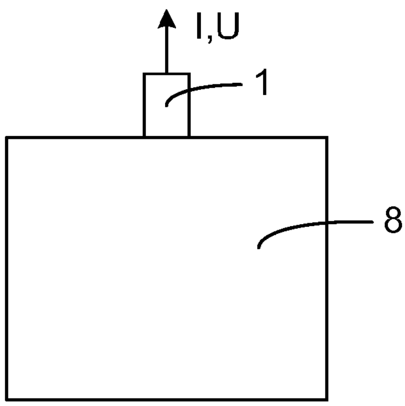

Fig. 1

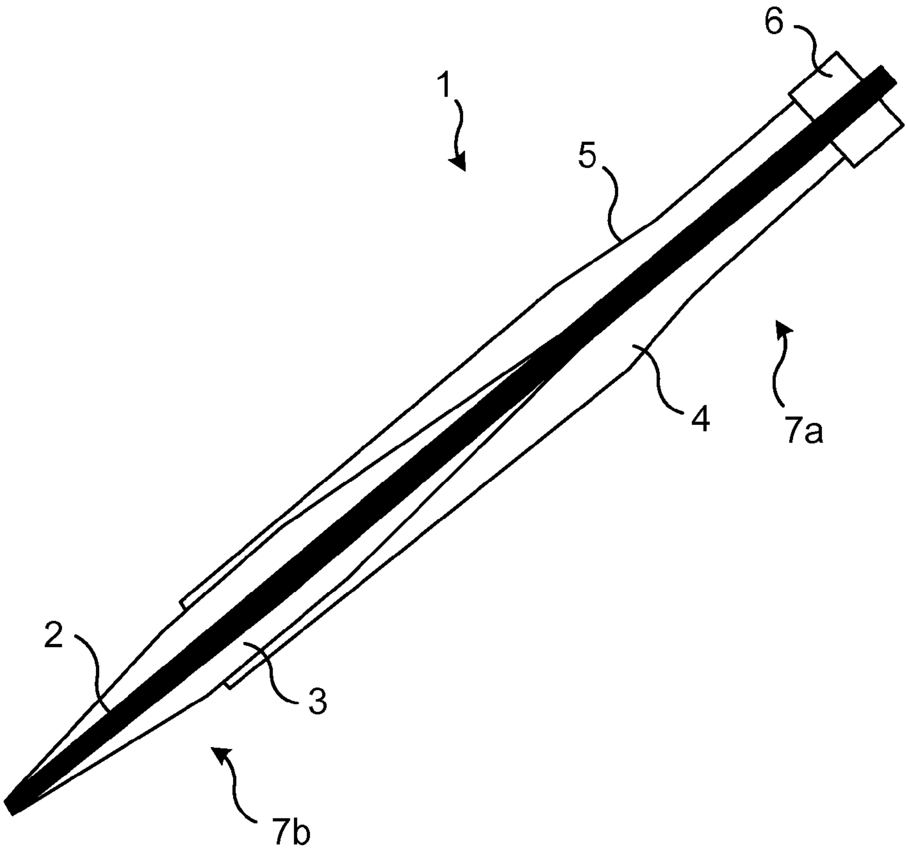

Fig. 2

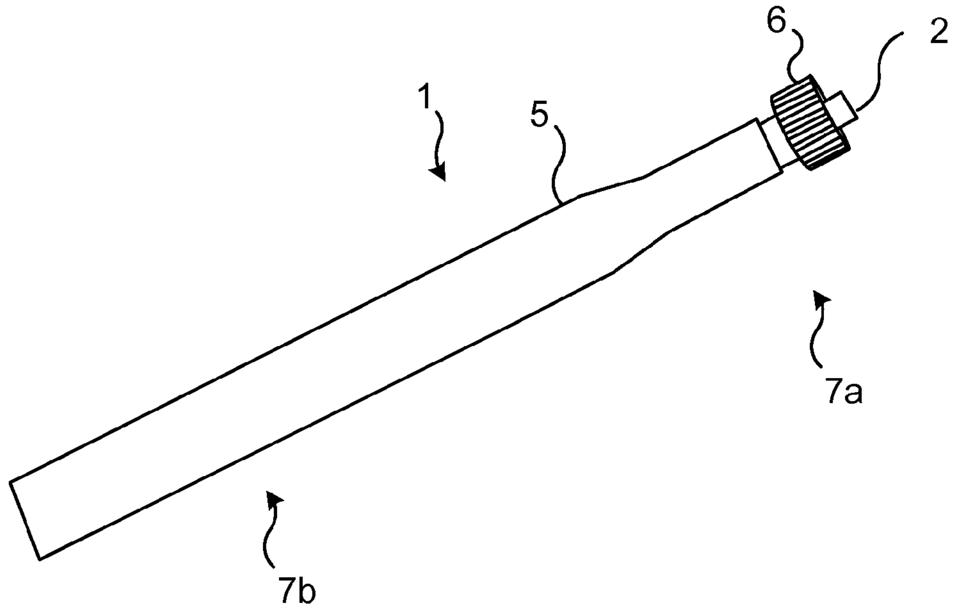

Fig. 3

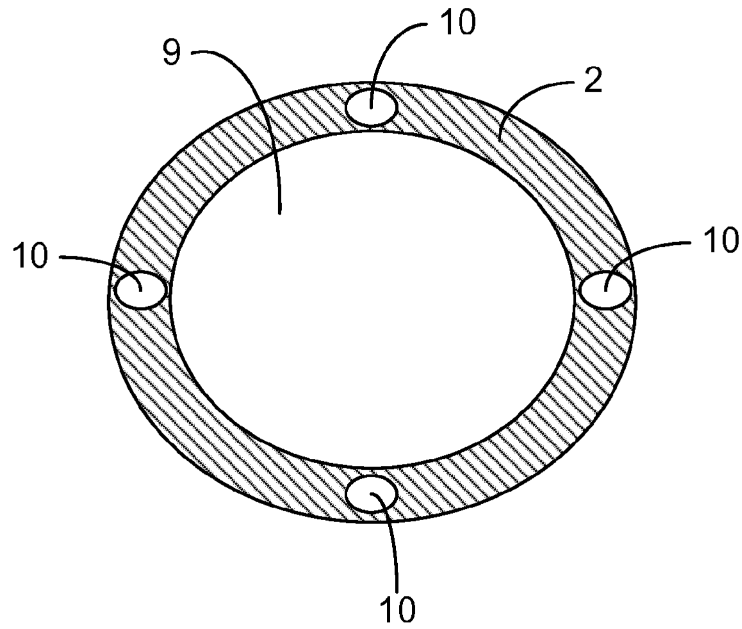

Fig. 4a

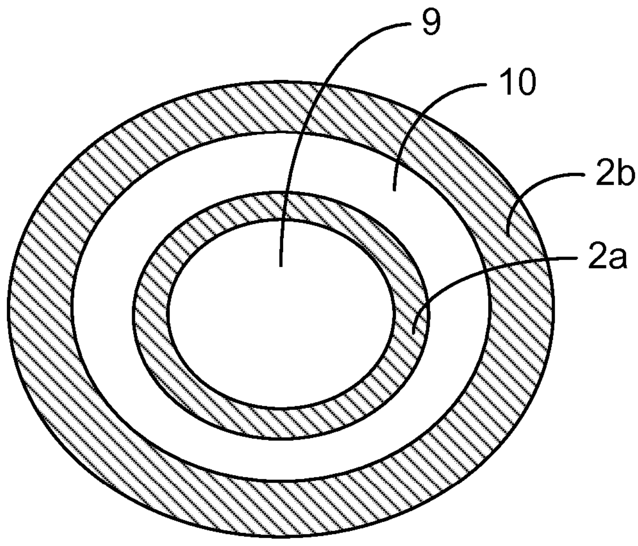

Fig. 4b

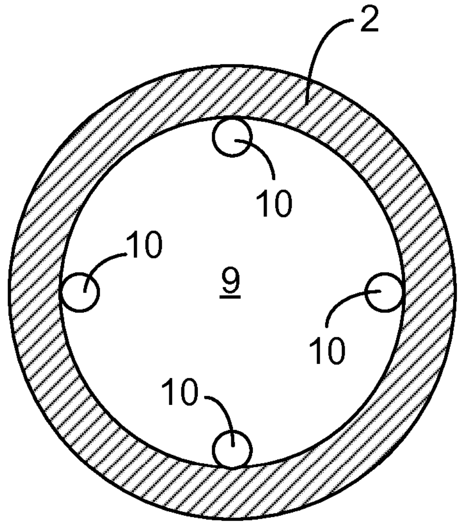

Fig. 4c

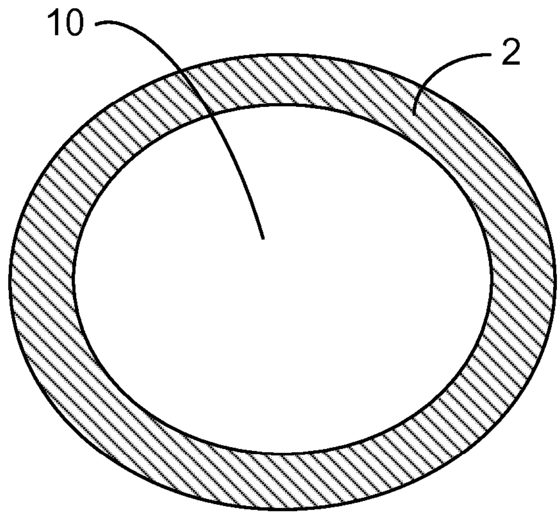

Fig. 4d

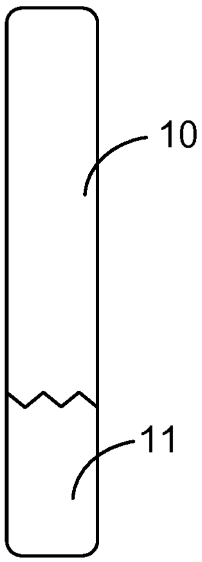

Fig. 5a

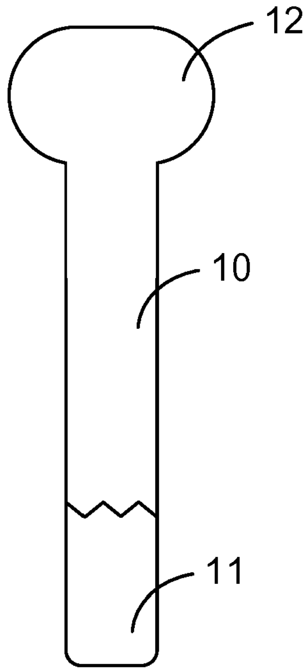

Fig. 5b

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EUROPEAN SEARCH REPORT

Application Number
EP 15 15 7306

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	JP H07 169351 A (TOSHIBA CORP) 4 July 1995 (1995-07-04) * paragraph [0003]; figures 1,4,7,10,11 *	1-15	INV. H01B17/54 ADD. H01B17/26 H01B17/36
X	JP H07 201242 A (TOSHIBA CORP) 4 August 1995 (1995-08-04) * abstract; figures 1,2 *	1,2,6	
A	EP 2 704 157 A1 (ABB TECHNOLOGY LTD [CH]) 5 March 2014 (2014-03-05) * paragraph [0016] - paragraph [0024] * * figures 1-7 *	7-15	
A	JP S52 107398 U (NN) 16 August 1977 (1977-08-16) * figures 3, 4b, 6 *	14,15	

TECHNICAL FIELDS SEARCHED (IPC)

H01B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	7 August 2015	Hillmayr, Heinrich

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 15 7306

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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