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(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 (4) of the sleeve (2); wherein the conductor (3) comprises at least a part of an eccentrically located cavity (6) extending longitudinally along the conductor (3); wherein the cavity (6) is at least partly filled with a fluid, the fluid being contained in the cavity (6) in a closed system; whereby the cavity (6) forms a heat pipe arranged for transferring heat within the bushing.

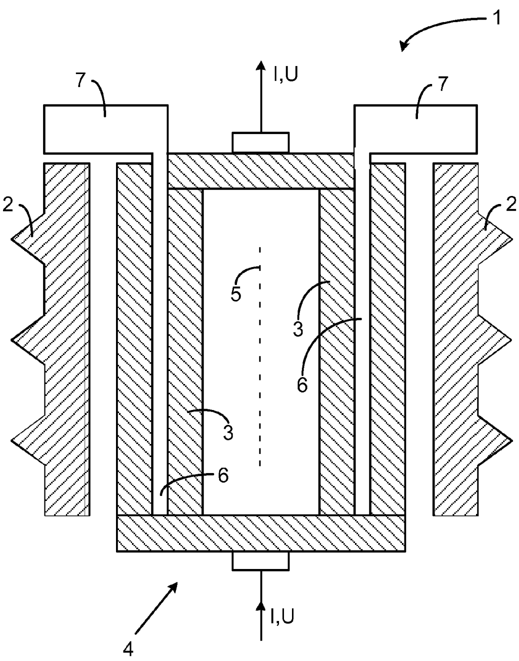

Fig. 1

EP 2 645 379 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 an part in oil in the transformer and a part in air outside of the transformer. Other bushings are air-to-air bushings 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 end 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] 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.

[0006] 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.

SUMMARY

[0007] It is an objective of the present invention to at alleviate a problem with cooling a bushing of the prior art.

[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; and an electrical conductor positioned through the central longitudinal through hole of the sleeve; wherein the conductor comprises at least a part of an eccentrically located cavity extending longitudinally along the conductor; wherein the cavity is at least partly filled with a fluid, the fluid being contained in the cavity in a closed system; whereby the cavity forms a heat pipe arranged for transferring heat within the bushing.

[0009] According to another aspect of the present invention, there is provided a method of transferring heat within an electrical insulator bushing having a central longitudinal axis. The method comprises allowing electrical current to pass through an electrical conductor positioned through a central longitudinal through hole of an electrically insulating sleeve; allowing heat formed by resistance in the conductor to be exchanged with a fluid in an eccentrically located cavity, at least a part of said cavity being comprised in the conductor and extending longitudinally along the conductor; allowing the fluid to transit from a liquid state to a gaseous state within a first part of the cavity as a result of the heat exchange; allowing the gaseous fluid to travel from the first part of the cavity to a second part of said cavity; allowing the fluid to condense to a liquid in the second part of the cavity; and allowing the liquid fluid to travel back to the first part of the cavity.

[0010] It is an advantage to use an eccentrically located cavity for forming a heat pipe in a bushing since this allows the central space of the 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.

[0011] In some embodiments, a second eccentrically located cavity is extending longitudinally along the conductor. Also the second cavity is at least partly filled with a fluid, the fluid being contained in the cavity in a closed system. Thus, a second heat pipe can be formed in the bushing, providing redundancy and improving heat transfer in the bushing, possibly in another part of the bushing than where the first heat pipe provides most of its heat transfer. Third and further cavities/heat pipes are also contemplated.

[0012] In some embodiments, the conductor comprises two concentrically arranged longitudinal tubes, the eccentrically located cavity being formed between the two concentrically arranged tubes. This is a convenient way of forming an eccentric longitudinal cavity defined by the conductor. One or both of the tubes is made from an electrically conducting material and is arranged to conduct electricity when the bushing is used.

[0013] In some embodiments, the conductor comprises a longitudinal tube surrounding the central longitudinal axis, the eccentrically located cavity being formed in a wall of the longitudinal tube. This is another convenient way of forming an eccentric longitudinal cavity defined by the conductor. The cavity may form a longitudinal pipe within the longitudinal envelope wall of the conducting tube. Further longitudinal pipes may be provided within the wall thickness to form additional cavities/heat pipes. The pipes may be equally distributed around the circumference of the tube. A tube with several small pipes can be extruded in one piece. Possibly, the pipes can be given dimensions so that the heat transfer surface becomes smaller than with a central space for the fluid and thus increases the heat flux density in the transfer surface between conducting material and fluid, whereby the fluid starts boiling easier. More than one heat pipe gives redundancy.

[0014] The cavity can be sealed at the ends of the conductor, or at least one end of the longitudinal cavity can form a condenser. Thus, the eccentrically located cavity comprises a condenser part at one end of the bushing, the condenser part being arranged to have a lower temperature than an other part of the cavity. By means of the condenser, heat can more efficiently be removed from the hot part of the bushing interior. In some embodiments, the condenser part extends longitudinally beyond an end of the electrically insulating sleeve. Thereby, the exchanged heat can more easily be dissipated to the ambient medium (e.g. air) since the heat is not retained by the insulating sleeve. It is also contemplated to use at least one condenser at each end of the bushing.

[0015] In some embodiments, the eccentrically located cavity extends longitudinally along the whole length of the electrically insulating sleeve. In this way, heat formed along the whole bushing, where the bushing is insulated by the sleeve, can be dissipated via one or both ends of the heat pipe cavity.

[0016] In some embodiments, a first end of the bushing is configured for operation in oil and a second end of the bushing is configured for operation in air. The inventive bushing may be especially advantageous for an oil-to-air bushing since heat may then have to be efficiently dissipated at the air end of the bushing. An example where such an oil-to-air bushing may be conveniently used is when it is mounted thorough a casing of an electrical transformer. An oil-filled electrical transformer, especially a high voltage transformer, can put high requirements for heat transfer for cooling the bushing interior. Thus, a bushing of the present invention may be used for conducing electrical current through a casing of an electrical transformer.

[0017] 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

[0018] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic view in longitudinal section of an embodiment of a bushing of the present invention.

Fig 2 is a schematic block diagram of an embodiment of an oil-filled transformer comprising an embodiment of a bushing of the present invention.

Fig 3 is a schematic view in transverse cross-section of an embodiment of a conductor of the present invention.

Fig 4 is a schematic view in transverse cross-section of an embodiment of a conductor of the present invention.

Fig 5 is a schematic view in transverse cross-section of an embodiment of a conductor of the present invention.

DETAILED DESCRIPTION

[0019] 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.

[0020] 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.

[0021] The cavity is an enclosed hole or space in which the fluid can be contained in a closed system.

[0022] 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.

[0023] 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).

[0024] 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. 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.

[0025] The bushing of the present invention can be beneficial in both direct current (DC) and alternating current (AC) applications.

[0026] Figure 1 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 through which the central longitudinal axis 5 passes. As discussed above, this central space can be used for different things, such as a draw rod or the like. Alternatively, a solid conductor 3 can be used. Within the conductor 3, there are formed at least one (two are shown in the figure) eccentrically located cavity 6 extending longitudinally along the conductor 3. The cavities are eccentric and do not intersect the central longitudinal axis 5. The cavities 6 are 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 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 heat pipe (to once again be evaporated) by act of gravity. In some embodiments each condenser 7 is comprised exclusively in one heat pipe cavity 6, but it is also contemplated that a condenser 7 may be associated with a plurality of heat pipes, being comprised in a plurality of the eccentric cavities. 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 2 is a schematic illustration of a transformer 8 where a bushing 1, e.g. as discussed in relation to figure 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 3 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 3, may conduct current from e.g. a winding of the transformer, through the casing of the transformer and to e.g. an airborne line of a power distribution network, the bushing 1 insulating the current from the casing and any other external structures.

[0028] Figure 3 schematically illustrates an embodiment of a conductor 3. The conductor is shown in a transverse section perpendicular to the longitudinal axis 5. According to the embodiment of figure 3, 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 1. In the longitudinal envelope wall of the tube 3, a plurality of pipe shaped cavities 6 are defined. The number of pipes 6 may vary greatly depending on design of the bushing/conductor and the need for heat exchange. Here, four pipes are shown as an example. The pipes 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.

[0029] Figure 4 schematically illustrates another embodiment of a conductor 3. The conductor is shown in a transverse section perpendicular to the longitudinal axis 5. According to the embodiment of figure 4, 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 1. In the longitudinal envelope wall of the tube 3, at least one (here a plurality are shown) cavity 6 is defined. According to the embodiment of figure 4, 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. 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.

[0030] Figure 5 schematically illustrates another embodiment of a conductor 3. The conductor is shown in a transverse section perpendicular to the longitudinal axis 5. According to the embodiment of figure 3, 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. In this embodiment, the heat pipe 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.

[0031] 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 at least a part of an eccentrically located cavity (6) extending longitudinally along the conductor (3);
wherein the cavity (6) is at least partly filled with a fluid, the fluid being contained in the cavity in a closed system;
whereby the cavity (6) forms a heat pipe arranged for transferring heat within the bushing (1).

2. The bushing of claim 1, further comprising:

a second eccentrically located cavity (6) extending longitudinally along the conductor (3);
wherein the second cavity is at least partly filled with a fluid, the fluid being contained in the cavity in a closed system.

3. The bushing of claim 1 or 2, wherein the conductor (3) comprises two concentrically arranged longitudinal tubes (3a, 3b), the eccentrically located cavity (6) being formed between the two concentrically arranged tubes.

4. The bushing of claim 1 or 2, wherein the conductor (3) comprises a longitudinal tube surrounding the central longitudinal axis (5), the eccentrically located cavity (6) being formed in a wall of the longitudinal tube.

5. The bushing of ant previous claim, wherein the eccentrically located cavity comprises a condenser part (7) at an end of the bushing (1), the condenser part being arranged to have a lower temperature than an other part of the cavity (3).

6. The bushing of claim 5, wherein the condenser part (7) extends longitudinally beyond an end of the electrically insulating sleeve (2).

7. The bushing of any previous claim, wherein the eccentrically located cavity (6) extends longitudinally along the whole length of the electrically insulating sleeve (2).

8. The bushing of any previous claim, wherein a first end of the bushing is configured for operation in oil and a second end of the bushing is configured for operation in air.

9. The bushing of any previous claim, mounted thorough a casing of an electrical transformer (8).

10. Use of a bushing (1) of any previous claim, for conducing electrical current through a casing of an electrical transformer (8).

11. A method of transferring heat within an electrical insulator bushing (1) having a central longitudinal axis (5), the method comprising:

allowing electrical current to pass through an electrical conductor (3) positioned through a central longitudinal through hole (4) of an electrically insulating sleeve (2);
allowing heat formed by resistance in the conductor (3) to be exchanged with a fluid in an eccentrically located cavity (6), at least a part of said cavity being comprised in the conductor and extending longitudinally along the conductor (3);
allowing the fluid to transit from a liquid state to a gaseous state within a first part of the cavity (6) as a result of the heat exchange;
allowing the gaseous fluid to travel from the first part of the cavity to a second part (7) of said cavity (6);
allowing the fluid to condense to a liquid in the second part of the cavity; and
allowing the liquid fluid to travel back to the first part of the cavity.

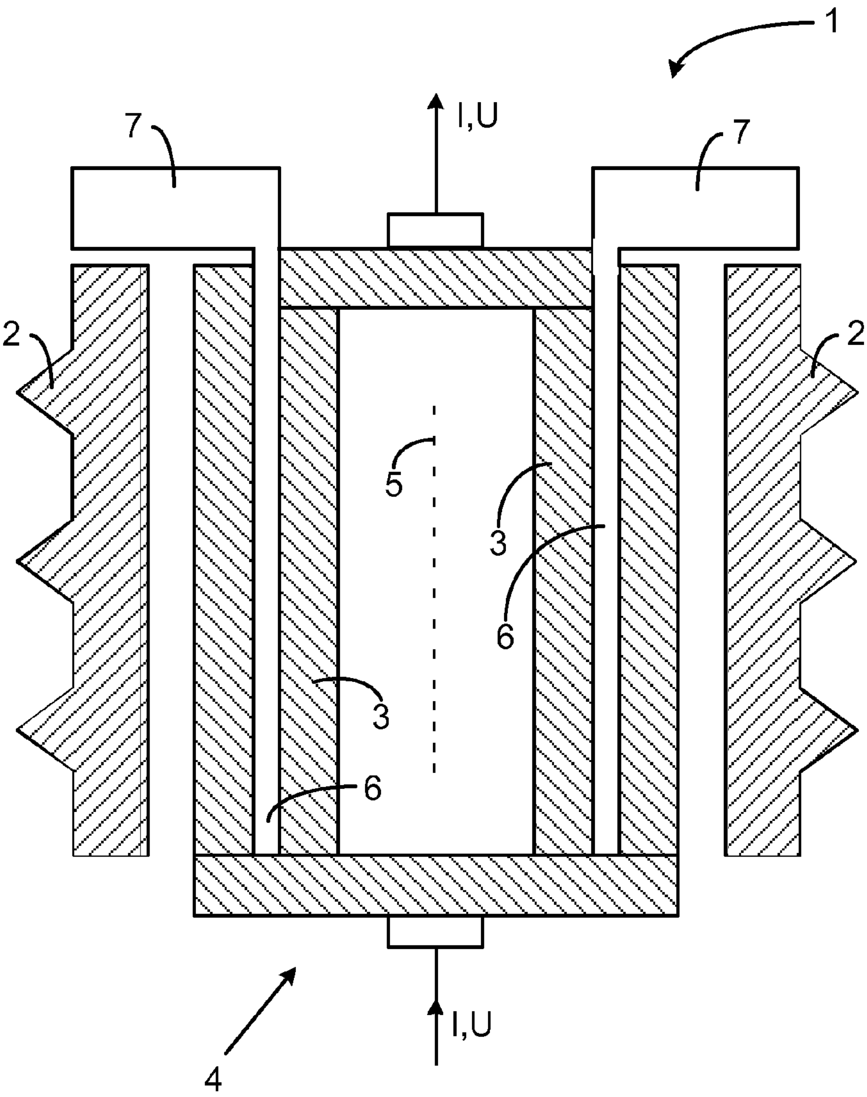

Fig. 1

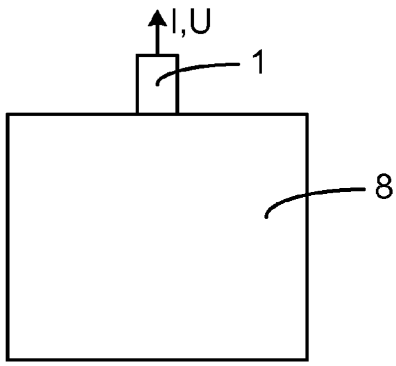

Fig. 2

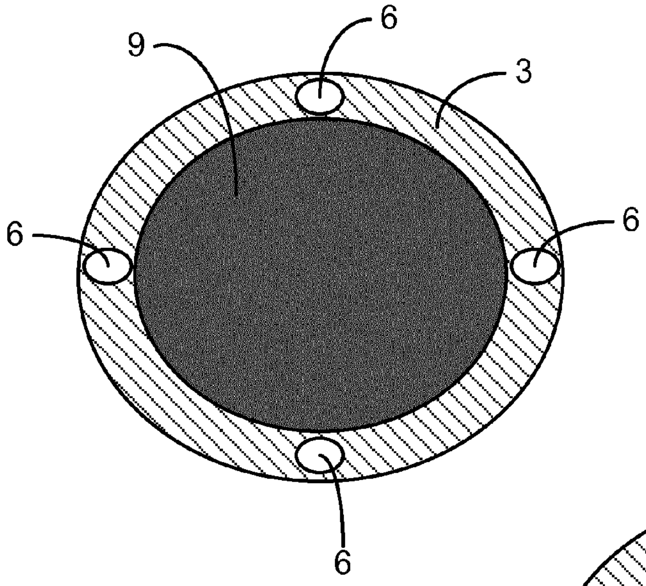

Fig. 3

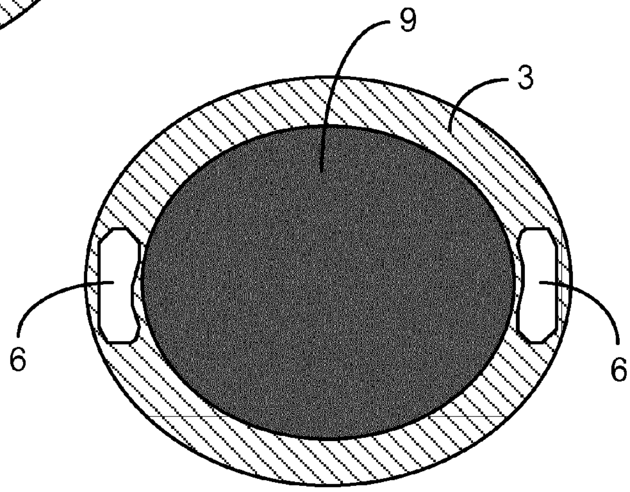

Fig. 4

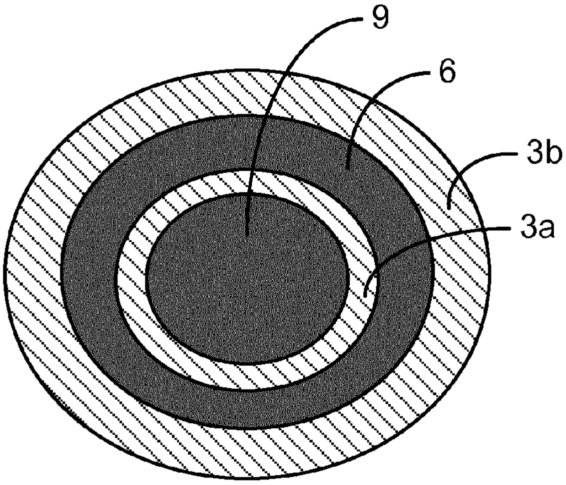

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 4931

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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 February 2013	Hillmayr, Heinrich

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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