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(54) **Electrical bushing**

(57) The present disclosure relates to an electrical 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. The conductor comprises a longitudinal outer tube and a longitudinal inner tube (3b), concentrically located within the outer tube (3a), such that a tubular space is formed between the outer tube and the inner tube. A first end of the tubular space is delimited by a tube spacer (10) between the outer tube and the inner tube, and a second end of the tubular space is capped to form an enclosed tubular space. The enclosed tubular space contains a heat transfer fluid whereby a heat-pipe (6) is formed between the outer tube and the inner tube of the conductor. The outer tube extends longitudinally beyond the heat-pipe delimited by the tube spacer at the first end of the tubular space, and the inner tube has a design at said first end such that fluid can pass from between the outer tube and the inner tube into a central longitudinal space (9) formed in the inner tube, without passing longitudinally beyond the extension of the outer tube.

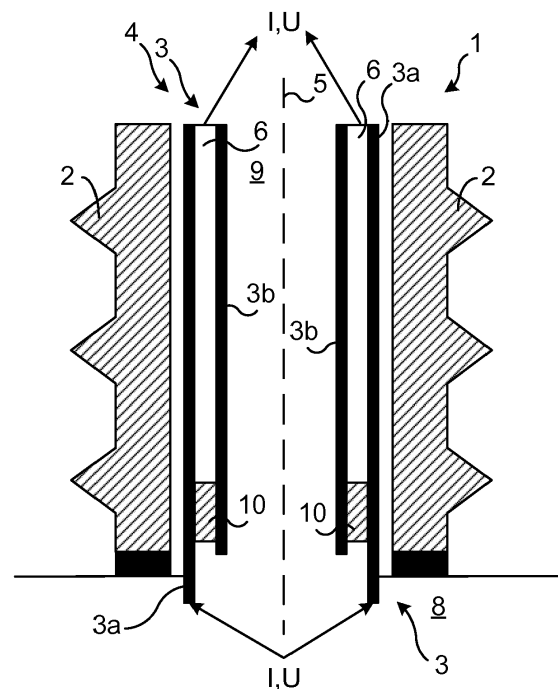


Fig. 2

Description

TECHNICAL FIELD

[0001] The present disclosure relates to an electrical bushing comprising a heat-pipe.

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 e.g. 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 transform-

ers, 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.

[0008] EP 2 704 157 discloses an electrical insulator bushing wherein the conductor comprises a cavity extending longitudinally along the conductor and having an opening at one end. The cavity is arranged for accommodating a heat-pipe. The cavity is arranged for allowing the heat-pipe to be introduced into and removed from said cavity via its opening.

[0009] A problem with using heat-pipes in the bushing is that if there is leakage from the heat-pipe, the heat transfer fluid therein may, in liquid or gaseous form, leak into the apparatus, e.g. a transformer, with which the bushing is used, potentially causing flash-overs or other problems. In some cases e.g. where the heat-pipe is used with an oil-filled transformer, the heat-pipe works under pressure, where the boiling temperature of the heat transfer fluid in the heat-pipe, at atmosphere pressure, is lower than the oil temperature of the transformer. This means that a leak of heat transfer fluid on the oil side of the bushing will be in gas form. A release of gas in the highly electrically stressed turret region of the transformer will likely cause a flash-over.

SUMMARY

[0010] It is an objective of the present invention to provide an improved electrical bushing comprising a heat-pipe for cooling the conductor in the bushing, which reduced risk of leakage of heat transfer fluid into the electrical apparatus to which the bushing is attached.

[0011] According to an aspect of the present invention, there is provided an electrical 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. The conductor comprises a longitudinal outer tube and a longitudinal inner tube, concentrically located within the outer tube, such that a tubular space is formed

between the outer tube and the inner tube. A first end of the tubular space is delimited by a tube spacer between the outer tube and the inner tube, and a second end of the tubular space is capped to form an enclosed tubular space. The enclosed tubular space contains a heat transfer fluid whereby a heat-pipe is formed between the outer tube and the inner tube of the conductor. The outer tube extends longitudinally beyond the heat-pipe delimited by the tube spacer at the first end of the tubular space, and the inner tube has a design at said first end such that fluid can pass from between the outer tube and the inner tube into a central longitudinal space formed in the inner tube, without passing longitudinally beyond the extension of the outer tube.

[0012] According to another aspect of the present invention, there is provided an electrical apparatus comprising an embodiment of the bushing of the present disclosure.

[0013] It is an advantage of the present invention that the inner tube of the conductor is designed, at the end which is intended to be attached to/inserted into an electrical apparatus, such that the risk of heat transfer fluid entering the electrical apparatus is reduced in case of leakage thereof from the heat-pipe. In accordance with the present invention, the inner tube has a design at said end such that the heat transfer fluid (typically in gas form) can pass from the space between the outer tube and the inner tube to the central longitudinal space formed in the inner tube, without passing longitudinally beyond the extension of the outer tube. This implies that the outer tube may extend into the electrical apparatus but that any leaking fluid may escape into the inner tube instead of being forced into the electrical apparatus by being trapped between the inner and outer tubes. In accordance with embodiments of the present invention, this design of the inner tube may be achieved e.g. by the inner tube being shorter than the outer tube, whereby the inner tube may end before entering the electrical apparatus when the bushing is in use. Thus, that the inner tube is shorter at the end of the conductor than the outer tube herein means that the outer tube extends further in the longitudinal direction beyond the heat-pipe than the inner tube does. As discussed herein, it may (depending on the design of the conductor and its heat-pipe, and on how the bushing is mounted to the electrical apparatus) be enough that the inner tube is shorter along a part of its circumference, to let the leaking fluid into the central space. Additionally or alternatively, the mantle of the inner tube may be provided with hole(s) connecting the space between the inner and outer tubes with the central space inside the inner tube beyond (typically below, when the bushing is mounted) the heat-pipe, to allow the leaking fluid to pass through the hole(s) and into the central space.

[0014] 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

[0015] 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 3a is a schematic perspective view in longitudinal section of an embodiment of a conductor in accordance with the present invention.

Fig 3b is a schematic cross-sectional view of an embodiment of a conductor in accordance with the present invention.

Fig 3c is a schematic view in longitudinal section of an embodiment of a part of a conductor in accordance with the present invention.

DETAILED DESCRIPTION

[0016] 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.

[0017] The bushing of the present invention may be used for a transformer, e.g. a power 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.

[0018] 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, or the outer part may also be fluid-filled. 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.

[0019] 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 is a tubular or essentially cylindrical device wherein an electrically insulating sleeve 2 forms an envelope surface surrounding the bushing in its longitudinal direction in parallel with the longitudinal axis 5. The sleeve 2 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 from an electrical apparatus 8, e.g. a liquid-filled transformer, and exiting at the upper end of said bushing, but the opposite direction, or alternating current, is of course equally possible).

[0020] In the embodiment of the figure, the conductor 3 is in the form of two concentrically positioned hollow tubes (could be called pipes or hollow cylinders), an outer tube 3a and an inner tube 3b, the inside of which inner tube 3b forms a central space or cavity 9 through which the central longitudinal axis 5 passes. At least part of the conductor 3 is configured for conducting the electrical current I, thus being made of an electrically conducting material such as copper, which is preferred, or aluminium. Typically, the outer tube 3a is made of a conducting material. The inner tube 3b may be electrically connected to the outer tube 3a e.g. via a tube spacer 10, and may be of a conductive material or a non-conducting material such as a non-conducting ceramic or synthetic/plastic material.

[0021] The outer and inner tubes 3a and 3b form an annular/tubular longitudinal space there between which functions as a heat-pipe 6 when at least partly filled with a heat transfer fluid. The tubular space is capped (e.g. by means of a tube spacer, lid or the like) at the upper end of the bushing 1, and delimited at the lower end of the bushing by means of the annular tube spacer 10 which is fastened to both the outer surface of the inner tube 3b and the inner surface of the outer tube 3a, e.g. by soldering or welding, whereby the tubular space is an enclosed space forming the heat-pipe 6 such that the

heat transfer fluid does not escape the heat-pipe unless there is an undesired leak. In accordance with the present invention, the tube spacer 10 delimits the lower end of the heat-pipe 6 some distance above the apparatus 8, allowing the inner tube 3b to also at least partially end some distance above the apparatus 8, thereby allowing any gas leaking through or past the tube spacer 10 to enter the central space 9, rising upwards there through, without entering the apparatus 8, e.g. the turret region of a transformer 8, thereby avoiding flash-overs in the apparatus caused by such leaking gas.

[0022] The central space 9 may be used for different things, such as a draw rod or the like, or for accommodating additional heat-pipes. The central space 9 may be at least partially filled by a liquid, typically a cooling and insulating liquid of the electrical apparatus 8 such as a transformer oil of a fluid-filled transformer 8. The liquid in the central space 9 may contribute to the cooling of and heat distribution in the bushing and may thus cooperate with the heat-pipe 6 for this.

[0023] Figure 3a schematically illustrates an end part of an embodiment of a conductor 3 of the present invention, in longitudinal section. The end of the conductor 3 shown is the end which is configured to be connected to/inserted in the electrical apparatus 8, and is thus typically a lower end of the conductor when the bushing 1 is mounted to the apparatus. The outer tube 3a forms the outside of the conductor 3 and may have an essentially circular cross-section with essentially the same radius along its whole longitudinal extension. The inner tube 3b is concentrically positioned inside the outer tube 3a, defining a tubular space between the inner and outer tubes 3b and 3a, as well as defining a central longitudinal space 9 inside the inner tube 3b, through which central longitudinal space the central longitudinal axis 5 runs. Also the inner tube 3b may have an essentially circular cross-section with essentially the same radius (smaller than the radius of the outer tube) along its whole longitudinal extension. A heat-pipe 6 is formed in the tubular space between the outer and inner tubes 3a and 3b. Thus, the tubular space is delimited at both longitudinal ends to form an enclosed space in which the heat transfer fluid can be enclosed to form the heat-pipe 6. At the depicted (lower) end a, typically annular, tube spacer 10 is used both for fixing the outer and inner tubes in relation to each other and for delimiting the heat-pipe 6 at this end. The tube spacer is typically soldered in place, but may alternatively be welded in place or wedged immobile between the inner and outer tubes. As can be seen in the figure, the inner tube 3b is substantially shorter than the outer tube 3a. The outer tube 3a extends a substantial distance beyond (below) the heat-pipe 6 delimited by the tube spacer 10, while the inner tube 3b ends at or shortly after the tube spacer 10. By this shorter design of the inner tube 3b, any gaseous or liquid (typically gaseous, due to the high temperature of the apparatus 8 and the conductor 3) heat transfer fluid leaking through or past the tube spacer 10, e.g. due to a crack in the soldering,

is not forced into the apparatus 8 by being trapped between the inner and outer tubes 3b and 3a. Instead, the leaking fluid is, as illustrated with the curved arrow from the heat-pipe 6 to the central space 9, allowed to enter the central space 9 without having to pass longitudinally beyond (typically below) the longitudinal extension of the outer tube 3a. The central longitudinal space may, when the bushing is mounted and in use, typically be at least partly filled with the insulation fluid, e.g. oil, of the apparatus 8, e.g. a fluid (e.g. oil) filled transformer or electrical motor.

[0024] Figures 3b and 3c schematically illustrates the conductor of figure 3a but without showing the special design of the inner tube at the end of the conductor. Rather, the figures are used to illustrate how the heat-pipe may be formed in the conductor, between the outer tube 3a and the inner tube 3b.

[0025] Figure 3b schematically illustrates the embodiment of the conductor 3 shown in figure 3a. The conductor 3 is shown in a cross-section perpendicular to the longitudinal axis 5. The conductor 3 comprises two concentrically arranged hollow tubes (could also be called pipes or hollow cylinders) of an electrically conducting material. The inner hollow tube 3b 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 3b and the outer tube 3a of the conductor 3. The cavity 6 is configured for forming a heat-pipe, as discussed herein, when filled with a heat transfer fluid. 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. However, it is also contemplated that one or more discrete heat-pipes 6 may be formed between the inner tube 3b and the outer tube 3a, e.g. a plurality of parallel longitudinal heat-pipes. Additionally or alternatively, the central space 9 can be used for accommodating one or more heat-pipes.

[0026] Figure 3c is a schematic longitudinal section of a part of the conductor 3 also shown in figures 3a and 3b. The concentric outer tube 3a and inner tube 3b form the heat-pipe 6 there between. The longitudinal axis 5 runs through the inner space 9 formed within the hollow inner tube 3b, the inner space 9 typically being oil-filled when the conductor is mounted in a bushing of an oil-filled electrical apparatus 8 e.g. a transformer.

[0027] In some embodiments of the present invention, the design of the of the inner tube 3b at the first end (i.e. the end configured for being connected to the apparatus 8, typically the lower (or bottom) end when the bushing is in use) is such that at least some circumferential parts of the inner tube are shorter than corresponding circumferential parts of the outer tube 3a thus extending longitudinally beyond the inner tube at the first end. As mentioned above, this is one way of allowing the leaking heat transfer fluid to pass from the space between the outer tube 3a and the inner tube 3b into the central longitudinal

space 9, without passing longitudinally beyond the extension of the outer tube 3a at said first end. In some embodiments, the inner tube 3b is simply shorter (around its whole circumference) than the outer tube 3a which thus extends longitudinally beyond the inner tube at the first end.

[0028] Additionally or alternatively, in some embodiments of the present invention, the design of the inner tube 3b at the first end (bottom end) is such that the lateral surface (also called the mantle) of the inner tube 3b, longitudinally beyond the heat-pipe 6, comprises at least one aperture (also called through hole or hole). As mentioned above, this is another way (optionally combinable with a shorter inner tube) of allowing the leaking heat transfer fluid to pass from the space between the outer tube 3a and the inner tube 3b into the central longitudinal space 9, without passing longitudinally beyond the extension of the outer tube 3a at said first end.

[0029] The circumferential position or size of the shortening or aperture/hole of the inner tube 3b may depend on how the bushing 1 is mounted to the apparatus 8, e.g. if it is mounted vertically or inclined to the apparatus, bearing in mind that leaking gas will attempt to move upwards in the liquid (oil).

[0030] In some embodiments of the present invention, the central cavity 9 is at least partly liquid-filled, typically with a cooling/insulation liquid with which the electrical apparatus 8 is filled. This improves the cooling of and heat transfer in the bushing 1, especially the inner tube 3b.

[0031] In some embodiments of the present invention, the heat-pipe 6 comprises a condenser extending beyond the sleeve 2. Thus, in some embodiments, the heat-pipe may extend, at its second (typically upper) end, beyond (above) the sleeve 2, and typically also beyond the inner and outer tubes 3b and 3a of the conductor 3, in order to more easily cool down and condense the heat transfer fluid away from the heat insulating effect of the sleeve 2. The condenser may e.g. be formed as part of the capping of the heat-pipe 6 discussed herein.

[0032] 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 or a fluorocarbon. As an example, the heat transfer fluid may have a boiling point at 75-80°C at atmospheric pressure, which implies that if the oil temperature of the apparatus is higher, e.g. around 90°C, any leakage of the heat transfer fluid will be in gas form. The heat transfer fluid in the heat-pipe 6 will be subjected to an over pressure allowing for the suitable two-phase system of a heat-pipe.

[0033] 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 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 longitudinal outer tube (3a) and a longitudinal inner tube (3b), concentrically located within the outer tube (3a), such that a tubular space is formed between the outer tube (3a) and the inner tube (3b);

wherein a first end of the tubular space is delimited by a tube spacer (10) between the outer tube (3a) and the inner tube (3b), and a second end of the tubular space is capped to form an enclosed tubular space;

wherein the enclosed tubular space contains a heat transfer fluid whereby a heat-pipe (6) is formed between the outer tube (3a) and the inner tube (3b) of the conductor; and

wherein the outer tube (3a) extends longitudinally beyond the heat-pipe (6) delimited by the tube spacer (10) at the first end of the tubular space, and the inner tube (3b) has a design at said first end such that fluid can pass from between the outer tube (3a) and the inner tube (3b) into a central longitudinal space (9) formed in the inner tube (3b), without passing longitudinally beyond the extension of the outer tube (3a).

2. The bushing of claim 1, wherein said design of the of the inner tube (3b) at the first end is such that at least some circumferential parts of the inner tube are shorter than corresponding circumferential parts of the outer tube (3a) thus extending longitudinally beyond the inner tube at the first end.**3.** The bushing of claim 2, wherein the inner tube (3b) is shorter than the outer tube (3a) which thus extends longitudinally beyond the inner tube at the first end.**4.** The bushing of claim 1, wherein said design of the of the inner tube (3b) at the first end is such that the lateral surface of the inner tube, longitudinally beyond the heat-pipe 6, comprises at least one aperture.**5.** The bushing of any preceding claim, wherein the central cavity (9) is at least partly liquid-filled.**6.** The bushing of any preceding claim, wherein the heat-pipe (6) comprises a condenser extending beyond the sleeve (2).**7.** An electrical apparatus (8) comprising the bushing (1) of any preceding claim.**8.** The electrical apparatus of claim 7, wherein the electrical apparatus is a power transformer.**9.** The electrical apparatus of claim 7 or 8, wherein the electrical apparatus is liquid-filled.

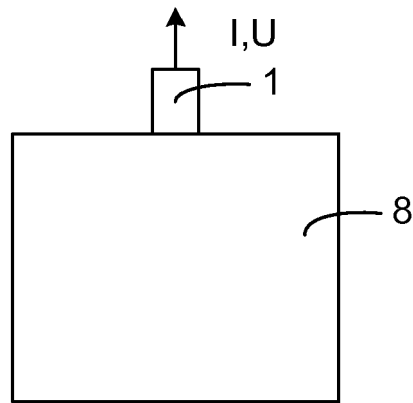


Fig. 1

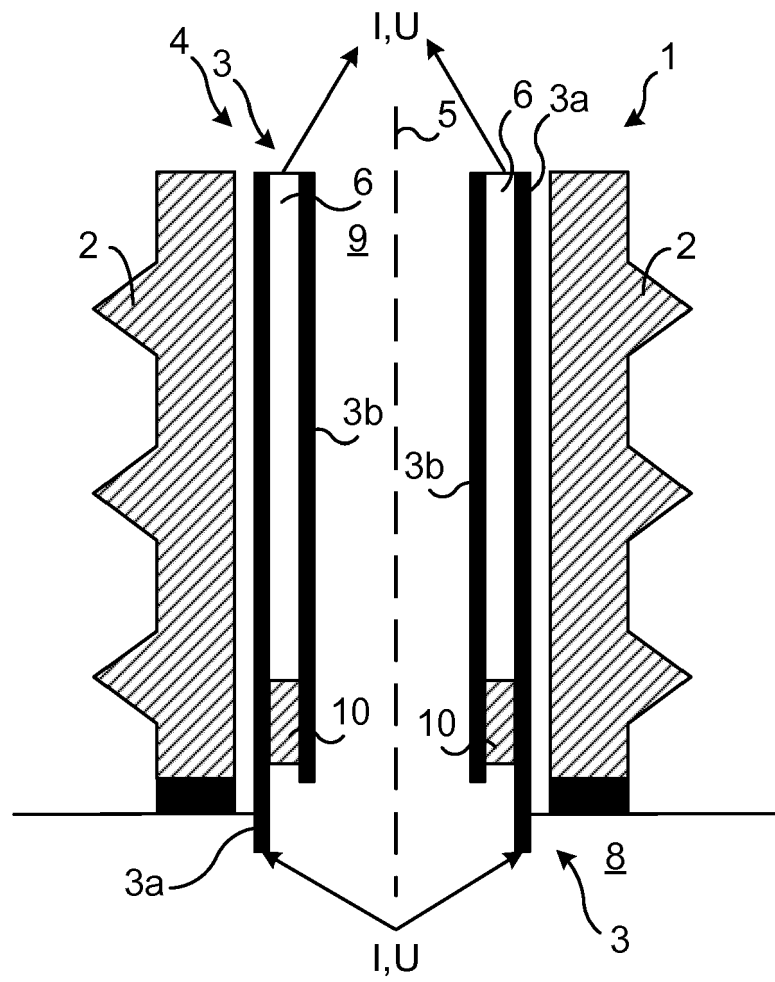


Fig. 2

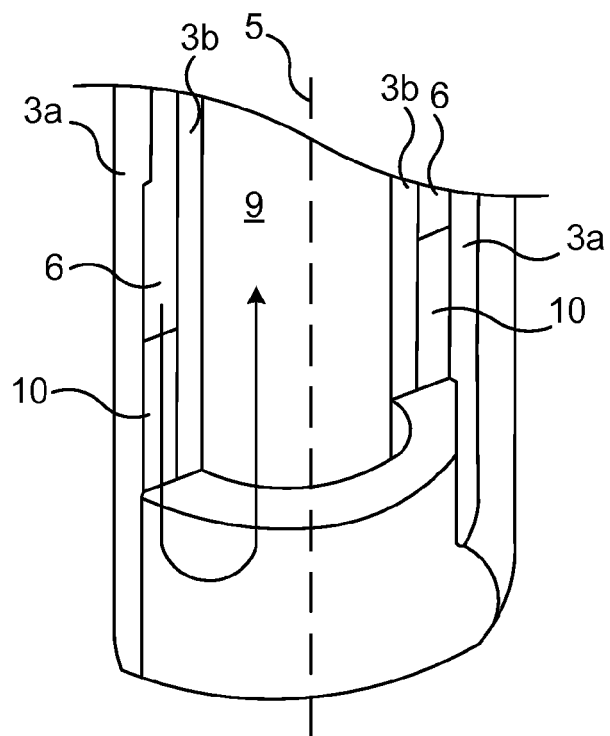


Fig. 3a

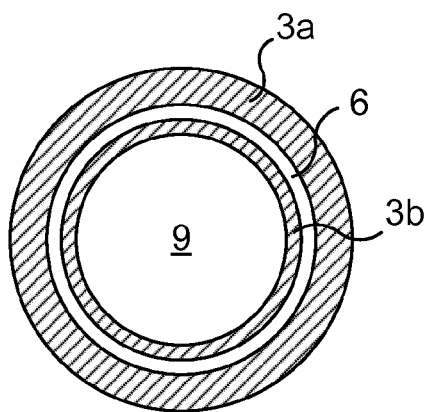


Fig. 3b

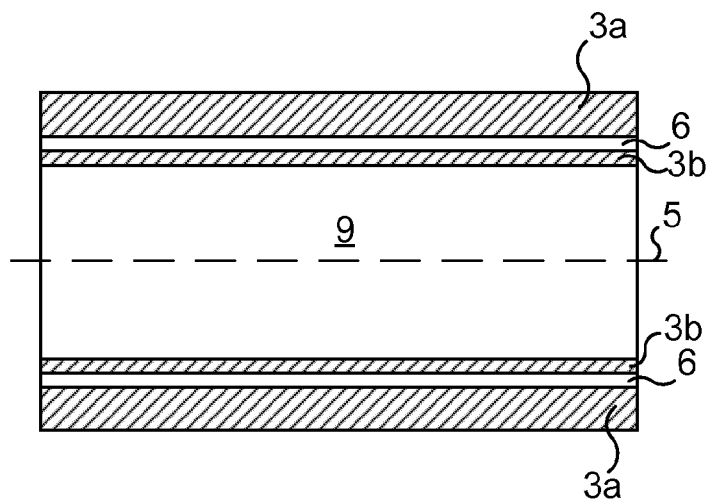


Fig. 3c



EUROPEAN SEARCH REPORT

Application Number
EP 14 18 7731

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 12 March 2015	Examiner Hillmayr, Heinrich
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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 14 18 7731

5 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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