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(54) **Electrical bushing**

(57) The present disclosure relates to an electrical bushing 1. The bushing comprises an electrically insulating sleeve 2 having a central longitudinal through hole 4 surrounding a central longitudinal axis 5 of the bushing. The bushing also comprises a tubular electrical conductor 3 positioned through the central longitudinal through hole of the sleeve and defining a central longitudinal cavity 9 around and along the longitudinal axis inside the tubular conductor. Also, the bushing comprises at least one heat-pipe 6 comprising a heat transfer fluid enclosed in a heat conducting pipe 10 for transferring heat along the bushing. The heat-pipe is longitudinally arranged and positioned in the central longitudinal cavity.

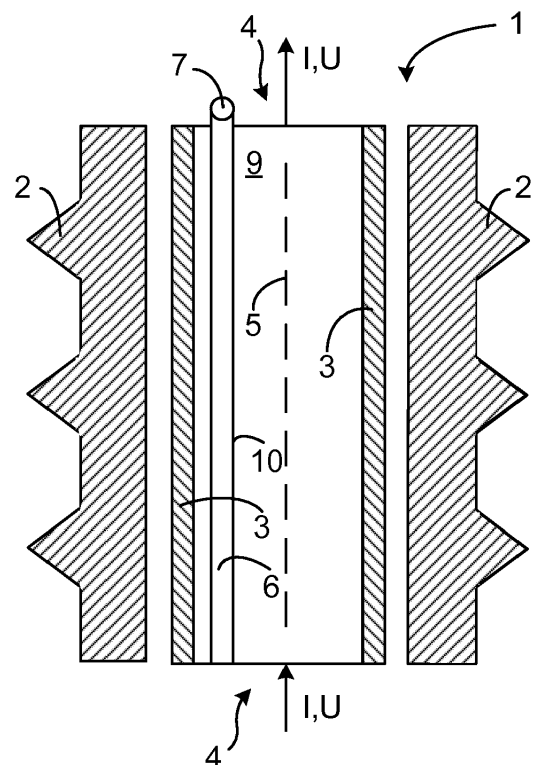


Fig. 2

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 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 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.

SUMMARY

[0009] 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.

[0010] According to an aspect of the present invention, there is provided an electrical bushing. The bushing comprises an electrically insulating sleeve having a central longitudinal through hole surrounding a central longitudinal axis of the bushing. The bushing also comprises a tubular electrical conductor positioned through the central longitudinal through hole of the sleeve and defining a central longitudinal cavity around and along the longitudinal axis inside the tubular conductor. Also, the bushing comprises at least one heat-pipe comprising a heat transfer fluid enclosed in a heat conducting pipe for transferring heat along the bushing. The heat-pipe is longitudinally arranged and positioned in the central longitudinal cavity.

[0011] According to an aspect of the present invention, there is provided an electrical device comprising an embodiment of the bushing of the present disclosure.

[0012] By positioning the heat-pipe in the central longitudinal space or cavity inside the tubular conductor, the need to redesign the bushing to allow the presence of one or more heat-pipes is reduced or eliminated. Thus, the central longitudinal space is utilized in accordance with the present invention.

[0013] 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

[0014] 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 cross-sectional view of an embodiment of a conductor in accordance with the present invention.

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

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

DETAILED DESCRIPTION

[0015] 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.

[0016] 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.

[0017] 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 trans-

former 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.

[0018] 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 a tube/pipe formed 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. Any concentric tubular space formed between the sleeve 2 and the conductor pipe 3 may comprise a capacitor core and/or be filled with e.g. oil, gas or vacuum. 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 an alternating current is of course also 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. This central space 9 can be used for different things, such as a draw rod or the like, and/or for accommodating longitudinal heat-pipe(s) 6 in accordance with the present invention for transporting heat from within the bushing out towards at least one of the ends of the bushing. Within the central space 9, there may positioned at least one, typically eccentrically located, heat-pipe 6 extending longitudinally along the conductor 3. The heat-pipe 6 illustrated in the figure comprises a heat-conducting pipe 10, and a condenser 7 extending outside of the bushing 1. The heat-pipe 6 of the embodiment of figure 2 is eccentrically located and does not intersect the central longitudinal axis 5 to not interfere with e.g. a draw rod used. In the embodiment of the figure, the heat pipe 6 comprises one or more condenser(s) 7, but in other embodiments no dedicated condenser is used (the fluid condensing in a cooler part of the pipe 10). The heat-pipe 6 may be any type of heat-pipe. The heat-pipe may, as illustrated in the figures herein, use gravity induced

return of the condensed heat transfer fluid, or a wick may be used to return the condensed fluid (e.g. if the heat-pipe/bushing is not vertically enough positioned for gravity return to be effective). Also, the heat-pipe 6 may be a loop heat-pipe (also called a thermo siphon). 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) e.g. by act of gravity or a wick. 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 (heat-pipes 6 sharing the same condenser 7). In view of gravity, as mentioned above, the condenser 7 is 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 6 to be connected to a condenser 7 at each end of the bushing 1, or allowing one heat pipe 6 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.

[0019] The conductor 3 is configured for conducting electrical current through the bushing 1. Thus, at least a part of the conductor is made of an electrically conducting material, e.g. a metal such as copper. In high-voltage applications, especially for alternating current (AC), the conductor 3 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 as well as accommodating heat-pipes 6 in accordance with the present invention.

[0020] The sleeve 2 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 2 is to insulate the conductor 3 from e.g. a wall (e.g. a casing of a power transformer as in figure 1) which the bushing 1 is intended to pass through. In some embodiments, the sleeve may comprise an insulating capacitor core which may be formed by 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 9 (or the heat-pipe 6 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 medium e.g. a gas. The sleeve 2 has a longitudinal through hole or opening 4 along the central longitudinal axis 5 of the bushing 1, the sleeve thus surrounding but not intersecting said central longitudinal axis 5 of the bushing.

[0021] The bushing 1 of the present invention may be beneficial in both direct current (DC) and alternating current (AC) applications.

[0022] The one or more heat-pipes 6 arranged in the central cavity 9 in the tube conductor 3 may conveniently be detachable, as mentioned herein, to improve the range of the power rating of the bushing by allowing adjustment of the number of heat-pipes used, and to reduce the cost and complexity of producing the conductor 3 since it may not need to be custom made with heat-pipes. The heat-pipes may be detachable one by one, but it may be more convenient if the heat-pipes are connected to each other and detachable together as a cassette/unit. However, in some embodiments, the heat-pipes may be non-detachable and formed with or permanently attached to the tube conductor 3. However, it is noted that in accordance with the present invention, the heat pipes are not formed within the conductor 3 but are distinct therefrom within the central cavity 9, typically at and along the inner surface of the conductor tube 3. More than one heat-pipe 6 may conveniently be used, in order to cool the conductor 3 around its circumference, e.g. between 4 and 12 heat-pipes equally distributed around the circumference of the conductor tube 3. The size of the heat-pipes may vary greatly depending on the application. Typically, the heat-pipes extend essentially along the whole bushing 1 and have an inner diameter which is large enough to allow liquid heat transfer fluid to circulate in the opposite direction of the gaseous fluid in the heat-pipe 6, while still being small enough to fit inside the central space 9. Thus, as an example, each heat-pipe may have an inner diameter of between 10 and 50 mm, and a length of between 1 and 20 m.

[0023] In some embodiments, the bushing 1 also comprises comprising a heat conducting condenser 7 (i.e. a condenser made from a heat conducting material) which is part of the heat-pipe 6 and typically extends outside of the cavity 9. By using a condenser, the heat transfer from the conductor 3 to the outside of the bushing 1 may be improved. The heat transfer fluid may thus vaporize down inside the cavity 9 where the conductor 3 may have a hot spot, and rise to the condenser 7 where it can be cooled and condensed, dissipating the heat, more efficiently than if the heat heat-pipe 6 was completely contained in the central space 9 of the conductor. It is noted, however, that in some embodiments, a condenser 7 may not be needed and in those embodiments the heat pipe 6 can be used for transporting heat from a hot spot of the conductor 3 to a cooler part of the bushing 1 (e.g. still inside the central space 9 in the conductor 3).

[0024] In some embodiments, the heat-pipe 6 is eccentrically located inside the conductor 3 such that the heat-pipe 6 does not intersect the central longitudinal axis 5 of the bushing 1. It may be an advantage to use an eccentrically located heat-pipe in a bushing since this allows the central part of the central space 9 of the tube-formed conductor 3 (the space along the central longitudinal axis of the bushing) to be free for other uses. 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 3 at a first

end of the bushing from the side of the opposite second end of the bushing. To use a heat pipe 6 is an efficient way of cooling a bushing by transferring heat formed by resistance within the bushing 1, from the bushing to an ambient medium or to another part (typically cooler part) of the bushing 1. That the heat-pipe 6 is eccentric means that it is not positioned in or at the central longitudinal axis 5 of the bushing. Thus, the heat-pipe 6 does not intersect the central longitudinal axis 5 of the bushing. The heat-pipe 6 extends longitudinally along at least a part of the longitudinal extension of the bushing 1, 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 2 since the sleeve also insulates heat). A problem with using the whole hollow cavity 9 of the conductor pipe 3 as a heat pipe is that this cavity 9 then cannot be used for other parts of, or associated with, the bushing 1. This central cavity 9 is often needed for other purposes, e.g. 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. Thus, distinct (and possibly detachable) heat-pipes positioned in the central space 9, in accordance with the present invention, are advantageous.

[0025] Figure 3 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 3, the conductor 3 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 3, a plurality of longitudinally arranged heat-pipes 6 are positioned. 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. The central cavity 9 is typically at least partly liquid-filled, e.g. with a conventional transformer oil, and the heat-pipe 6 may be at least partly immersed in said liquid. The heat-pipes 6 may thus cool the conductor 3 by heat transfer via the liquid in the central cavity 9. Additionally, if a heat-pipe 6 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 10 of the heat-pipe 6 and the conductor tube 3. The number of heat-pipes 6 may vary greatly depending on design of the bushing/conductor and the need for heat exchange. Here, four heat-pipes 6 are shown as an example. Each of the heat-pipes 6 may be detachable, allowing the number of heat-pipes used to be adjusted in view of the cooling need of the bushing. The heat-pipes 6 may conveniently be essentially equidistantly distributed along the circumference of the conductor tube 3, along the inner wall of said tube 3, in order to achieve heat exchange relatively evenly around the conductor 3.

[0026] Figure 4 illustrates an embodiment of a detach-

able heat pipe 6 configured for being inserted and/or withdrawn from the central through hole 9 of the pipe-formed conductor 3. A heat conducting pipe 10 forms a closed system enclosing the heat transfer fluid 11 therein.

[0027] Figure 5 illustrates another embodiment of a detachable heat pipe configured for being inserted and/or withdrawn from the central through hole 9 of the pipe-formed conductor 3. A heat conducting pipe 10 forms a closed system together with a condenser 7, enclosing the heat transfer fluid 11 therein.

[0028] 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.

[0029] In some embodiments of the present invention, the at least one heat-pipe 6 is detachable. The power-rating of the bushing may thus be changed, as discussed herein, and the heat-pipe may more easily be serviced or exchanged as needed.

[0030] In some embodiments of the present invention, the at least one heat-pipe 6 is eccentrically positioned in the central cavity 9 such that it does not intersect the central axis 5. Thus, the central space may be used for other purposes, as discussed herein, without the heat-pipe being in the way.

[0031] In some embodiments of the present invention, the at least one heat-pipe 6 is in direct longitudinal contact with the conductor 3, whereby the heat transfer between the heat-pipe and the conductor 3 may be improved.

[0032] In some embodiments of the present invention, the central cavity 9 is at least partly liquid-filled such that the at least one heat-pipe 6 is at least partly immersed in said liquid. This may improve the heat transfer in the conductor 3 as well as the heat transfer between the heat-pipe and the conductor 3.

[0033] In some embodiments of the present invention, the heat-pipe 6 comprises a condenser 7 extending beyond the sleeve 2. Thus, the heat-pipe may extend at one (typically upper) end, beyond (above) the sleeve 2, and typically also beyond 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. Alternatively, the condenser 7 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 bushing (1) comprising:

an electrically insulating sleeve (2) having a cen-

tral longitudinal through hole (4) surrounding a central longitudinal axis (5) of the bushing; a tubular electrical conductor (3) positioned through the central longitudinal through hole (4) of the sleeve and defining a central longitudinal cavity (9) around and along the longitudinal axis (5) inside the tubular conductor; and at least one heat-pipe (6) comprising a heat transfer fluid (11) enclosed in a heat conducting pipe (10) for transferring heat along the bushing (1), being longitudinally arranged and positioned in the central longitudinal cavity (9).

2. The bushing of claim 1, wherein the at least one heat-pipe (6) is detachable. 15
3. The bushing of claim 1 or 2, wherein the at least one heat-pipe (6) is eccentrically positioned in the central cavity (9) such that it does not intersect the central axis (5). 20
4. The bushing of any preceding claim, wherein the at least one heat-pipe (6) is in direct longitudinal contact with the conductor (3). 25
5. The bushing of any preceding claim, wherein the central cavity (9) is at least partly liquid-filled such that the at least one heat-pipe (6) is at least partly immersed in said liquid. 30
6. The bushing of any preceding claim, wherein the heat-pipe (6) comprises a condenser (7) extending beyond the sleeve (2).
7. An electrical device (8) comprising the bushing (1) of any preceding claim. 35
8. The electrical device of claim 7, wherein the electrical device is a power transformer. 40
9. The electrical device of claim 7 or 8, wherein the electrical device is liquid-filled. 45

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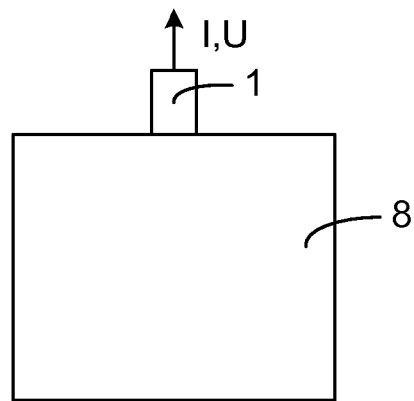


Fig. 1

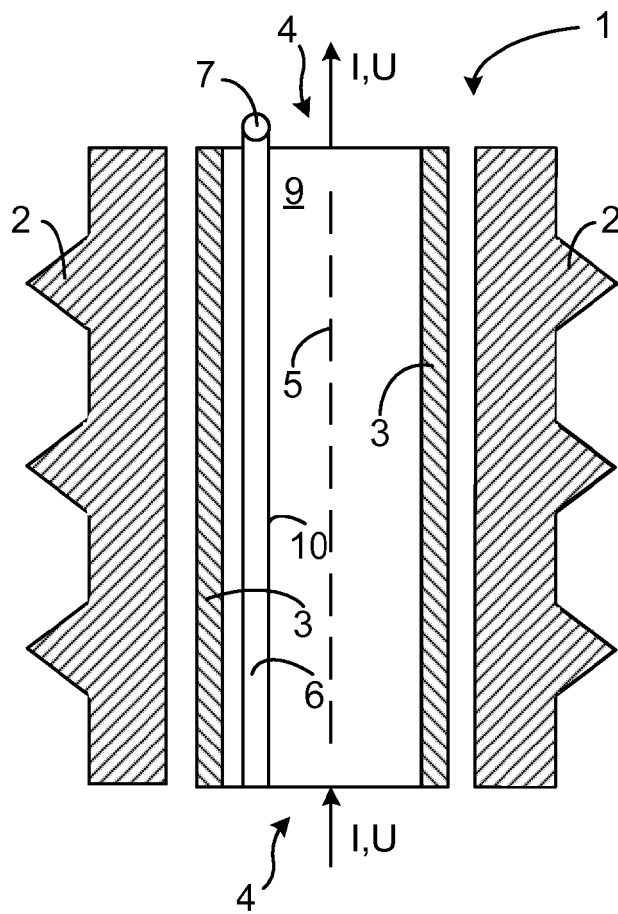


Fig. 2

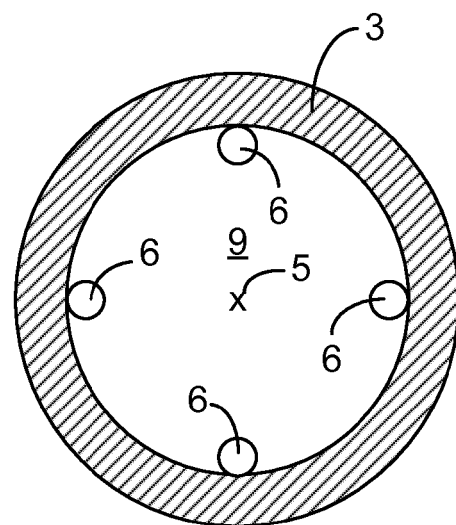


Fig. 3

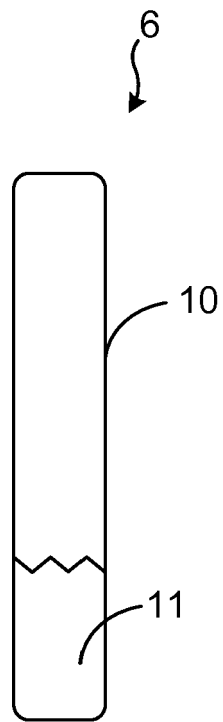


Fig. 4

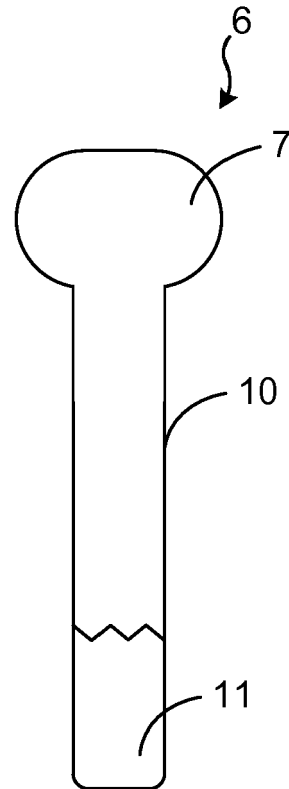


Fig. 5



EUROPEAN SEARCH REPORT

 Application Number
EP 14 18 8027

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		13 March 2015	Hillmayr, Heinrich
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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