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GRAVITY-ASSISTED HEAT PIPE

(57) The present disclosure describes a pipe element for heat pipe and a cold plate utilizing the pipe element. The pipe element comprises at least one through-hole between a first opening at a first end of the pipe element and a second opening at a second end of the pipe element so that the at least one through-hole forms an evaporation section and a condenser section to the pipe element. The evaporation section comprises a first helical thread on the wall of the through-hole. The crests of the first helical thread curve away from the condenser section such that, during the use of a heat pipe comprising the pipe element, the at least one first ridge and the at least one first groove form at least one pocket for boiling coolant in the evaporator section.

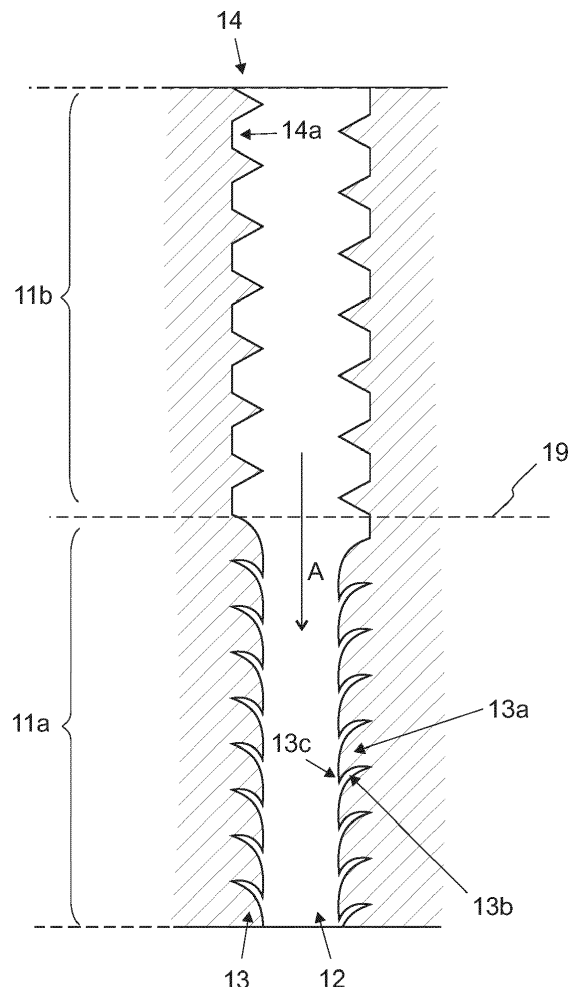


Figure 2

Description

FIELD

[0001] The invention relates to cooling of electric components, and particularly to cooling by gravity-assisted heat pipes.

BACKGROUND

[0002] Heat pipes provide an efficient cooling approach which may be utilized in various applications. Cooling generated by a heat pipe is based on phase transition of a coolant. A heat pipe has a pipe structure with two sections: an evaporator section which acts as the hot interface and a condenser section which acts as a cold interface. A component to be cooled, e.g. a power electric component, is attached to the hot interface. Cooling fins may be attached to the cold interface to improve transfer of heat from the cold interface to ambient air.

[0003] At the hot interface, the coolant which is in liquid form is in contact with a thermally conductive solid surface. The coolant evaporates into a vapor by absorbing heat from that surface. The vapor then travels along the heat pipe to the cold interface and condenses back into a liquid, thereby releasing the latent heat.

[0004] Piping for a heat pipe structure may be formed by embedding copper pipes to the front or the base of the cooling element. The copper pipes may be attached to the cooling element by soldering or by press-fit, for example. However, due to different metals being used, such a piping configuration may be prone to corrosion.

BRIEF DESCRIPTION

[0005] An object of the present invention is to provide a pipe element for a heat pipe and a method for manufacturing the pipe element so as to alleviate the above disadvantages. The objects of the invention are achieved by a method and an arrangement which are characterized by what is stated in the independent claims. The preferred embodiments of the invention are disclosed in the dependent claims.

[0006] A cold plate may be formed from a pipe element having at least one through-hole between its two ends. A closed volume for a heat pipe may be formed to the pipe element by adding seals to the ends of the through-hole. Coolant may be added to the closed volume through one of the seals. The efficiency of the cooling may be improved by forming a helical thread to the evaporator section of the heat pipe. The crests of the thread may be bent such that the thread forms pockets that hold boiling coolant, thereby improving the efficiency. The pipe element, and thus the cold plate, may be formed from a single material, e.g. extruded aluminum. As a result, the formed cold plate is not prone to corrosion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached [accompanying] drawings, in which

Figures 1a to 1c show different views of an exemplary cold plate according to the present disclosure; Figure 2 shows an exemplary cross section of a through-hole of a pipe element in Figures 1a to 1c; and

Figure 3 shows an exemplary embodiment of the second seal 16 for a pipe element as discussed in relation to Figures 1a to 1c and Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

[0008] The present disclosure describes a pipe element for a heat pipe thermosyphon, i.e. a vertically oriented, gravity-assisted heat pipe. The present disclosure further describes a cold plate comprising a pipe element according to the present disclosure.

[0009] The pipe element may comprise at least one through-hole between a first opening at a first end of the pipe element and a second opening at a second end of the pipe element. The pipe element may be formed out of malleable material that has high thermal conductivity, such as metal. The pipe element may be made from extruded aluminium, for example.

[0010] The at least one through-hole forms an evaporation section and a condenser section to the pipe element. The evaporation section may comprise a first internal, helical thread on the wall of the through-hole, comprising at least one first ridge and at least one first groove. The crest of the at least one first ridge veers away from the condenser section. As a result, when the pipe element has a vertical orientation (i.e. an orientation where the axis of the thread is substantially vertical) such that the evaporator section is below the condenser section, the crest of the ridge of the first helical thread in a cross section of the thread is below a centreline of the base of the ridge. During the use of a heat pipe comprising the pipe element, the at least one first ridge and the at least one first groove form at least one pocket for boiling coolant in the evaporator section. The at least one pocket prevents the boiling coolant from rising freely upwards.

[0011] In addition to the first helical thread in the evaporator section, the condenser section may comprise a second helical thread. The second helical thread may be in the form of a trapezoidal thread, for example.

[0012] A pipe element according to the present disclosure may be used for constructing a cold plate according to the present disclosure. The cold plate may comprise the pipe element, a first seal at the first end of the pipe element, and a second seal at the second end of the pipe element. The first seal may be arranged to seal the first opening of the at least one through-hole. The second

seal may be adapted for sealing the second opening of the at least one through-hole. With the first seal and second seal each of the at least one through-hole creates a closed cavity. When the coolant has been added to this closed cavity, and the cavity has been vacuumized and sealed, the through-hole forms a heat pipe thermosiphon.

[0013] In order to be used, the cold plate is positioned substantially vertically such that the evaporator section is below the condenser section and a component or device to be cooled is attached to the evaporator section. The component or device heats the evaporator section. When the coolant enclosed inside the through-holes becomes in contact with the wall of the through-hole in the evaporator section, it evaporates and rises to the condenser section above the evaporator section. The evaporated coolant becomes in contact with the wall of the through-hole in the condenser section, and releases heat to the wall. As a result, the coolant condenses back into liquid. Assisted by gravity, the liquid returns back to the evaporator section below the condenser section.

[0014] The cold plate may be adapted to cool components or devices that generate hundreds of watts or thousands of watts of heat, or more. A cold plate according to the present disclosure may be utilized for cooling power modules of inverters, for example. The cold plate may be used for cooling an IGBT (insulated gate bipolar transistor) module or modules, for example. In addition, the cold plate may be simultaneously be used for cooling an RC circuit or a brake resistor, for example.

[0015] In order to facilitate mounting of the components to be cooled, the cold plate may further comprise a cooling interface at the evaporator section of the at least one through-hole. The cooling interface may be adapted for mounting at least one power electric component to the cold plate. Further, at least one cooling fin may be arranged to extend from the pipe element at the condenser section of the at least one through-hole.

[0016] Figures 1a to 1c show simplified views of an exemplary cold plate according to the present disclosure.

[0017] Figure 1a shows a side view of the cold plate. The cold plate comprises a pipe element 11. In Figure 1a, the pipe element 11 comprises a straight through-hole 12 between a first opening at the first (bottom) end of the pipe element 11 and a second opening at the second (top) end of the pipe element 11. Further, the cold plate comprises a first seal 15 at the first end of the pipe element 11, and a second seal 16 at the second end of the pipe element 11. The first seal 15 is welded to the bottom end of the pipe element 11 to seal the first opening. The same first seal 15 may be used for sealing a plurality of first openings. The second seal 16 is welded to the second end of the pipe element 11 for sealing the second opening. The method of attaching the seals to the pipe element is not limited to welding. The seals may be attached by using other means, e.g. by gluing, brazing or stamping. The second seal 16 in Figure 1a comprise a sealable filling hole for adding coolant to the through-hole 12. With the first seal 15 and second seal 16, the

through-hole 12 creates a closed cavity. The closed cavity may be filled with a coolant through the filling hole. The closed cavity may be filled such that, when the cold plate is positioned for operation, the evaporation section 11a is completely filled with coolant, for example. When the coolant has been added to the closed cavity, and the cavity has been vacuumized and sealed, the through-hole 12 forms a heat pipe. The heat pipe comprises two sections: an evaporator section 11a and a condenser section 11b. During use, the cold plate is in an upright position so that center axes of the through-holes 12 are substantially vertical. The condenser section 11b is above the evaporator section 11a so that the coolant condensing back to liquid in the condenser section 11b flows to the evaporator 11a assisted by gravity.

[0018] The cold plate may further comprise at least one cooling interface in the evaporator section 11a of the pipe element 11. Figure 1a shows electric components 17 attached to their respective cooling interfaces. Further, cooling fins 18 extend from the condenser section 11b of the pipe element 11.

[0019] Figure 1b shows a front view of the cold plate in Figure 1a. In Figure 1b, the pipe element 11 of the cold plate comprises a plurality of through-holes 12. Each hole 12 has been provided with a separate second seal 16. When sealed and provided with coolant, each hole 12 forms a separate heat pipe. Figure 1b shows the electric component (or device) 17 attached to the front side of the cold plate being cooled by a plurality of heat pipes.

[0020] Figure 1c shows a bottom view of the cold plate of Figures 1a and 1b. A plurality of cooling fins 18 extend from the condenser section 11b. Figure 1c shows electric components 17 mounted on the cold plate on the same side and on the opposite side as the fins 18.

[0021] In order to improve the efficiency of cooling of a pipe element according to the present disclosure, the portion of through-hole in the evaporator section of the pipe element may comprise a helical thread. Figure 2 shows an exemplary cross section of a through-hole of a pipe element in Figures 1a to 1c. In Figure 2, the evaporation section 11a comprises a first, internal helical thread 13 on the wall of the through-hole 12. Figure 2 shows the first helical thread 13 comprising ridges 13a and grooves 13b. The crests 13c of the ridges 13a curve away (in direction A in Figure 2) from the condenser section 11b. In addition to the first helical thread 13 in the evaporator section, the condenser section 11b in Figure 2 comprises a second helical thread 14. The second helical thread 14 is a trapezoidal thread, for example. In this manner, the cooling area of the condenser section 11b can be increased. The trapezoidal thread may have a wide root 14a, as shown in Figure 2. The difference between the major diameter of the thread and the pitch diameter of the second thread 14 may be smaller than the difference between the minor diameter of the thread and the pitch diameter.

[0022] Figure 3 shows an exemplary embodiment of the second seal 16 for a pipe element as discussed in

relation to Figures 1a to 1c and Figure 2. The second seal 16 comprises a base 16a, a hollow dome 16b extending from the base 16a, and a hollow, elongated tip or nozzle extending from the dome 16b. The second seal 16 may be attached by its base 16a on top of the second opening of a through-hole in a pipe element according to the present disclosure in order to close the second opening and form a heat pipe. The second seal 16 may be attached to the pipe element by welding, for example. The first seal may be attached on top of the first opening by using the same method as with the second seal, for example.

[0023] The present disclosure also describes a method for manufacturing a pipe element according to the present disclosure and a cold plate according to the present disclosure.

[0024] The method for manufacturing a pipe element may comprise forming a pipe element out of a malleable material with high thermal conductivity. The pipe element may comprise at least one through-hole between a first opening at a first end of the pipe element and a second opening at a second end of the pipe element. The pipe element may be formed by extruding aluminium, for example.

[0025] The at least one through-hole forms an evaporation section and a condenser section to the pipe element. A first helical thread may be formed, e.g. by machining, to an inside wall of the through-hole in the evaporator section of the pipe element. The first helical thread may comprise at least one first ridge and at least one first groove.

[0026] The crest of the at least one first ridge may be bent to curve away from the condenser section. The crests of the first ridges may be bent by forcing an arbor to propagate inside the through-hole in a direction from the condenser section to the evaporator section, for example. As a result, the at least one first ridge and the at least one first groove form at least one pocket for boiling coolant in the evaporator section during the use of a heat pipe comprising the pipe element. In order to facilitate bending of the first helical thread, the first helical thread may be in the form of a sharp V-thread (i.e. a triangular thread). In this context, the term "sharp V-thread" refers to a V-thread in which there is no truncation (or a minuscule amount considered negligible). A second thread may be formed to the condenser section. The second thread may be a trapezoid thread with a wide root, for example. Further, a cooling interface may be machined to the pipe element at the evaporator section of the at least one through-hole. The cooling interface may be adapted for mounting a power electric component to the cold plate.

[0027] A cold plate may be built by using the pipe element manufactured with the above method. A first seal may be attached to the first end of the pipe element to seal the first opening of the at least one through-hole, and a second seal may be attached to the second end of the pipe element. The seals may be attached by weld-

ing, gluing, brazing or stamping, for example. Further, at least one cooling fin may be attached to the pipe element to extend from the pipe element at the condenser section of the at least one through-hole. The at least one cooling fin may be attached by welding, gluing, brazing or stamping, for example.

[0028] Once the first and second seal have been attached to the pipe structure, coolant may be added to the closed cavity formed by the seals and the pipe structure. The coolant may be injected to the closed cavity and the closed cavity may be vacuumized through the tip or nozzle of the second seal, for example. After the coolant has been added and the cavity has been vacuumized, the closed cavity may be sealed by closing the tip or nozzle of the second seal.

[0029] It is obvious to a person skilled in the art that the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A pipe element for a vertically oriented, gravity-assisted heat pipe, wherein the pipe element comprises at least one through-hole between a first opening at a first end of the pipe element and a second opening at a second end of the pipe element so that the at least one through-hole forms an evaporation section and a condenser section to the pipe element, wherein the evaporation section comprises a first helical thread on the wall of the through-hole, wherein the first helical thread comprises at least one first ridge and at least one first groove, and the crest of the at least one first ridge curves away from the condenser section such that, during the use of a heat pipe comprising the pipe element, the at least one first ridge and the at least one first groove form at least one pocket for boiling coolant in the evaporator section.
2. A pipe element according to claim 1, wherein the condenser section comprises a second helical thread.
3. A pipe element according to claim 2, wherein the second helical thread is in the form of a trapezoidal thread.
4. A pipe element according to any one of preceding claims, wherein the pipe element is made from extruded aluminium.
5. A cold plate comprising, a pipe element according to any one of preceding claims,

a first seal at the first end of the pipe element, the first seal sealing the first opening,
 a second seal at the second end of the pipe element, the second seal being adapted for sealing the second opening,
 a cooling interface at the evaporator section of the at least on through-hole, the cooling interface being adapted for mounting a power electric component to the cold plate, and
 at least one cooling fin arranged to extend from the pipe element at the condenser section of the at least on through-hole.

6. A method for manufacturing a pipe element for a vertically oriented, gravity-assisted heat pipe, the method comprising
 - forming a pipe element out of thermally conducting, malleable material, wherein the pipe element comprises at least one through-hole between a first opening at a first end of the pipe element and a second opening at a second end of the pipe element so that the at least one through-hole forms an evaporation section and a condenser section to the pipe element, forming a first helical thread on an inside wall of the through-hole in the evaporator section of the pipe element, wherein the first helical thread comprises at least one first ridge and at least one first groove, and
 - bending the crest of the at least one first ridge to curve away from the condenser section so that, during the use of a heat pipe comprising the pipe element, the at least one first ridge and the at least one first groove form at least one pocket for boiling coolant in the evaporator section.
7. A method according to claim 6, wherein the forming of the pipe element comprises extruding aluminium to form the pipe element.
8. A method according to claim 6 or 7, wherein the forming of the first helical thread comprises machining the first helical thread to the evaporator section of the at least one through-hole.
9. A method according to claim 8, wherein the first helical thread is machined to a sharp v-thread.
10. A method according to any one of claims 6 to 9, wherein the bending of the crest of the first ridges comprises
 - forcing an arbor to propagate inside the through-hole in a direction from the condenser section to the evaporator section.
11. A method for manufacturing a cold plate, wherein the method comprises
 - using a method according to any one of claims 6 to 10 to manufacture a pipe element,

attaching a first seal to the first end of the pipe element in order to seal the first opening of the at least one through-hole,
 attaching a second seal to the second end of the pipe element, wherein the second comprises means for sealing the second opening,
 machining a cooling interface to the pipe element at the evaporator section of the at least on through-hole, the cooling interface being adapted for mounting a power electric component to the cold plate, and
 attaching at least one cooling fin to extend from the pipe element at the condenser section of the at least on through-hole.

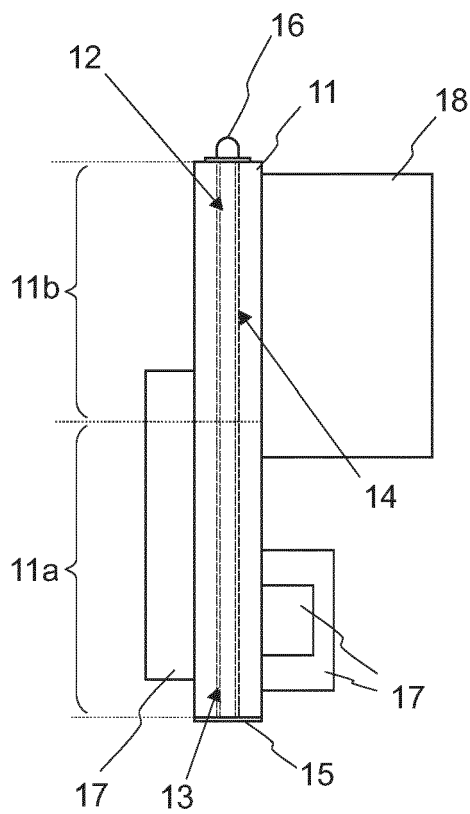


Figure 1a

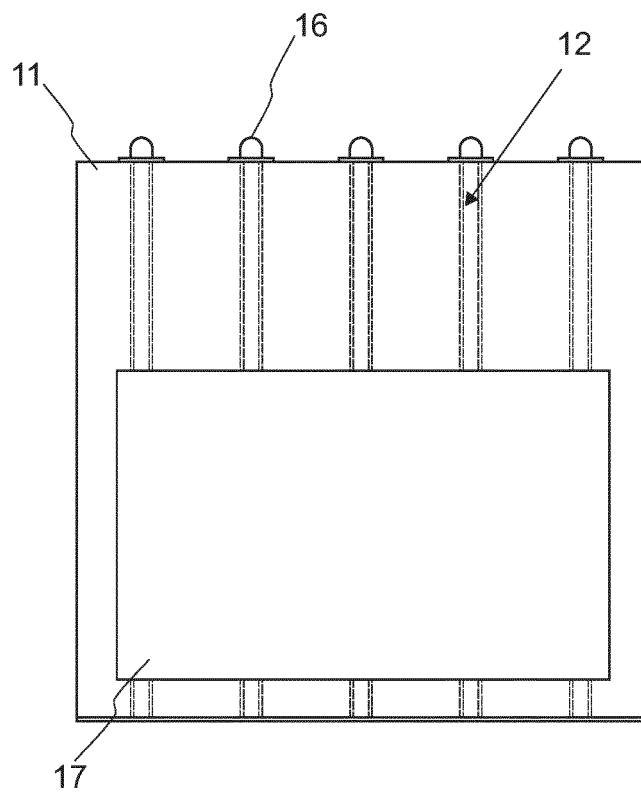


Figure 1b

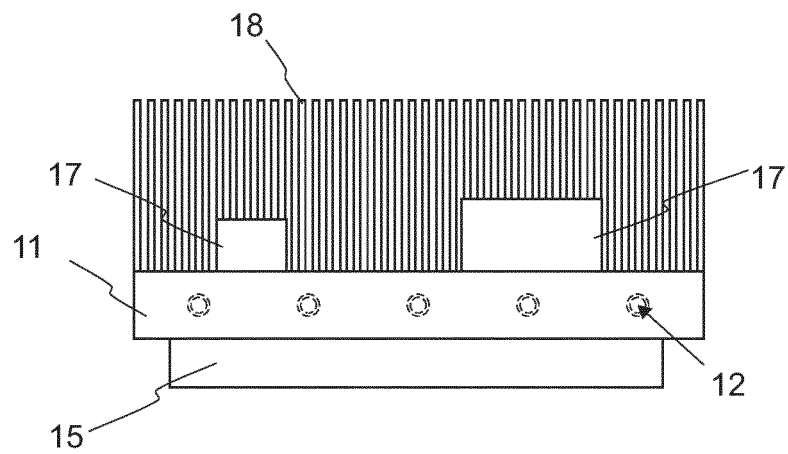


Figure 1c

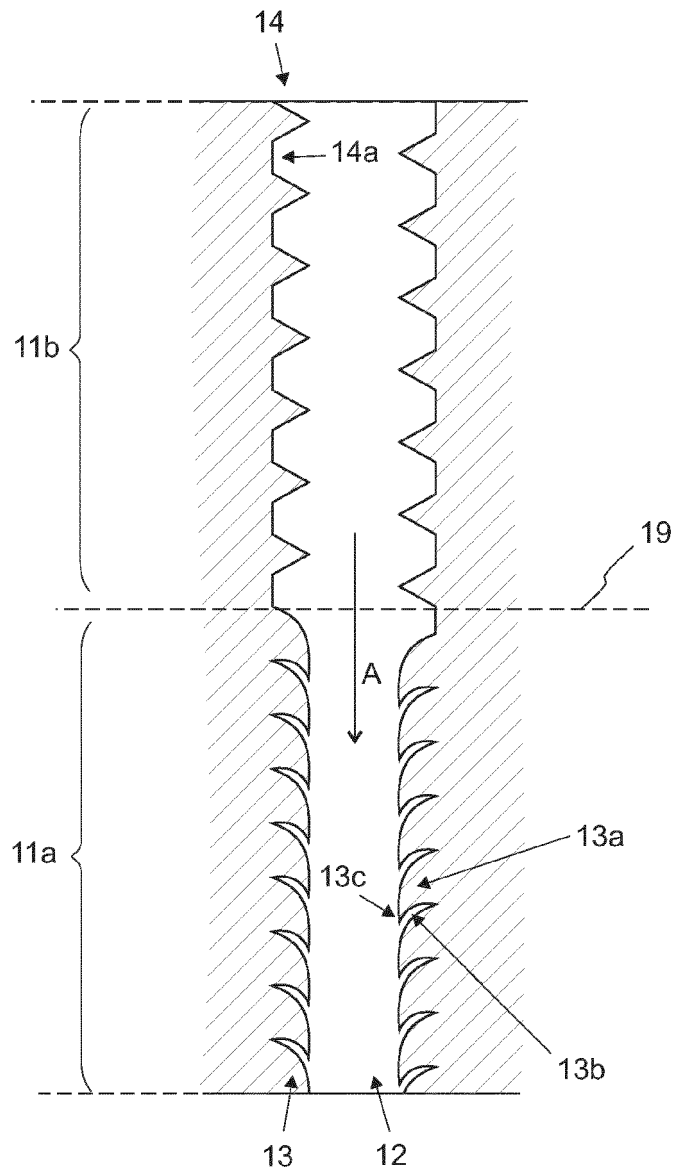


Figure 2

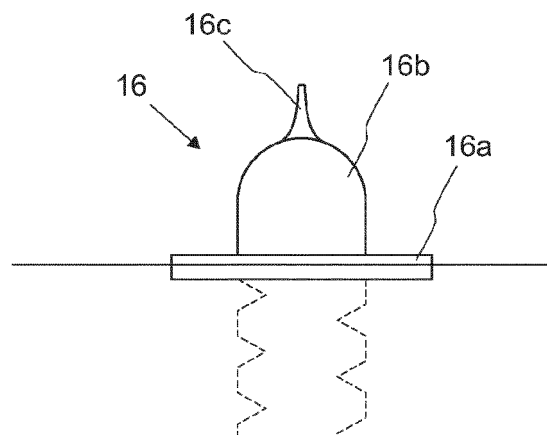


Figure 3



EUROPEAN SEARCH REPORT

 Application Number
 EP 16 17 2588

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
			F28F F28D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 November 2016	Examiner Martínez Rico, Celia
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 17 2588

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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