(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 053 487 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.09.2022 Bulletin 2022/36

(21) Application number: **21159906.3**

(22) Date of filing: **01.03.2021**

(51) International Patent Classification (IPC):
F28D 15/02 *(2006.01)* ***F28D 15/04*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F28D 15/025; F28D 15/0233; F28D 15/046;
F28D 2015/0216

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **ABB Schweiz AG**
5400 Baden (CH)

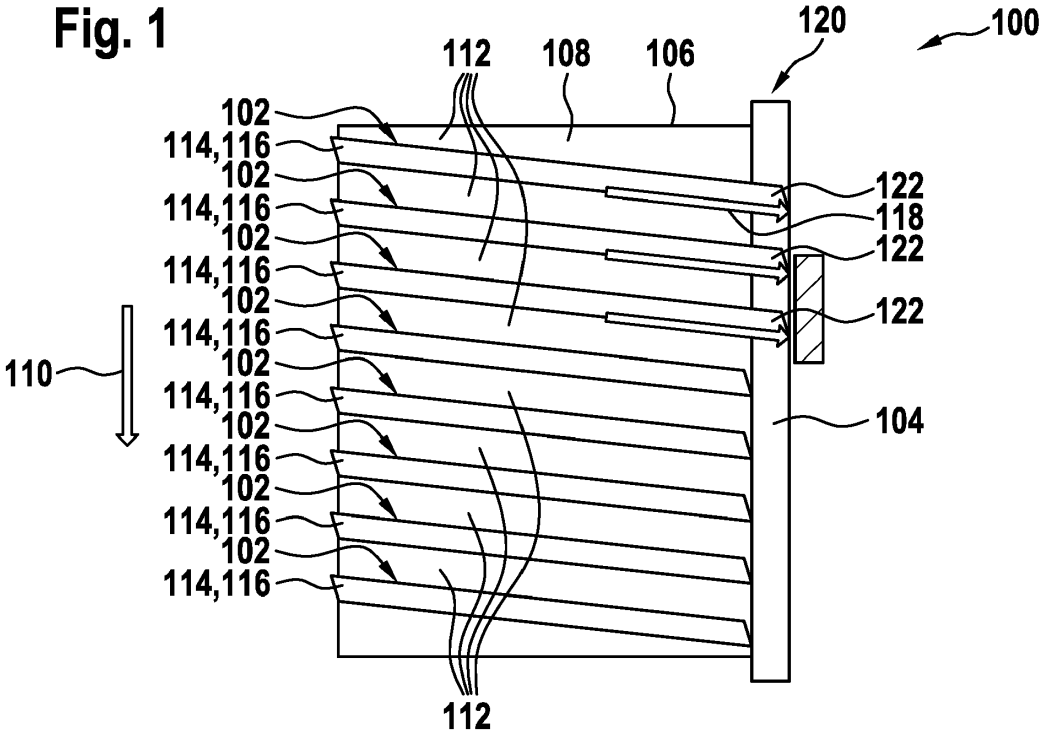
(72) Inventors:
- **Petrov, Andrey**
  8048 Zürich (CH)
- **Agostini, Bruno**
  8006 Zürich (CH)
- **Torresin, Daniele**
  5400 Baden (CH)
- **Sologubenko, Oleksandr**
  8906 Bonstetten (CH)

(74) Representative: **Qip Patentanwälte**
Dr. Kuehn & Partner mbB
Goethestraße 8
80336 München (DE)

(54) **HEAT-TRANSFER DEVICE**

(57) A heat-transfer device (100) comprises an evaporator (104) and a condenser (106) with at least one fluid-guide (102) to passively guide condensate (200) in a direction of the evaporator (104), wherein the fluid-guide (102) has at least one guide-structure (114) protruding from a condenser wall (108) of the condenser (106).

Fig. 1



EP 4 053 487 A1

Description

FIELD OF THE INVENTION

[0001] The invention relates to a heat-transfer device.

BACKGROUND OF THE INVENTION

[0002] A heat-transfer device may be a phase-change device. Inside the heat-transfer device a fluid may evaporate at an evaporator inside a vacuum chamber of the heat-transfer device. The vacuum affects a phase-change temperature of the fluid. The evaporated fluid condenses at a condenser in the vacuum chamber. Condensate moves back to the evaporator to be evaporated once again.

[0003] The movement of the condensate may be facilitated by a wick between the condenser and the evaporator.

DESCRIPTION OF THE INVENTION

[0004] It is an objective of the invention to provide an improved heat-transfer device. This objective is achieved by the subject-matter of the independent claim. Further exemplary embodiments are evident from the dependent claims and the following description.

[0005] The invention relates to a heat-transfer device, comprising an evaporator and a condenser with at least one fluid-guide to passively guide condensate in a direction of the evaporator, wherein the fluid-guide has at least one guide-structure protruding from a condenser wall of the condenser.

[0006] A heat-transfer device may use two consecutive phase changes of a fluid enclosed in a vapor chamber of the heat-transfer device to transfer thermal energy through the device. A first phase change may be an evaporation of the fluid from liquid to vapor at an evaporator of the heat-transfer device. A second phase change may be a condensation of the fluid from vapor to liquid at a condenser of the heat-transfer device. A vacuum inside the vapor chamber may affect a temperature of the phase changes.

[0007] A heat source may be thermally connected to the evaporator. The heat source may supply the thermal energy. A heat sink may be thermally connected to the condenser. The heat sink may absorb the thermal energy. The heat source may be a power electronics module, for example. The heat sink may be a heat dissipator, for example. The heat sink may have a larger surface area than the heat source. The heat-transfer device may distribute the thermal energy over the larger surface area.

[0008] The vaporization takes place at the evaporator. Ideally, the thermal energy from the heat source is isothermally absorbed by the enthalpy of the vaporization and leads to the first phase change from liquid to vapor. The vapor transports and distributes the thermal energy through the vapor chamber to the condenser. The movement of the vapor is driven by a vapor pressure gradient inside the vapor chamber. The vapor is produced at the evaporator and disappears at the condenser. The effect of gravity on the vapor is negligible.

[0009] The condensation of the vapor takes place at a surface of the condenser. Ideally, the enthalpy of the condensation is isothermally released to the heat sink and leads to the second phase change from vapor back to liquid. The heat sink may be arranged on an outside of a condenser wall of the condenser. The liquid fluid may be referred to as condensate. The condensate may form drops on the condenser wall. The drops may follow gravity and run down the condenser wall. The drops may join and form a liquid film on the condenser. The liquid film may encumber the condensation, since the condensate may have a higher thermal resistance than a material of the condenser. A thickness of the liquid film may increase from top to bottom, as more and more condensate follows gravity and flows downward.

[0010] A fluid-guide may collect the condensate on the condenser wall before it has flown down to an end of the condenser wall. The fluid-guide may remove the condensate from the condenser wall near the place where it condenses. By removing the condensate, the fluid-guide may limit the film thickness of the liquid film on the condenser wall. Below the fluid-guide the film thickness may be less than above the fluid-guide. The fluid-guide may be configured to lead the condensate along the condenser wall and towards the evaporator. A direction towards the evaporator may be transverse and/or in opposition to a direction of gravity. The fluid-guide may use gravity and/or capillary pressure of the liquid fluid to propel the condensate sideways and/or upwards towards the evaporator. Gravity may induce a downhill-slope force in the condensate. The capillary pressure may lead to capillary pumping. The capillary pumping may be powered by a pressure gradient across the fluid-guide.

[0011] A guide-structure may extend into the vapor chamber. The guide-structure may stick out of the condenser wall. The guide-structure may be an obstacle for the liquid film. The guide-structure may be elongated in the direction of the evaporator. The guide-structure may be referred to as protrusion, rib, strip, fin or ridge. The guide-structure may be thermally coupled to the condenser wall. The guide-structure may enlarge the condensation surface of the condenser. Vapor may also condense on the guide-structure.

[0012] The condenser wall may feature multiple fluid-guides. The fluid-guides may run across a main area of the condenser wall. The fluid-guides may be equal or different. The fluid-guides may be approximately parallel to each other and/or convene at the evaporator.

[0013] In an embodiment, the fluid-guide has a flume located on an upper side of the guide-structure. A flume may be referred to as a gutter or channel. The flume may be a depression between two higher sides. At least one of the sides maybe formed by the guide-structure. The flume may collect condensate and channel it in the di-

rection of the evaporator. The flume may be arranged transverse to gravity. The flume may have a low flow resistance. The flume may have a high permeability and a high transport capacity.

[0014] In an embodiment, the flume has a downward slope in the direction of the evaporator. A downward slope may intensify a downhill-slope force to move the condensate sideways towards the evaporator. The flume may end over the evaporator and the liquid fluid may spill out of the flume onto the evaporator.

[0015] In an embodiment, the guide-structure protrudes from the condenser wall at an upward angle and the flume is arranged between the condenser wall and the guide-structure. The guide-structure may prevent the liquid film from running down the condenser wall.

[0016] In an embodiment, the fluid-guide has a capillary channel between two guide-structures. A capillary channel may suck in the condensate because of the capillary force. The capillary force may lead to capillary pumping. If the liquid fluid runs out of the capillary channel at an end in proximity of the evaporator, a pressure gradient inside the capillary channel sucks the liquid fluid away from the condenser. The capillary channel may have a low flow resistance. The capillary channel may have a high permeability.

[0017] In an embodiment, the capillary channel has an upward slope in the direction of the evaporator. The capillary pumping may be strong enough to overcome gravity. That way, the evaporator may be arranged higher than the condenser.

[0018] In an embodiment, the fluid-guide has at least one segment with a flume located on an upper side of the guide-structure and at least one segment with a capillary channel between two guide-structures. An operating mode of the fluid-guide may change along a length of the fluid-guide.

[0019] In an embodiment, a slope of the fluid-guide changes along the length of the fluid-guide. The fluid-guide may have segments with different slopes. The fluid-guide may also have a gradually changing slope. The slopes may be upward and downward. On the downward slope the liquid may be moved along by gravity. On the upward slope the liquid may be moved along by capillary pumping.

[0020] In an embodiment, a profile of the fluid-guide changes along a length of the fluid-guide. a profile may be referred to as cross-section area of the fluid-guide. A profile size may determine a transport capacity of the fluid-guide. The profile size may increase in the direction of the evaporator as more and more condensate may be collected in the fluid-guide.

[0021] In an embodiment, the fluid-guide extends over the condenser wall in the direction of the evaporator. The condenser wall may end at a distance from the evaporator. The fluid-guide may bridge the distance between the condenser and the evaporator.

[0022] In an embodiment, at least the fluid-guide is selectively sintered from loose metal powder grains by additive manufacturing. Additive manufacturing may be referred to as metal-3D-printing. By selectively sintering metal powder, advantageous shapes may be created. Unused metal powder grains may be reused. Selectively sintered material may have advantageous thermal characteristics. The metal material may be an aluminum material or a copper material for example. The metal material may be an alloy. The body may be sintered according to a CAD model. The body may be shaped irregularly.

[0023] In an embodiment, the fluid-guide is sintered integrally with the condenser wall. The fluid-guide may be thermally coupled to the condenser wall. The fluid-guide may be an extension of the condenser wall. Thermal properties of the condenser wall may be defined by selectively sintering.

[0024] In an embodiment, the guide-structure is sintered at least partially porous. A porous sinter material may create a high capillary force to attract the condensate. The porous sinter material may literally suck up the condensate like sponge. In particular, the capillary channel may be arranged between two strips of porous sinter material.

[0025] In an embodiment, the guide-structure is sintered at least partially dense. A dense sinter material may be fluid-proof. The dense sinter material may be an obstacle for the condensate and may prevent the condensate from running downward. In particular, the flume may be made of dense sinter material.

[0026] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The subject matter of the invention will be explained in more detail in the following text with reference to exemplary embodiments which are illustrated in the attached drawing.

[0028] Figs. 1 to 10 schematically show heat-transfer devices with fluid-guides according to embodiments of the invention.

[0029] The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. In principle, identical parts are provided with the same reference symbols in the figures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0030] Fig. 1 shows a heat-transfer device 100 with multiple fluid-guides 102 according to an embodiment. The heat-transfer device 100 has an evaporator 104 and a condenser 106. The evaporator 104 and the condenser 106 are dedicated areas of a vapor chamber of the heat-transfer device 100. Here, the evaporator 104 is arranged on a side wall of the vapor chamber. A heat-transfer fluid of the heat-transfer device 100 evaporates at the evaporator 104, travels as vaporous fluid through the vapor

chamber to the condenser 106, condensates at the condenser 106 to condensate and is guided back to the evaporator 104 in liquid form by the fluid-guides 102.

[0031] The condenser 106 has at least one condenser wall 108. The condenser wall 108 is an outer wall of the vapor chamber. The fluid-guides 102 are arranged on the condenser wall 108 and collect the condensate. The fluid-guides deviate the liquid fluid from running down the condenser wall 108 following gravity 110. The fluid-guides 102 deflect the condensate sideways in the direction of the evaporator 104.

[0032] In an embodiment, the fluid-guides 102 are arranged essentially horizontally on the condenser wall 108. The fluid-guides 102 subdivide the condenser wall 108 into condensation areas 112. Essentially all the condensate condensing in one condensation area 112 above one fluid-guide 102 is collected by that fluid-guide 102 and guided back to the evaporator 104. The fluid-guides 102 are arranged regularly spaced on the condenser wall 108. The fluid-guides 102 are arranged approximately parallel to each other.

[0033] Each fluid-guide 102 has at least one guide-structure 114 protruding from the condenser wall 108 into the vapor chamber. In this embodiment, each fluid-guide 102 has a flume 116 formed by the condenser wall 108 and the guide-structure 114. The guide-structure 114 protrudes angled upwards from the condenser wall 108. The flumes 116 are like gutters arranged between the condenser wall 108 and the guide-structures 114. The condensate is stopped running down the condenser wall 108 when it reaches the flumes 116. The flumes 108 have a downward slope 118 towards the evaporator 104.

[0034] In an embodiment, the condenser wall 108 is spaced apart from the evaporator 104 by a gap 120. The fluid-guides 102 have extensions 122 extending over the condenser wall 108, bridging the gap 120. The liquid fluid spills from the extensions 122 directly onto the evaporator 104 at the side wall of the vapor chamber.

[0035] Fig. 2 shows a side view of the heat-transfer device 100 of fig. 1. Here the condensation of the fluid 200 on the condenser wall 108 is shown. The vaporous fluid 200 turns into liquid fluid 200. Condensate 200 is used synonymously to liquid fluid 200. The condensate 200 forms a liquid film 202 on the condenser wall 108 and starts flowing down the condenser wall 108 following gravity 110. When the condensate 200 reaches the next fluid-guide 102, the downward flow is stopped and the liquid fluid 200 is collected by the fluid-guide 102. The fluid-guide 102 then transports the liquid fluid 200 to the evaporator, which is not shown here. As the condensation area 112 above each fluid-guide 102 is limited, a thickness of the liquid film 202 is also limited, which ensures a low thermal resistance of the whole condenser 106.

[0036] In an embodiment, the guide-structures 114 are thermally coupled to the condenser wall 108 and enlarge the condensation area 112 above each fluid-guide 102. The vapor also condenses on a surface of the guide-structures 114. The additional condensation area 112 may be covered by a minimum thickness of the liquid film 202 and may therefore have a low thermal resistance. A surface of each guide-structure 114 facing the condenser wall 108 forms part of the flume 116 for the liquid fluid 200 from the condensation area 112 above it.

[0037] In an embodiment the guide-structures 114 are made out of a dense sinter material 204. The dense sinter material is selectively sintered from loose metal powder grains. The dense sinter material is fluid-proof and prevents seepage of the condensate 200.

[0038] In other words, the effect of the condenser designs on the liquid film thickness and flow are depicted.

[0039] Fig. 3 shows a heat-transfer device 100 according to an embodiment. The heat-transfer device 100 is essentially similar to the heat-transfer device in Fig. 1. In contrast to that, here the evaporator 104 is arranged below a central area 300 of the condenser wall 108. The fluid-guides 102 are divided into segments 302 at the central area 300. The segments 302 have a downward slope 118 toward the central area 300. There is a vertical aisle 304 between the segments 302 across the central area 300. The collected condensate runs along the segments 302 towards the central area 300 and runs down the aisle 304 on the condenser wall 108 onto the evaporator 104.

[0040] Fig. 4 shows a heat-transfer device 100 according to an embodiment. Here the evaporator 104 is arranged above the condenser 106. The condensate is transported towards the evaporator 104 by the fluid-guides 102 against gravity 110.

[0041] The fluid-guides 102 have two guide-structures 114 each. A capillary channel 400 per fluid-guide 102 is arranged between the two guide-structures 114. The condensate is sucked into the capillary channel 400 along its length by the capillary force. Inside the capillary channel 400 the liquid fluid is moved towards the evaporator by capillary pumping. The capillary pumping is driven by liquid fluid evaporating at the evaporator 104. The evaporating liquid fluid creates an underpressure at an end of the capillary channel 400 next the evaporator 104. The capillary pressure moves the liquid fluid along the capillary channel 400 against gravity 110 to equalize the resulting pressure gradient inside the capillary channel 400.

[0042] Fig. 5 shows a heat-transfer device 100 according to an embodiment. The heat-transfer device 100 is a mixture of the heat-transfer devices in the figures 3 and 4. The evaporator 104 is above the condenser 106 as in Fig. 4. Fluid-guides 102 with capillary channels 400 lead to the evaporator 104. Additionally, there are segments 302 of fluid-guides 102 with flumes 116 on the condenser wall 108 as in Fig. 3. Here each end-to-end fluid-guide 102 has a segment 302 with a capillary channel 400 and segment 302 with a flume 116. The segments 302 have different slopes and different profiles. The segments 302 with the flumes 116 have one guide-structure 114 each and are arranged essentially horizontally on a peripheral

area of the condenser wall 108. The segments 302 with the capillary channels 400 have two guide-structures each and are arranged with an upward slope in the central area 300 of the condenser wall 108. The segments 302 with the capillary channels 400 converge at the evaporator 104.

[0043] In other words, various designs, depending on the vapor chamber orientation (vertical, horizontal, against gravity) and combinations of porous strips and gutters are depicted.

[0044] Fig. 6 shows a heat-transfer device 100 according to an embodiment. The heat-transfer device 100 is essentially similar to the heat-transfer device in Figs. 1 and 2. In contrast to that, here the fluid-guide 102 has three segments 302 with varying downward slopes 118.

[0045] Fig. 7 shows a side view of a heat-transfer device 100 according to an embodiment. The heat-transfer device 100 is essentially similar to the heat-transfer device in Figs. 1 and 2. In contrast to that, here the fluid-guides 102 have different profiles. All fluid-guides 102 have a flume 116 and one guide-structure 114. A first fluid-guide 102 has profile similar to the profiles in Fig. 2. The guide-structure 114 protrudes from the condenser wall 108 at an upward angle. A second fluid-guide 102 has a quarter round profile. The guide-structure 114 protrudes from the condenser wall 104 at right angles and curves upward in a cylinder segment shape. A third fluid-guide has a segmented profile. A first segment of the guide-structure 114 protrudes from the condenser wall 108 at an upward angle. The first segment has a flatter angle than a second segment of the guide-structure 114. A third segment of the guide-structure 114 has the same angle as the first segment.

[0046] In other words, possible design variations of gutters are depicted. The shown inclination angles are in relation to the condenser wall and gravity. Different cross-section profiles and a multi sectoral gutter are shown.

[0047] Fig. 8 shows a heat-transfer device 100 according to an embodiment. Here the fluid-guides 102 have at least two guide-structures 114 each. Between each two neighboring guide-structures 114 there is a capillary channel 400. Here the guide-structures 114 are made out of a porous sinter material 800. The porous sinter material 800 creates a high capillary force to attract the liquid fluid. Inside the capillary channels 400 the liquid fluid is transported towards the evaporator, which is not shown here.

[0048] A first fluid-guide 102 has one capillary channel 400 between two guide-structures 114. A second fluid-guide 102 has three capillary channels 400 between four stacked guide-structures 114.

[0049] Fig. 9 shows a side view of a heat-transfer device 100 according to an embodiment. Here all fluid-guides 102 have at least one capillary channel 400 between two guide-structures 114. At least part of each fluid-guide 102 is made out of the porous sinter material 800.

[0050] A first fluid-guide 102 has two guide-structures 114 protruding from the condenser wall 108 at right angles. The guide-structures 102 are made out of the porous sinter material 800. The capillary channel 400 is arranged at right angles to the condenser wall 108.

[0051] A second fluid-guide 102 has two guide-structures 114 protruding from the condenser wall 108 at upward angles. The guide-structures 114 are made out of the porous sinter material 800. The capillary channel 400 is arranged at the upward angle to the condenser wall 108. Above the upper guide-structure 114 this fluid-guide 102 has a flume 116 in addition to the capillary channel 400.

[0052] A third fluid-guide 102 has two guide-structures 114 protruding from the condenser wall 108 at upward angles. The upper guide-structure 114 is completely made out of the porous sinter material 800. The lower guide-structure 114 is partially made out of the porous sinter material 800 and partially made out of the dense sinter material 204. A lower part of the lower guide-structure 114 is made of the dense sinter Material 204. The capillary channel 400 is arranged at the upward angle to the condenser wall 108. Above the upper guide-structure 114 this fluid-guide 102 has a flume 116 in addition to the capillary channel 400.

[0053] A fourth fluid-guide 102 has two capillary channels 400. The capillary channels 400 are formed by an outer segmented guide-structure 114, a middle segmented guide-structure 114 and an additional unsegmented guide-structure 114 on the condenser wall 108. Lower segments of the segmented guide-structures 114 protrude from the condenser wall 108 at an upward angle. Upper segments of the segmented guide-structures 114 are arranged approximately parallel to the condenser wall 108 and the guide-structure 114 on the condenser wall 108.

[0054] Upper parts of the capillary channels 400 are arranged approximately parallel to the condenser wall 108. Lower parts of the capillary channels 400 are arranged at the upward angle. This way the capillary channels 400 also function as flumes 116.

[0055] The guide-structure 114 on the condenser wall 108 is completely made out of the porous sinter material 800. The middle guide-structure 114 also is completely made out of the porous sinter material 800. The outer guide-structure 114 is partially made out of the porous sinter material 800 and partially made out of the dense sinter material 204. An outer layer of the outer guide-structure 114 is made of the dense sinter material 204. The outer layer is fluid-proof and keeps the condensate from seeping through the outer guide-structure 114.

[0056] Fig. 10 shows a heat-transfer device 100 according to an embodiment. The heat-transfer device 100 has two fluid guides 102 on the condenser wall 108. Both fluid guides 102 have capillary channels 400 arranged between porous guide-structures 114.

[0057] The upper fluid-guide 102 is curvy. The upper fluid-guide 102 has a bend of more than 90°. The upper

fluid-guide 102 starts vertically, turns to the side until it has an upward slope and then evens out in the direction of the evaporator 104.

[0058] The lower fluid-guide 102 has a junction of capillary channels 400. Two capillary channels 400 converge and merge into a single capillary channel 400. An upper capillary channel 400 has a downward slope, a lower capillary channel 400 has an upward slope. A capillary channel 400 running toward the evaporator 104 is oriented horizontally.

[0059] In other words, possible design variations of parallel porous strips are shown. A fluid-guide with two strips and a fluid-guide with multiple stacked stripes as well as strips with inclination, strips combined with a gutter, curvy strips and intersecting strips are shown.

[0060] A condenser with fluid-guides is presented. A condenser design for a two-phase cooling device like a vapor chamber or thermosyphon is disclosed, which at the same time provides an increased condensation area, promotes a direct liquid flow from the condenser to the evaporator and reduces a liquid film resistance.

[0061] Conventional Two-dimensional or three-dimensional vapor chambers may be composed of a solid enclosure consisting of at least two solid plates soldered together. A porous structure may cover their inner surface. The purpose of the porous structure is to return the working fluid from the cold end (condenser) to the hot end (evaporator), by exerting a capillary force against the pressure difference between the hot end and the cold end.

[0062] The porous structure may be comprised of sintered powder, mesh, fiber or a combination thereof. There may even be no porous structure on the condenser side at all, particularly when working in a vertical orientation. Sintered powder may provide the highest capillary force to move the fluid back to the evaporator, but the permeability of sintered powder is low, which limits the maximum fluid flux. The sintered powder also retains a thick fluid film on the condenser side, which may increase the overall thermal resistance of the condenser. Fiber and mesh provide lower film resistance and higher permeability, but significantly lower capillary force. The absence of a wick structure on the condenser leads to the lowest thermal resistance, but at the cost of having no direct fluid return to the hot end. Irrespective of the wick type, the liquid film thickness tends to increase along the gravity axis, which makes the condenser less and less efficient along that axis.

[0063] Here an improved fluid management on the condenser side is proposed to improve an efficiency of two-phase cooling systems. The presented condenser structure improves the liquid return to the hot end of the vapor chamber by combining both the high capillary force of the sintered powder, high permeability of fiber and low liquid film resistance.

[0064] The proposed solution may consist of at least one of the following features or a combination thereof. The fluid-guide may consist of at least one ledge or protrusion on the condenser inner wall, which is arranged in such a shape, that prevents the working fluid from flowing further down the condenser surface along a gravity axis. The fluid-guide may have a thin gutter-like slab. Such a gutter may be made either from fully dense of from porous material. Alternatively or supplementary, the fluid-guide may consist of at least two porous stripes attached to the condenser wall and arranged in parallel to each other, forming a channel directing towards the hot end of the vapor chamber.

[0065] The purpose of a gutter is to physically separate the condensation regions of the condenser without splitting the condenser itself. Such an arrangement allows to reduce the liquid film thickness in each particular condenser subsection, as well as to increase the total condensation area. This reduces the overall thermal resistance of the condenser, as well as the saturation pressure inside the vapor chamber. It is particularly advantageous that the condenser volume does not get split by such structures, as the vapor can freely move and hence the resistance in the vapor phase does not increase and overall vapor transport is not obstructed.

[0066] The fluid collected by the gutter may be guided to the hot end of the vapor chamber by gravity or by capillary force. For a gravity assisted flow, the gutter may have an inclination angle with respect to the gravity, to facilitate the fluid flow. For cases when the hot end is located above the cold end of the vapor chamber, or the pressure losses are too high to be compensated solely by gravity, the fluid collected by the gutter may be moved to the hot end by means of a porous structure with a capillary channel, which combines permeability of fiber and capillary force of sintered powder. The porous structure with the capillary channel can be used together with a gutter or separately.

[0067] The ledge/protrusion may have an inclination angle relative to the condenser wall between one and 90 degrees, preferably between 20 and 45 degrees, such that it forms a collecting gutter for the working fluid, preventing it from flowing straight down forced by the gravity. The profile of the gutter can be a straight line, or a more complex shape, for instance moon-shape or polyline.

[0068] With regards to the vapor chamber and gravity orientation, the gutter may be placed perpendicular to the gravity (90 degrees) or at an inclination angle between 0 and 90 degrees, preferably between 70 and 80 degrees with respect to the gravity. An inclination angle with respect to the gravity promotes the flow of the fluid in the specific direction, preferably in the direction of the hot end of the vapor chamber. Such inclination is especially useful when the vapor chamber is working in vertical or horizontal orientation, since those cases the fluid can be guided directly to the hot spot and the hot end of the vapor chamber. However, the gutter can also be used independently of the gravity when combined with the porous strips.

[0069] Both inclinations with respect to the condenser wall and to gravity can have more than one section with

varying angles. For example, a first section with an angle 80 degrees to gravity and 45 degrees to the condenser wall, and a second section with an angle 70 degrees to gravity and 30 degrees to the condenser wall, or any other combination of the described angle range.

[0070] In an embodiment, more than one gutter is arranged on the condenser wall. The gutters may be placed as close as 0.1 mm from each other. An optimal range is between 2 and 10 mm. In an embodiment, the gutters are cascaded, so that two or more gutters flow into a single bigger third gutter, which then brings the fluid to the hot end.

[0071] For cases when the hot end is located above the cold end of the vapor chamber, the fluid collected by the gutters can be moved against the gravity. In this case, the porous structure with the capillary channel may be used, which combines permeability of fiber and capillary force of sintered powder.

[0072] The porous structure consists of at least two parallel thin strips of sintered porous powder, preferably thinner than 1 mm, more preferably thinner than 0.4 mm. The channel or gap between the porous strips and a pore size of the strips can be adjusted to fit the properties of the working fluid. For instance, the wetting angle and surface tension. The mean pore size of the sintered powder strips may be between 200 μm and 5 μm. Preferably, the mean pore size is between 50 μm and 20 μm. The pore size may be non-uniform and change as a gradient or in steps along the strip. The gap between the strips may vary between 50 and 2000 μm.

[0073] The structure of the porous strips provides the necessary driving force (capillary force) to overcome the pressure drop and gravity, while the gap acts as a high permeability highway, which provides large amounts of fluid to the hot end, in the direction defined by the porous strips.

[0074] The height of the porous strips can be adjusted to vary the maximum fluid flux through such a structure, as the geometrical cross-section of the gap will increase proportionally. Additionally, more than two porous strips can be used to provide more than one gap. Hence, such stacking can provide an extra fluid flow to the hot end, when the flow provided by a single gap is not sufficient.

[0075] With regard to the geometry, the strips may have any cross-section. Preferably the cross-section is rectangular or square. The cross-section of the strips may vary along their length. The strip may change direction along its length by smooth or sharp bends. Multiple sets of parallel strips may be intersected with each other, can be split or merged with each other, or can be stacked on top of each other.

[0076] Porous strips may be used alone, when the use of gutters is not reasonable, for example, a short line size of the vapor chamber in the gravity direction and hence a low liquid film thickness.

[0077] The gutters and the strips may be combined. In this case the gutters are separating the condensation area into several areas, each of which is further connected to the hot end by the strips, where one end of the strip is connected with the gutter and the other to the hot end of the vapor chamber (preferably directly to the hotspot).

[0078] The strips may be embedded or merged with the gutter, hence producing a double porous gutter.

[0079] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art and practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or controller or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE SYMBOLS

[0080]

100	heat-transfer device
102	fluid-guide
104	evaporator
106	condenser
108	condenser wall
110	gravity
112	condensation area
114	guide-structure
116	flume
118	downward slope
120	gap
122	extension
200	liquid fluid, condensate,
202	liquid film
204	dense sinter material
300	middle
302	segment
304	aisle
400	capillary channel
800	porous sinter material

Claims

1. A heat-transfer device (100), comprising:
an evaporator (104) and a condenser (106) with at

least one fluid-guide (102) to passively guide condensate (200) in a direction of the evaporator (104), wherein the fluid-guide (102) has at least one guide-structure (114) protruding from a condenser wall (108) of the condenser (106).

2. The heat-transfer device (100) of claim 1, wherein the fluid-guide (102) has a flume (116) located on an upper side of the guide-structure (114).

3. The heat-transfer device (101) of claim 2, wherein the flume (116) has a downward slope (118) in the direction of the evaporator (104).

4. The heat-transfer device (100) of one of the claims 2 to 3, wherein the guide-structure (114) protrudes from the condenser wall (108) at an upward angle and the flume (116) is arranged between the condenser wall (108) and the guide-structure (114).

5. The heat-transfer device (100) of one of the previous claims, wherein the fluid-guide (102) has a capillary channel (400) between two guide-structures (114).

6. The heat-transfer device (100) of claim 5, wherein the capillary channel (400) has an upward slope in the direction of the evaporator (104).

7. The heat-transfer device (100) of one of the previous claims, wherein the fluid-guide (102) has at least one segment (302) with a flume (116) located on an upper side of the guide-structure (114) and at least one segment (302) with a capillary channel (400) between two guide-structures (114).

8. The heat-transfer device (100) of one of the previous claims, wherein a slope (118) of the fluid-guide (102) changes along a length of the fluid-guide (102).

9. The heat-transfer device (100) of one of the previous claims, wherein a profile of the fluid-guide (102) changes along a length of the fluid-guide (102).

10. The heat-transfer device (100) of one of the previous claims, wherein the fluid-guide (102) extends over the condenser wall (108) in the direction of the evaporator (104).

11. The heat-transfer device (100) of one of the previous claims, wherein at least the fluid-guide (102) is selectively sintered from loose metal powder grains by additive manufacturing.

12. The heat-transfer device (100) of claim 11, wherein the fluid-guide (102) is sintered integrally with the condenser wall (108).

13. The heat-transfer device (100) of one of the claims 11 to 12, wherein the guide-structure (114) is sintered at least partially porous.

14. The heat-transfer device (100) of one of the claims 11 to 13, wherein the guide-structure (114) is sintered at least partially dense.

Fig. 1

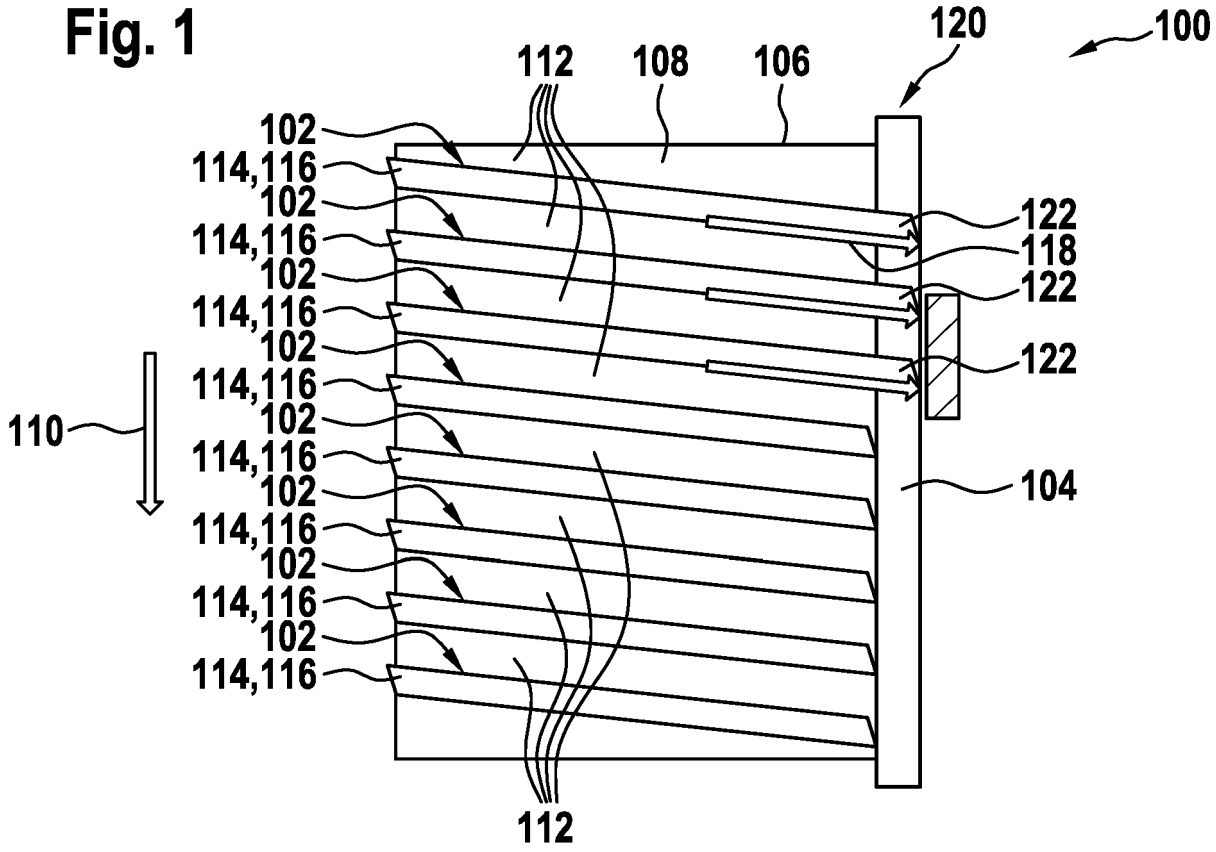

120
100
112
108
106
102
114,116
102
114,116
102
114,116
102
114,116
102
114,116
102
114,116
102
114,116
102
114,116
102
114,116
110
122
118
122
122
104
112

Fig. 2

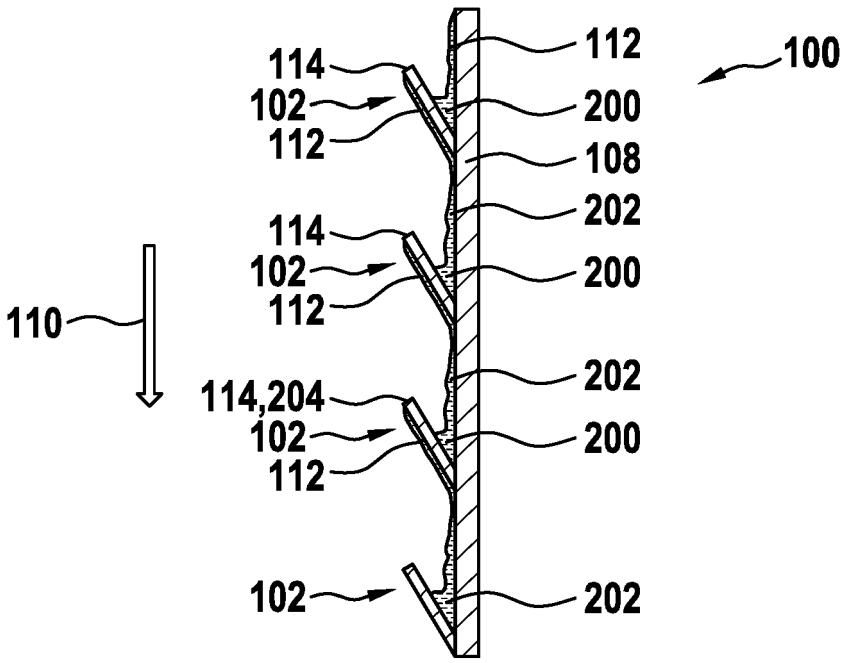

112
100
114
102
112
200
108
202
114
102
112
200
110
202
114,204
102
112
200
102
202

Fig. 3

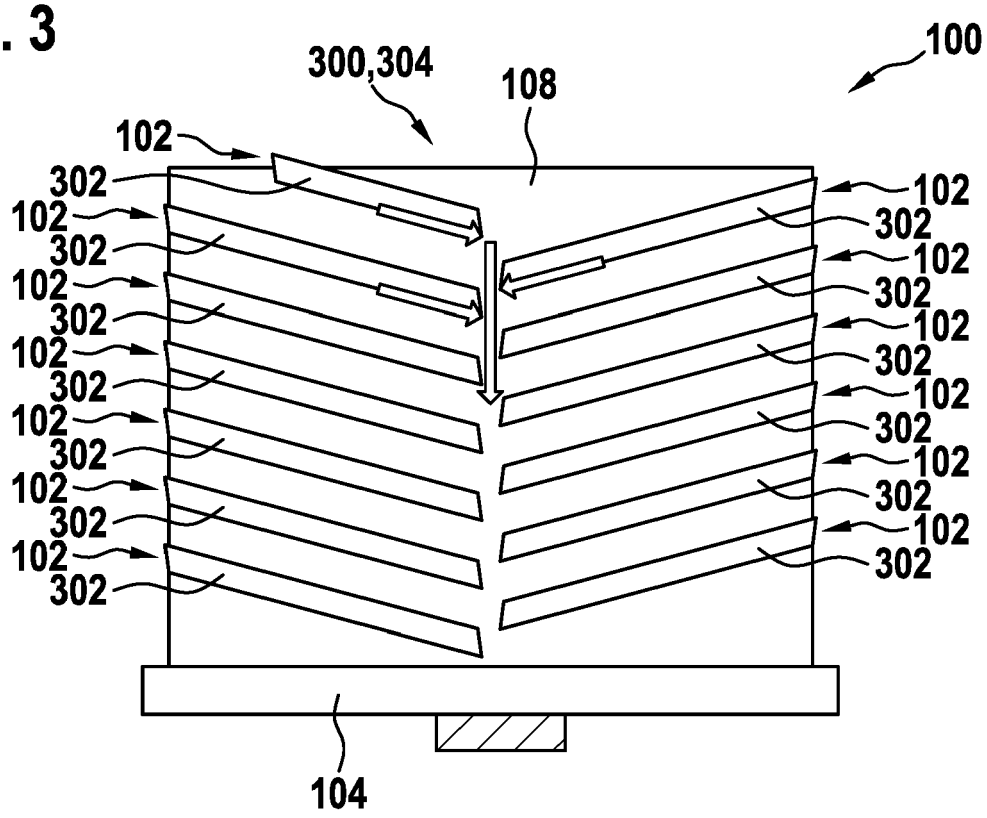


Fig. 4

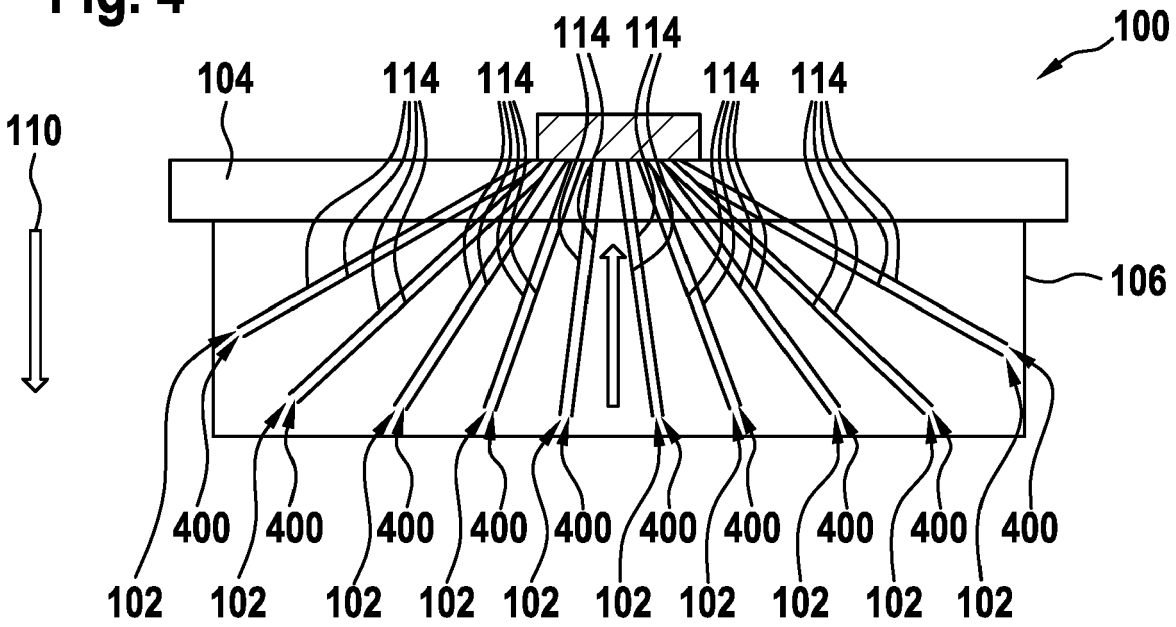


Fig. 5

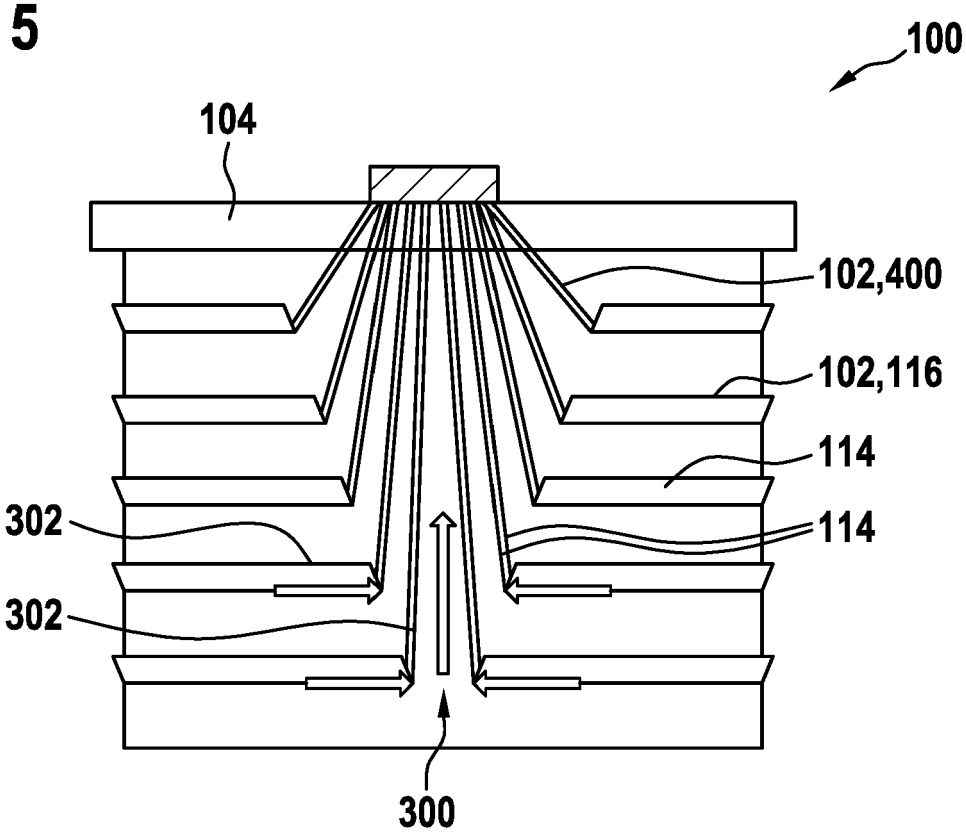

100
104
102,400
102,116
114
114
302
302
300

Fig. 6

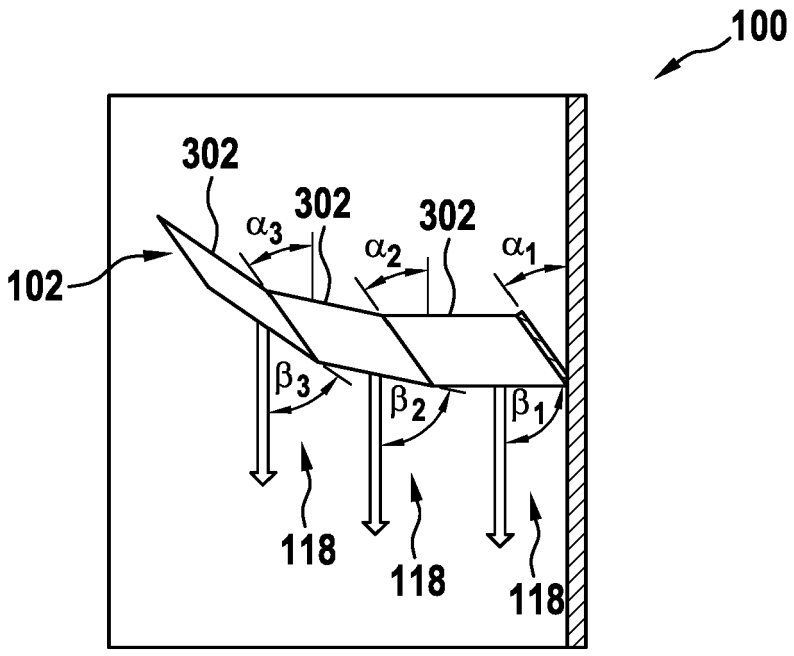

100
302
302
302
102
α_3
α_2
α_1
β_3
β_2
β_1
118
118
118

Fig. 7

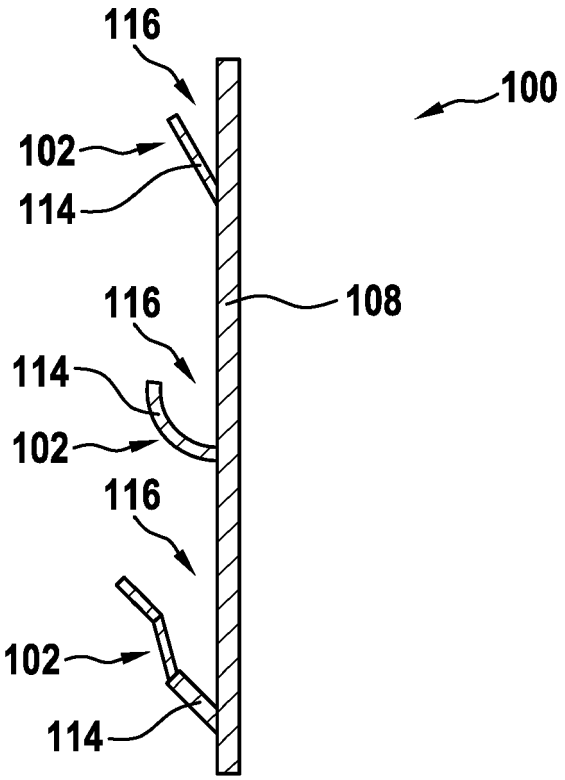

116
100
102
114
116
108
114
102
116
102
114

Fig. 8

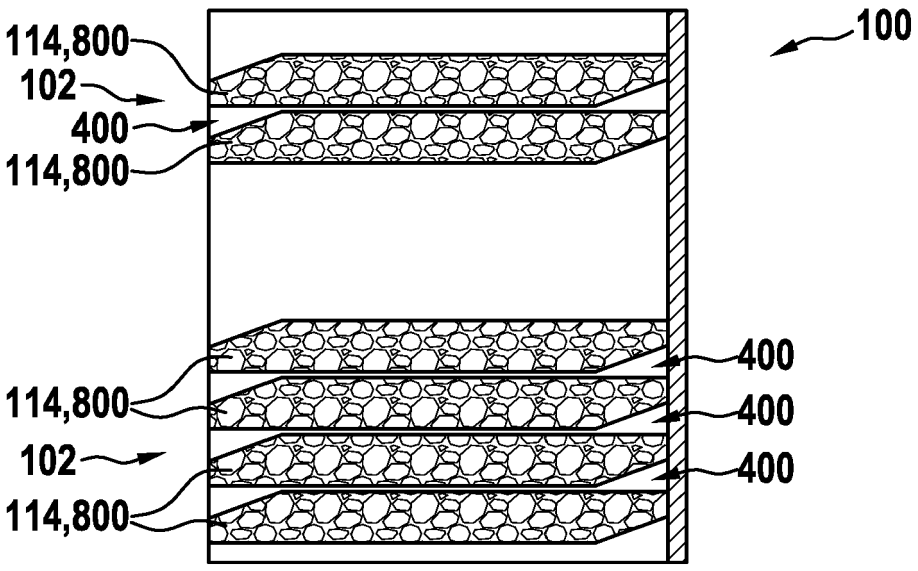

114,800
102
400
114,800
100
400
114,800
400
102
400
114,800

Fig. 9

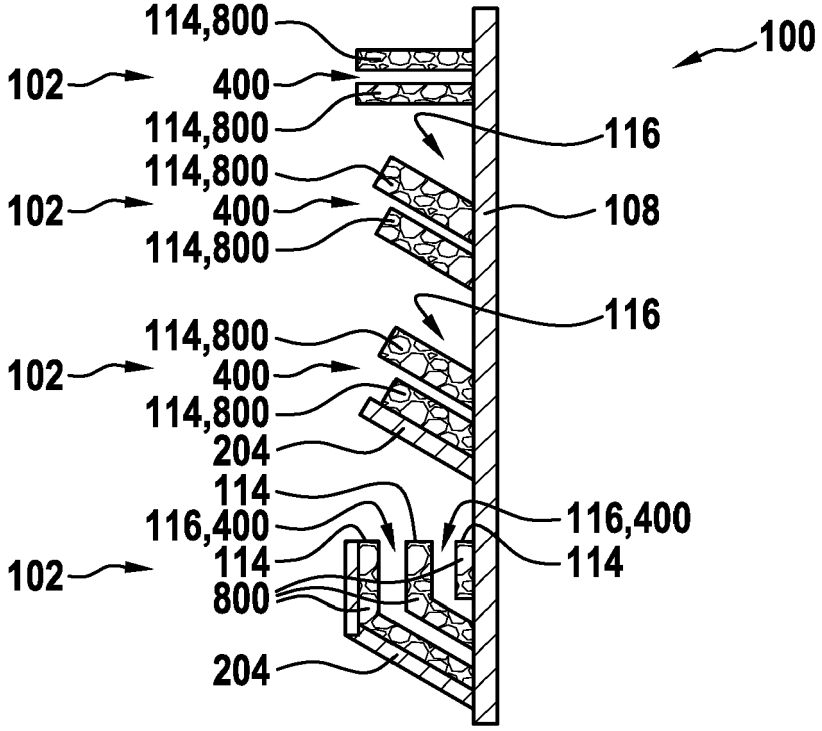
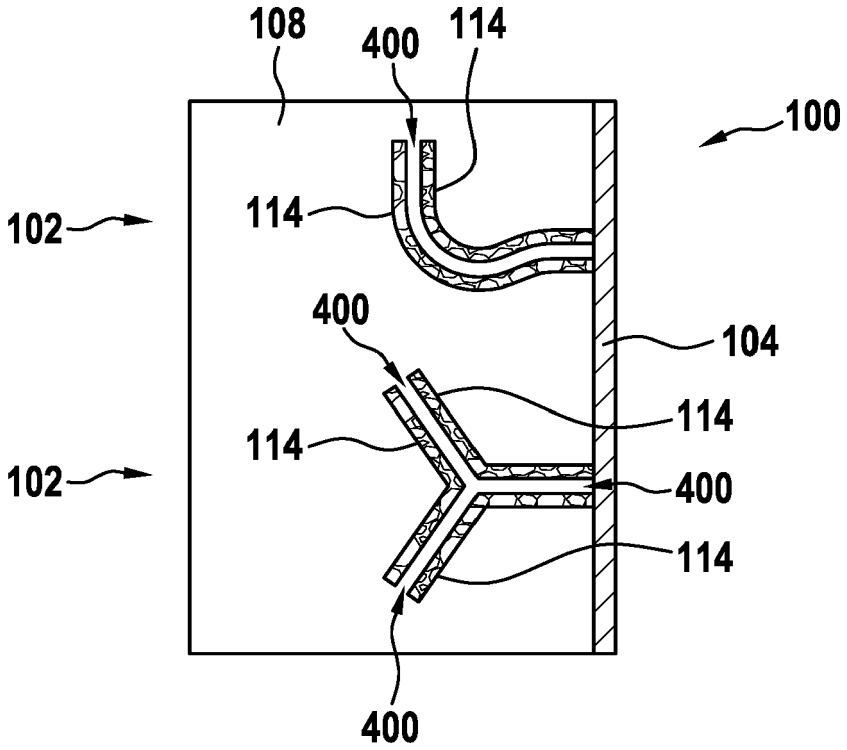

114,800
102
400
114,800
102
400
114,800
114,800
102
400
114,800
204
114
116,400
102
114
800
204
100
116
108
116
116,400
114

Fig. 10


108
400
114
100
102
114
400
104
114
114
102
400
114
400

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 15 9906

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 2006/131002 A1 (MOCHIZUKI MASATAKA [JP] ET AL) 22 June 2006 (2006-06-22) * the whole document *	1,9-14 6	INV. F28D15/02 F28D15/04
X	US 8 356 657 B2 (TELEDYNE SCIENT & IMAGING LLC; ZHAO YUAN [US]; CHEN CHUNG-LUNG [US]) 22 January 2013 (2013-01-22) * the whole document *	1,2,4,5, 7,9-14	
X A	US 2020/271390 A1 (RICE JEREMY [US]) 27 August 2020 (2020-08-27) * the whole document *	1,11-14 2-5	
X	DE 20 2009 004630 U1 (ABB OY [FI]) 6 August 2009 (2009-08-06) * the whole document *	1-4, 11-14	
X	US 6 085 831 A (DIGIACOMO GIULIO [US] ET AL) 11 July 2000 (2000-07-11) * the whole document *	1,8,9, 11-14	
X	JP 2000 356485 A (FUJIKURA LTD) 26 December 2000 (2000-12-26) * figure 1 *	1,10-14	TECHNICAL FIELDS SEARCHED (IPC) F28D
X	US 2003/136550 A1 (TUNG CHAO-NIEN [TW] ET AL) 24 July 2003 (2003-07-24) * the whole document *	1,11-14	
X	JP 2010 236792 A (TOYOTA IND CORP) 21 October 2010 (2010-10-21) * figure 1 *	1,11-14	
X	US 2009/159243 A1 (ZHAO YUAN [US] ET AL) 25 June 2009 (2009-06-25) * abstract; figures 1-11 *	1,11-14	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 August 2021	Bloch, Gregor

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

EPO FORM 1503 03.82 (P04C01)

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 15 9906

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	DE 20 2011 100657 U1 (ASIA VITAL COMPONENTS CO LTD [TW]) 18 July 2011 (2011-07-18) * claim 1; figures 1-9 *	1	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 August 2021	Bloch, Gregor

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

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 15 9906

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-08-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006131002 A1	22-06-2006	CN 1789879 A	21-06-2006
		JP 2006170602 A	29-06-2006
		US 2006131002 A1	22-06-2006
		US 2007235178 A1	11-10-2007
US 8356657 B2	22-01-2013	US 2009159242 A1	25-06-2009
		US 2013112376 A1	09-05-2013
US 2020271390 A1	27-08-2020	US 2020271390 A1	27-08-2020
		WO 2020176781 A1	03-09-2020
DE 202009004630 U1	06-08-2009	DE 202009004630 U1	06-08-2009
		FI 8044 U1	20-10-2008
US 6085831 A	11-07-2000	NONE	
JP 2000356485 A	26-12-2000	NONE	
US 2003136550 A1	24-07-2003	NONE	
JP 2010236792 A	21-10-2010	NONE	
US 2009159243 A1	25-06-2009	NONE	
DE 202011100657 U1	18-07-2011	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82