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Enright et al.

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(54) **THERMOSYPHON HEAT EXCHANGER APPARATUS WITH POROUS LAYER**

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F28D 15/04 (2006.01)

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CPC ***F28D 15/0266*** (2013.01); ***F28D 15/043*** (2013.01); ***F28D 15/046*** (2013.01); *F28F 2270/00* (2013.01)

(58) **Field of Classification Search**
CPC .. F28D 15/0266; F28D 15/043; F28D 15/046; F28D 15/0275; F28F 2270/00;
(Continued)

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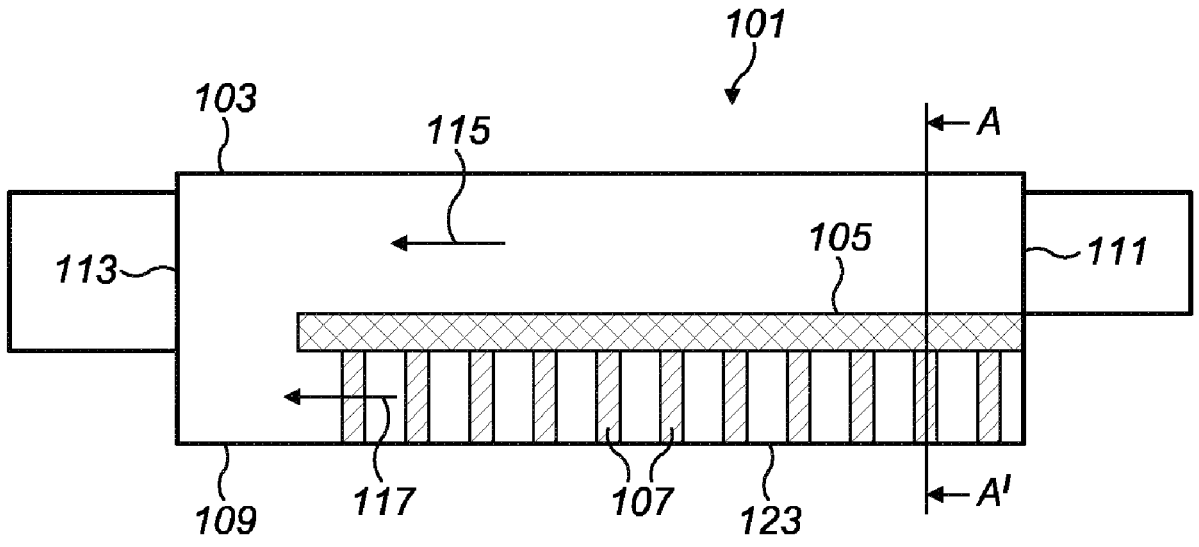
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(57) **ABSTRACT**

The application relates to a heat exchanger apparatus comprising: a channel for fluid flow extending between an inlet and an outlet; a porous layer dividing a first portion of the channel from a second portion of the channel, wherein the porous layer comprises a plurality of pores configured to enable fluid to be transferred from the first portion of the channel to the second portion of the channel; a plurality of evaporator structures located within the second portion of the channel wherein the evaporator structures comprise a wicking layer configured to enable evaporation of fluid from the surface of the evaporator structures; an ejector section configured to combine fluid from the first portion of the channel with fluid from the second portion of the channel and provide the combined fluid to the outlet.

13 Claims, 6 Drawing Sheets



(58) **Field of Classification Search**
CPC . H05K 7/20336; H05K 7/20663–2069; H05K 7/208–20818
See application file for complete search history.

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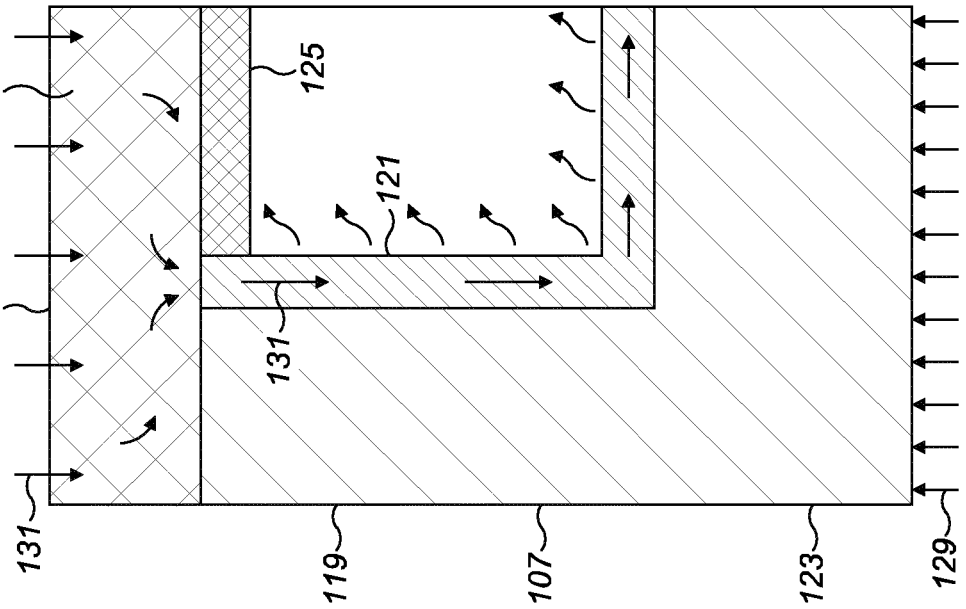


FIG. 1C

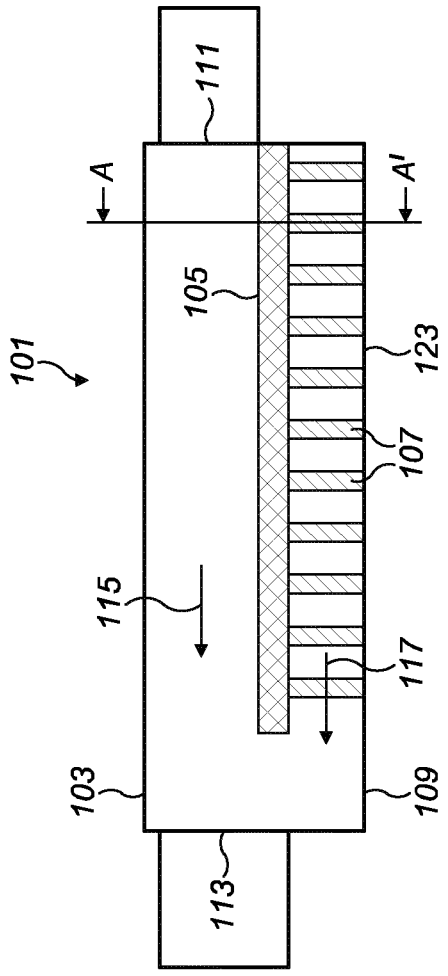


FIG. 1A

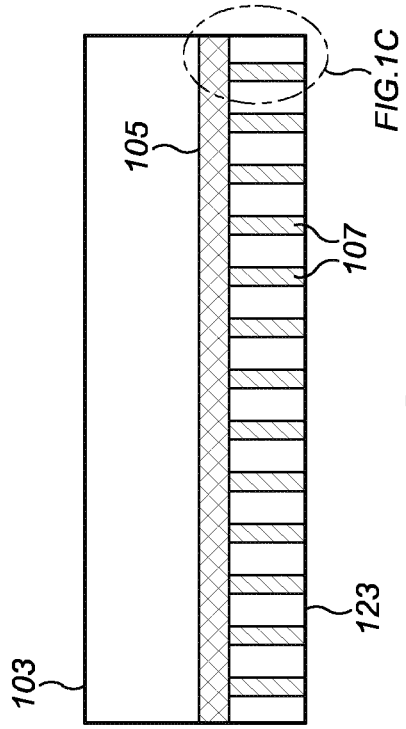


FIG. 1B

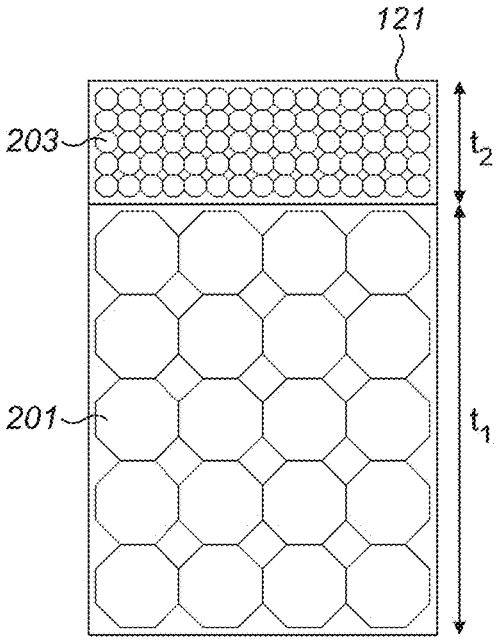


FIG. 2A

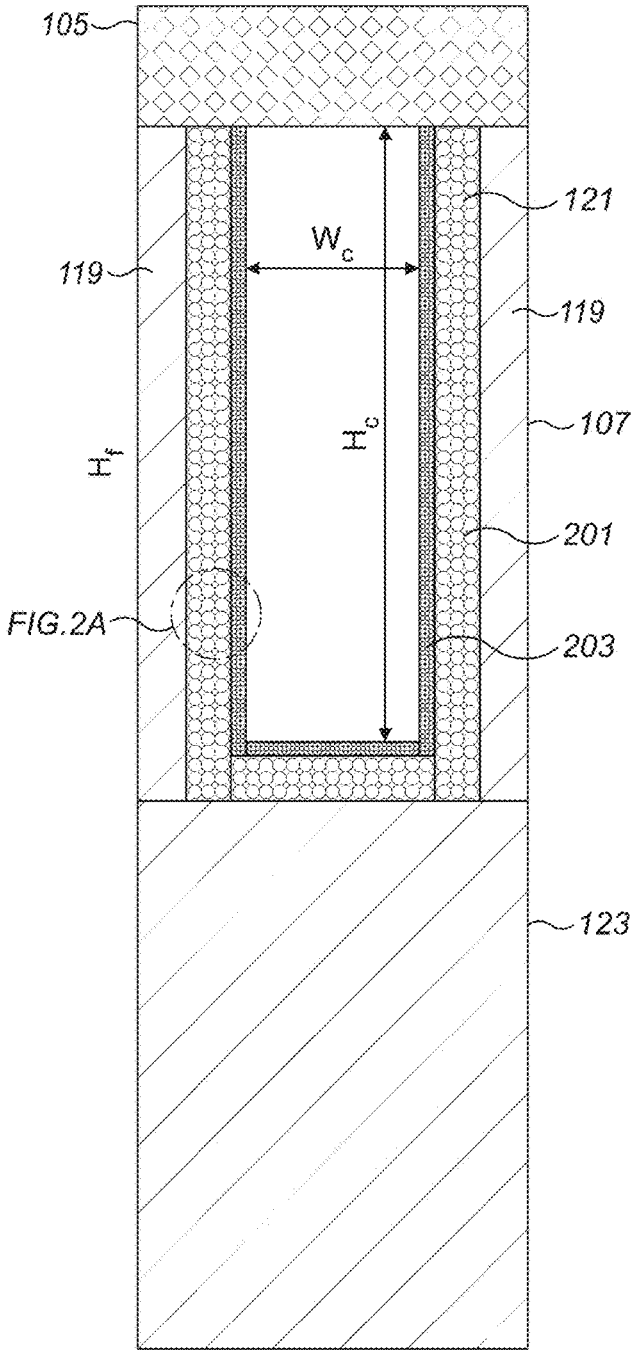


FIG. 2B

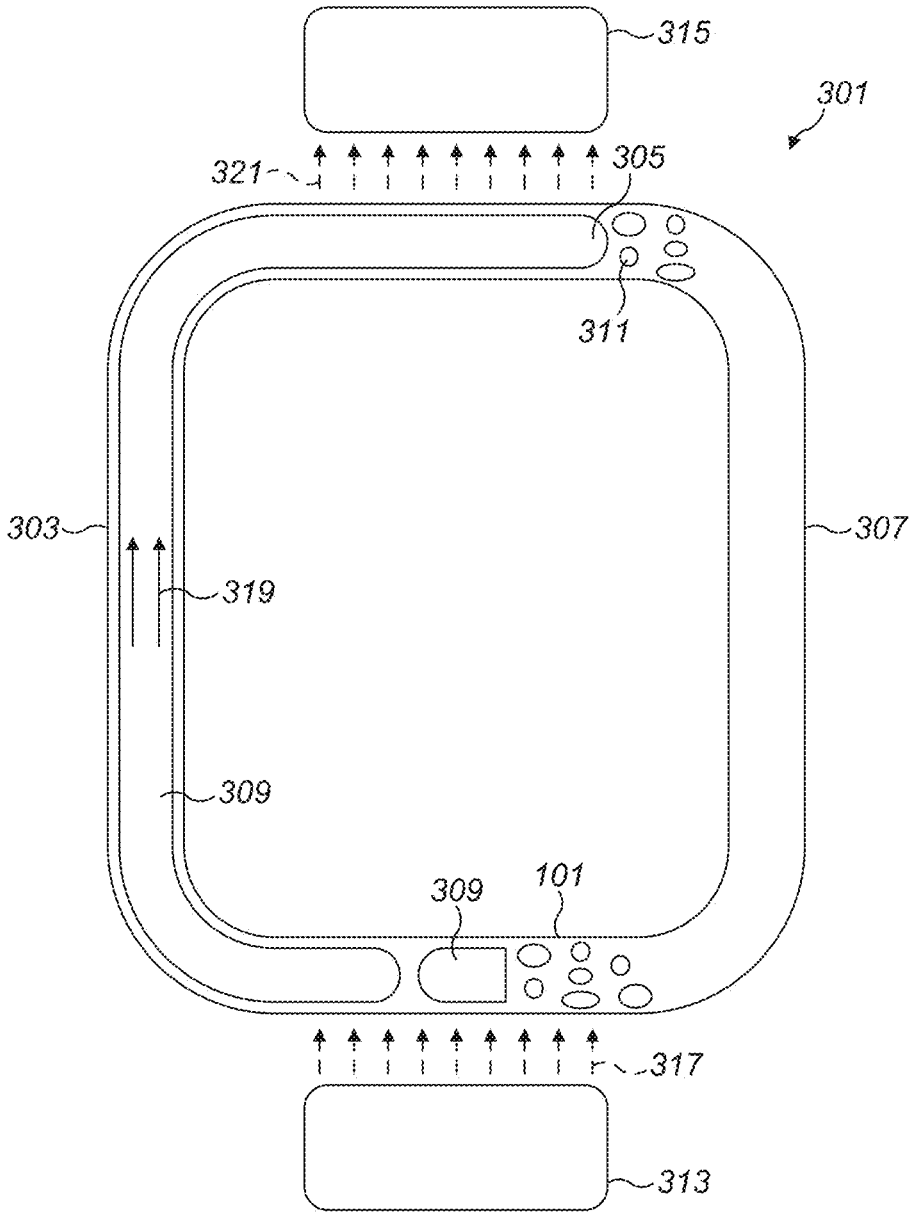


FIG. 3

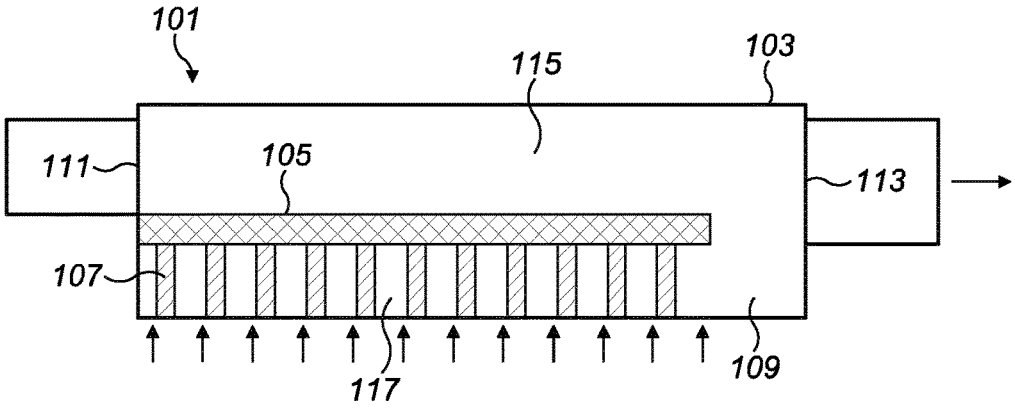


FIG. 4A

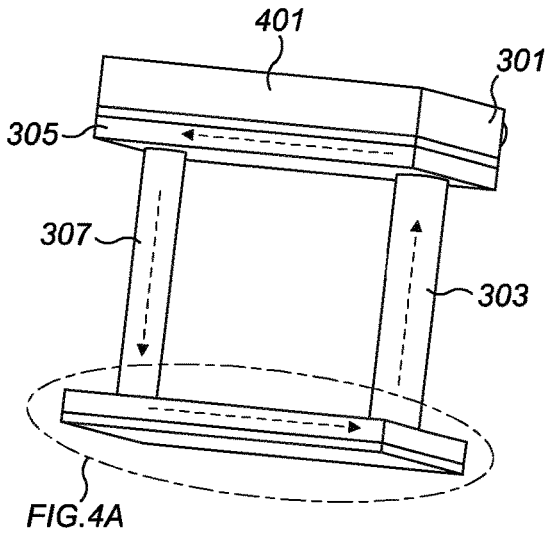


FIG. 4B

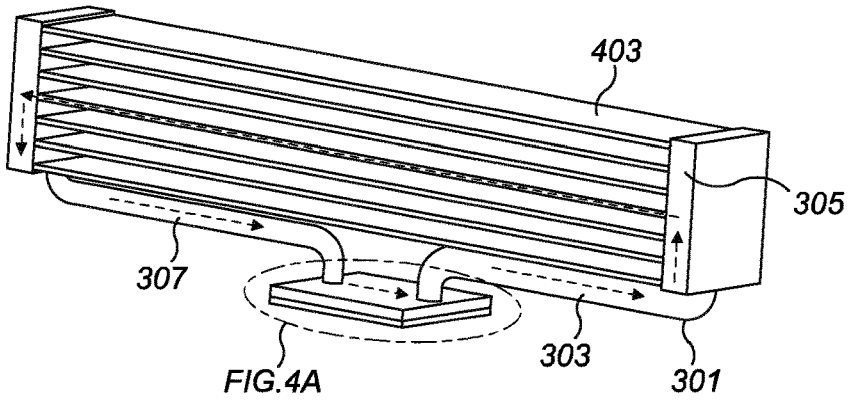


FIG. 4C

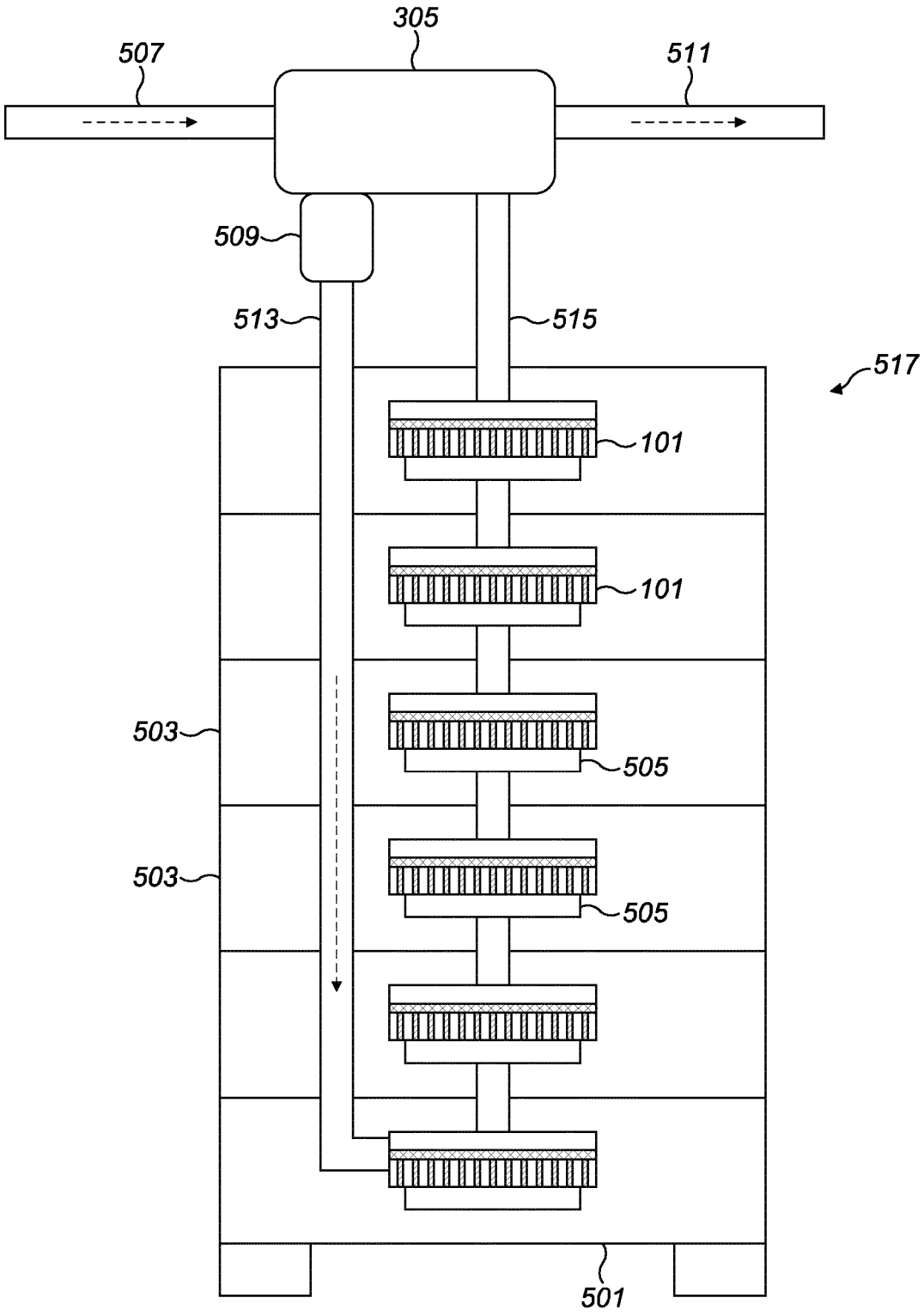


FIG. 5

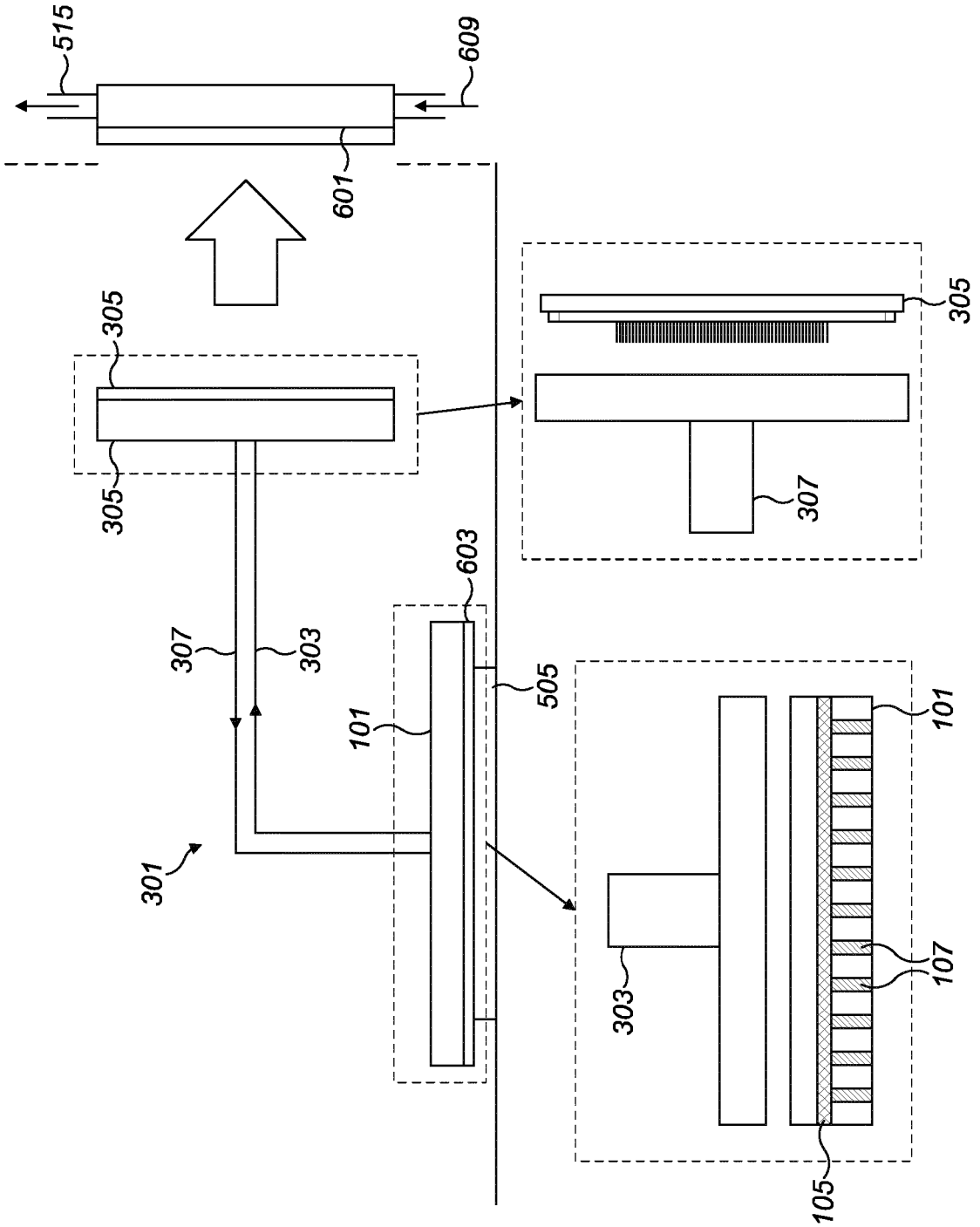

515
609
601
305
305
305
307
603
307
303
505
101
101
301
303
107
105

FIG. 6

THERMOSYPHON HEAT EXCHANGER APPARATUS WITH POROUS LAYER

TECHNOLOGICAL FIELD

Examples of the present disclosure relate to heat exchanger apparatus and cooling systems comprising heat exchanger apparatus. Some relate to heat exchanger apparatus and cooling systems for use in cooling electronic apparatus.

BACKGROUND

Cooling systems for cooling electronic apparatus such as servers and data centers are known. These systems are configured to enable heat to be transferred away from parts of the apparatus that generate unwanted heat.

BRIEF SUMMARY

According to various, but not necessarily all, examples of the disclosure there is provided a heat exchanger apparatus comprising: a channel for fluid flow extending between an inlet and an outlet; a porous layer dividing a first portion of the channel from a second portion of the channel, wherein the porous layer comprises a plurality of pores configured to enable fluid to be transferred from the first portion of the channel to the second portion of the channel; a plurality of evaporator structures located within the second portion of the channel wherein the evaporator structures comprise a wicking layer configured to enable evaporation of fluid from the surface of the evaporator structures; an ejector section configured to combine fluid from the first portion of the channel with fluid from the second portion of the channel and provide the combined fluid to the outlet.

The porous layer may be provided overlaying at least a subset of the evaporator structures.

The porous layer may be configured to allow fluid to flow through the pores from the first portion of the channel to the second portion of the channel via capillary action.

The porous layer may comprise a thermally insulating material.

The porous layer may be coupled to the wicking layer of the evaporator structures so that fluid can flow from the porous layer into the wicking structure.

The wicking layer may comprise a plurality of capillary structures and the capillary structures have a smaller pore size than the pores in the porous layer.

The evaporation of fluid from evaporation structures may provide fluid in the second portion of the channel with a higher vapour content than fluid in the first portion of the channel.

The apparatus may be configured so that the second portion of the channel can be provided in proximity to a heat source so as to enable heat to be transferred from the heat source to fluid in the second portion of the channel via the evaporator structures.

The evaporator structures may comprise a plurality of fins that, at least partially, define flow paths through the second portion of the channel.

According to various, but not necessarily all, examples of the disclosure there is provided a cooling system comprising one or more heat exchangers as claimed in any preceding claim.

The cooling system may comprise one or more thermosyphon loops.

The cooling system may comprise one or more thermosyphon loop comprising a plurality of heat exchanger apparatus connected in series to cool a plurality of heat sources.

The cooling system may comprise one or more liquid accumulators.

BRIEF DESCRIPTION

For a better understanding of various examples that are useful for a detailed description, reference will now be made by way of example only to the accompanying drawings in which:

FIGS. **1**A to **1**C illustrate a heat exchanger apparatus;

FIGS. **2**A and **2**B illustrate evaporator structures;

FIG. **3** illustrates a schematic of a cooling system;

FIGS. **4**A to **4**C illustrate example cooling systems;

FIG. **5** illustrates an example cooling system; and

FIG. **6** illustrates an example cooling system.

DETAILED DESCRIPTION

Examples of the disclosure relate to a heat exchanger apparatus **101** that can be used in cooling systems **301** to enable dissipation of high heat loads. The cooling systems **301** could be used to cool electronic apparatus such as servers, data centers or other types of apparatus that generate unwanted high heat loads during use.

FIGS. **1**A to **1**C schematically illustrate heat exchanger apparatus **101** according to examples of the disclosure.

The heat exchanger apparatus **101** is shown in FIG. **1**A. The heat exchanger apparatus **101** comprises a channel **103**, a porous layer **105**, a plurality of evaporator structures **107** and an ejector section **109**.

The channel **103** extends between an inlet **111** and an outlet **113**. The channel **103** is configured to enable fluid to flow between the inlet **111** and the outlet **113**. The size of the channel **103** can be of the order of several mm to several cm. For example, the channel **103** can have a length between 4 mm or 10 cm. The size of the channel **103** can be dependent on the application for which the heat exchanger apparatus **101** is being used. The size of the channel **103** will depend on factors such as the power dissipation that is required and the mass flow rate needed.

The diameter of the inlet **111** can be smaller than the diameter of the outlet **113** so as to balance the pressure drops within the channel **103** and ensure fluid can flow from the inlet **111** to the outlet **113**.

The fluid provided to the inlet **111** can comprise any suitable working fluid that is configured to undergo a phase change from liquid to gas as it passes through the heat exchanger apparatus **101**. The working fluid can be configured to undergo a partial phase change so that the amount of gas within the fluid increases between the inlet **111** and the outlet **113**.

The channel **103** is divided into a first portion **115** and second portion **117** by the porous layer **105**. The first portion **115** is coupled to the inlet **111** so that fluid can flow from the inlet **111** into the first portion **115** of the channel **103**. The fluid in the first portion **115** is therefore cooler, liquid rich fluid.

The first portion **115** is provided above the second portion **117**. The porous layer **105** is provided between the first portion **115** and the second portion **117**. The porous layer **105** is configured to enable fluid to be transported from the first portion **115** to the second portion **117** but restrict heat being transferred from the second portion **117** to the first portion **115**. The porous layer **105** can comprise a thermally

insulating material. In some examples the porous layer **105** can comprise other materials in addition to a thermally insulating material. The porous layer **105** can comprise a thermally insulating material so that heat is not conducted from the first portion **115** to the second portion **117** via the porous layer **105**.

The porous layer **105** comprises a plurality of pores that enables fluid from the first portion **115** of the channel **103** to be transported to the second portion **117** of the channel **103**. The porous layer **105** is configured to enable fluid to be transported to the second portion **117** of the channel **103** via capillary action. The size of the pores in the porous layer **105** may be determined by the pore size of the wicking structure **121** in the second portion of the channel **103**. The size of the pores in the porous layer **105** will be larger than or approximately equal to the pore size of the wicking structure **121** so that fluid can flow from a region that generates low capillary pressure to a region that generates a higher capillary pressure.

The plurality of evaporator structures **107** are provided in the second portion **117** of the channel **103**. The plurality of evaporator structures **117** extend out of a wall **123** of the channel **103**. The wall **123** can be coupled to a heat load. In the example shown in FIG. **1**A the evaporator structures **107** have a rectangular cross section. It is to be appreciated that other shapes of evaporator structures **107** could be used in other examples of the disclosure.

In the example heat exchanger apparatus **101** in FIG. **1**A the plurality of evaporator structures **107** comprises a plurality of fins **119** with a wicking structure **121** provided on the surface of the fins **119**. The wicking structure **121** and fins **119** are shown in more detail in FIG. **1**C.

The evaporator structures **107** at least partially, define a flow path through the second portion **117** of the channel **103**. The evaporator structures **107** are configured with a large surface area so as to enable heat to be dissipated through the evaporator structures **107** to fluid passing through the second portion **117** of the channel **103**.

The heat exchanger apparatus **101** comprises an ejector section **109** which is configured to combine fluid from the first portion **115** of the channel **103** with fluid from the second portion **117** of the channel **103** and provide the combined fluid to the outlet **113**. The porous layer **105** is not provided in the ejector section **109**. This enables the entrainment of vapor rich fluid from the second portion **117** of the channel **103** with liquid rich fluid from the first portion **115** of the channel **103**. The ejector section **109** can comprise a nozzle or any other suitable means for controlling pressure within the channel **103** and directing fluid flow towards the outlet **113**. The combined fluid can then be removed from the heat exchanger apparatus **101** via the outlet **113**.

In the example shown in FIG. **1**A there are no evaporator structures **107** provided in the ejector section **109**. It is to be appreciated that in other examples of the disclosure some evaporator structures **107** could be provided within the ejector section **109**.

FIG. **1**B illustrates a cross section of the heat exchanger apparatus **101** through the line A-A' shown in FIG. **1**A.

FIG. **1**B shows that the plurality of evaporator structures **107** extend across the width of the channel **103**. Spaces are provided between the evaporator structures **107** to enable fluid to flow through the second portion of the channel **103**. It is to be appreciated that any suitable geometry of the evaporator structures **107** can be used. In some examples the evaporator structures **107** can comprise ridges that extend parallel to, or substantially parallel to, the flow of the working fluid. The evaporator structures **107** are arranged so that there is an exit path for fluid in the channel **103**. In some examples the evaporator structures **107** can comprise an array of pillars or other similar structures.

The porous layer **105** is provided overlaying the evaporator structures **107** and also extends across the width of the channel **103**. The porous layer **105** is provided overlaying the evaporator structures **107** so that the porous layer **105** is provided between at least a subset of the evaporator structures **107** and the first portion **115** of the channel **103**. The porous layer **105** is provided above the evaporator structures **107** but below the first portion **115** of the channel **103**.

FIG. **1**C shows a section of the evaporator structures **107** and porous layer **105** in more detail. FIG. **1**C shows the arrangement of the wicking structures **121** on the surface of the evaporator structures **107**.

In this example the evaporator structures **107** comprise a plurality of fins **119** that extend out of the wall **123** of the channel **103**. The fins **119** have rectangular cross sections. Other shapes of fins **119** can be provided in other examples of the disclosure.

The fins **119** can comprise any suitable thermally conductive material. The fins **119** can comprise the same material as the walls **123** of the channel **103**.

The wicking structure **121** is provided on the surface of the fins **119** and is configured to enable fluid to be removed from the evaporator structures **107** by capillary action. In the example shown in FIG. **1**A the wicking structure **121** is also provided on the wall **123** of the channel **103**. The wicking structure **121** can comprise a mesh or other suitable structure which provides pores that enable the capillary action.

In some examples the wicking structure **121** can be formed using three dimensional printing, electrodeposition processes, sintering processes or any other suitable process. The process used to form the wicking structure **121** enables the size of the pores within the wicking structure **121** to be controlled. This size of the pores within the wicking structure **121** will affect the porosity of the wicking structure **121** and how efficiently the wicking structure **121** removes fluid from the evaporator structures **107**.

The fins **119** and the wicking structures **121** can be made of any suitable material. The fins and the wicking structures **121** can be made of the same material or different materials. The fins **119** and the wicking structures **121** can be made of thermally conductive material, such as crystalline ceramics or metals such as copper, to enable heat to be transferred from the evaporator structures **107** to fluid passing through the wicking structures **121**.

In the example shown in FIG. **1**C the porous layer **105** is a heterogenous porous layer **105** that comprises pores of different sizes. In FIG. **1**C the porous layer **105** comprises a first sub-layer **125** having a smaller pore size and a second sub-layer **127** having a larger pore size. The first sub-layer **125** is provided underneath the second sub-layer **127**. The second sub-layer **127** provides, at least part of the boundary of the first portion **115** of the channel **103** and enables fluid to flow from the first portion **115** of the channel **103** into the porous layer **105**. The first sub-layer **125** provides, at least part of the boundary of the second portion **117** of the channel **103** and enables fluid to flow from the porous layer **105** into the second portion **117** of the channel **103** but restricts fluid from flowing in the reverse direction, from the second portion **117** of the channel **103** back into the first portion **115** of the channel **103**.

The porous layer **105** is provided overlaying the evaporator structures **107** so that the porous layer **105** is fluidically coupled to the wicking structure **121**. This enables fluid from the first portion **115** of the channel **103** to flow through the

porous structure **105** to the wicking structure **121** as indicated by the arrows **131**. This enables the cooler fluid from the first portion **115** of the channel **103** to flow into the wicking structure **121** where the heat from the fins **119** causes fluid to evaporate. As fluid evaporates from the wicking structure **121** more fluid is drawn up from the porous layer **105** and through the wicking structure **121** via capillary action.

The wicking structure **121** can be configured so that the size of the pores within the wicking structure **121** is smaller than the size of the pores within the porous layer **105**. This provides a higher capillary pressure within the wicking structure **121** which prevents fluid from being transferred back into the porous layer **105**.

The evaporation of fluid from the wicking structures **121** creates a vapour rich fluid in the second portion of the channel **103**.

When the heat exchanger apparatus **101** is in use heat is transferred from the heat source into the heat exchanger apparatus **101** through the walls **123** of the channel **103** as indicated by the arrows **129**. Heat transfers through the thermally conductive material of the evaporator structure **107** to the wicking structure **121** on the surface of the fins **119**. This heat causes the evaporation of fluid from the wicking structure **121** into fluid flow within the second portion **117** of the channel **103**. This creates a vapour rich flow in the second portion **117** of the channel **103** that is hotter than the liquid rich flow in the first portion **115** of the channel **103**.

FIG. **2**A shows an example wicking structure **121** and FIG. **2**B shows an evaporator structure **107** comprising the example wicking structure **121**.

In the example of FIGS. **2**A and **2**B the wicking structure **121** comprises a heterogenous structure having two different pore sizes within the wicking structure **121**. The wicking structure **121** comprises a first sub-layer **201** having a first pore size and a second sub-layer **203** having a second pore size where the second pore size is smaller than the first pore size. In some examples the second pore size can be smaller than the first pore size by a factor of about four. In some examples the pores in the first sub-layer **201** could have a diameter of 40 μm and the pores in the second sub-layer **203** could have a diameter of 10 μm. It is to be appreciated that different pore sizes and ratios of pore sizes could be used in other examples of the disclosure.

The second sub-layer **203** has the smaller pore size and forms the outer surface of the wicking structure **121**. This ensures that evaporated fluid flows from the wicking structure **121** into the second portion **117** of the channel **103** of the heat exchanger apparatus **101**.

In this example the first sub-layer **201** has a thickness that is several times greater than the thickness of the second sub-layer **203**. In the example shown in FIG. **2**A the first sub-layer **201** has a thickness of t_1=0.2 mm and the second sub-layer has a thickness of t_2=0.05 mm. It is to be appreciated that other thicknesses and ratios of thicknesses can be used in other examples of the disclosure.

FIG. **2**B shows the heterogenous wicking structure **121** of FIG. **2**A coupled to the fins **119** of the evaporator structures **107**. In the example of FIG. **2**B the wicking structure **121** is also provided on the wall **123** of the channel **103**.

The porous layer **105** is provided overlaying the evaporator structures **107** so that fluid can flow from the porous layer **105** into the wicking structure **121**. In the example shown in FIG. **2**B the porous layer **105** has pores that have a larger size than the pores within the wicking structure **121**. This ensures that fluid flows from the first portion **115** of the channel **103** though the porous layer **105** and into the wicking structure **121** and restricts fluid from flowing in the other direction.

In the example of FIG. **2**A the porous layer **105** is a homogenous porous layer **105** and comprises a single section with a single pore size. It is to be appreciated that heterogenous porous layers **105** having different sections with different pore sizes could be used in some examples of the disclosure.

The fins **119** have a height of H_f. H_f could be several mm. In some examples H_f could be 2.5 mm. Other heights for the fins **119** could be used in other examples of the disclosure.

In the example shown in FIG. **2**B the width between the wicking structures **121** of adjacent fins **119** is W_c=0.6 mm and the height of the gap between the wicking structure **121** on the wall of the channel **103** and the porous layer is 2.25 mm. It is to be appreciated that other dimensions for the fins **119** and spacing between the fins **119** could be used in other examples of the disclosure.

It is to be appreciated that a plurality of evaporator structures **107** as shown in FIG. **2**B would be distributed throughout the channel **103**. The evaporator structures **107** can be evenly distributed throughout the channel **103** so that the evaporator structures **107** are equally spaced from each other.

The thermal resistance R_{HEx} of a heat exchanger apparatus **101** comprising a plurality of evaporator structures **107** as shown in FIG. **2**B is given by

$$R_{HEx} = \frac{h_{wick}^{-1} + (t_{wall}/k_{wall})}{L_c W_c}$$

Where h_{wick} is the heat transfer coefficient of the wicking structure **121**, t_{wall} is the thickness of the wall **123** of the channel **103**, k_{wall} is the thermal conductivity of the wall **123**, and L_c and W_c are the length and width of the channel **103**.

The wicking structure **121** can handle heat fluxes in excess of 60 W/cm^2 so that for a channel **103** of width 40 mm and length 40 mm comprising evaporator structures **107** as shown in FIG. **2**B the thermal resistance of the heat exchanger apparatus **101** can be of the order R_{HEx}=0.01 K/W. The values of the thermal resistance will depend on factors such as the materials used for the walls of the channel **103** and the evaporator structures **107** and the dimensions of the evaporator structures **107** and the wicking structure **121** and the working fluid.

FIG. **3** illustrates a schematic of a cooling system **301**. FIG. **3** shows how the heat exchanger apparatus **101** can be integrated into a cooling system **301**. In the example of FIG. **3** the cooling system **301** comprises a thermosyphon loop or a passive two-phase gravity driven system. The cooling system **301** comprises a heat exchanger apparatus **101**, a riser **303**, a condenser **305**, and a downcomer **307**.

The heat exchanger apparatus **101** can be as shown in FIGS. **1**A to **2**B and corresponding reference numerals are used for corresponding features. The cooling system **301** is configured so that the heat exchanger apparatus **101** is thermally coupled via a thermal interface material to a heat source **313** so that heat from the heat source **313** is transferred to the heat exchanger apparatus **101** as indicated by the arrows **317**. The heat source **313** could be an electronic apparatus such as a server that generates unwanted heat during use.

The heat causes evaporation of fluid within the heat exchanger apparatus **101** and converts fluid from the liquid phase **311** into two phase fluid **309**. The two-phase fluid **309** comprises a mixture of liquid and vapour.

The outlet **113** of the heat exchanger apparatus **101** is coupled to the riser **303** so that fluid from the ejector portion **109** of the heat exchanger apparatus **101** is provided to the riser **303**. Fluid ejected from the heat exchanger apparatus **101** comprises the two-phase fluid **309** as it comprises the mixture of liquid and vapour from the heat exchanger apparatus **101**. The vapour comprises evaporated gas from the evaporator structures **107**.

The two phase fluid **309** rises up the riser **303** to the condenser **305** as indicated by the arrows **319**. The condenser **305** is coupled to a coolant **315** so that heat is transferred from fluid in the condenser **305** to the coolant **315** as indicated by the arrows **321**. This cools fluid in the vapour phase **309** so that the vapour is condensed back to the liquid phase **311**. The condenser **305** could be a water-cooled condenser, an air cooled condenser or any other suitable type of condenser **305**.

Fluid in the liquid phase **311** is then provided to the downcomer **307** where it is returned to the inlet **111** of the heat exchanger apparatus **101**. The height of the downcomer **307** can be selected so that the static head of fluid within the downcomer **307** causes fluid to flow through the heat exchanger apparatus **101**.

In some examples the cooling system **301** can also comprise a reservoir. The reservoir can be provided in the downcomer **307**. The reservoir can be configured to store liquid and prevent fluid in the liquid phase **311** from entering the condenser **305** to avoid flooding of the condenser **305** that would result in a decrease in thermal performance.

FIGS. **4**A to **4**C illustrate how the heat exchanger apparatus **101** can be integrated into example cooling systems **301**. FIG. **4**A shows a heat exchanger apparatus **101** as shown in FIG. **1**A and described above. Corresponding reference numerals are used for corresponding features. The heat exchanger apparatus **101** can be provided in the cooling systems **301** shown in FIGS. **4**B and **4**C.

FIG. **4**B shows an example cooling system **301** comprising the heat exchanger apparatus **101**. In the cooling system **301** of FIG. **4**B the condenser **305** comprises a liquid-cooled condenser **401**. The liquid-cooled condenser **401** is coupled to the heat exchanger apparatus **101** by a downcomer **307** and a riser **303** as shown in FIG. **3**.

FIG. **4**C shows another example cooling system **301** comprising the heat exchanger apparatus **101**. In the cooling system **301** of FIG. **4**C the condenser **305** comprises an air-cooled condenser **403**. The air-cooled condenser **403** is coupled to the heat exchanger apparatus **101** by a downcomer **307** and a riser **303** as shown in FIG. **3**.

FIG. **5** illustrates another example cooling system **517** comprising a thermosyphon loop **301** as shown in FIG. **3** with a plurality of heat exchanger apparatus **101** connected in series to cool a plurality of heat sources. The cooling system **517** of FIG. **5** could be used to cool electronic apparatus such as servers, datacentres or other similar types of apparatus.

The cooling system **517** of FIG. **5** is configured to cool a server rack **501** comprising a plurality of servers **503**. Each of the servers **503** comprises a central processing unit (CPU) **505** that generates unwanted heat during use. In the example shown in FIG. **5** the server rack **501** comprises six servers **503**. It is to be appreciated that this is an illustrative example and that other numbers of servers **503** could be provided in other examples of the disclosure.

The cooling system **517** comprises a plurality of heat exchanger apparatus **101**. Each of the heat exchanger apparatus **101** can be provided in a thermosyphon loop **301** as shown in FIG. **3**. In the example of FIG. **5** the cooling system **517** comprises at least one heat exchanger apparatus **101** for each of the servers **503** within the server rack **501**. In the example of FIG. **5** the cooling system **301** comprises six heat exchanger apparatus **101** so that there is one heat exchanger apparatus **101** for each of the servers **503**.

The heat exchanger apparatus **101** are thermally coupled to the CPUs **505** of the servers **503** via a thermal interface material so that heat from the CPU is transferred to the heat exchanger apparatus **101**.

When the cooling system **301** is in use cold water **507**, or other suitable fluid, is provided to the cooling system **301** to condense the two-phase fluid in the heat exchanger apparatus **101** back to liquid in the inlet channel **513**. In the example of FIG. **5** a reservoir **509** is provided at the outlet of the condenser **305**. The reservoir **509** can be configured to store liquid and prevent fluid in the liquid phase in the inlet channel **513** from entering the condenser **305** to avoid flooding, which would result in a decrease in thermal performance.

The plurality of heat exchanger apparatus **101** are configured to enable the working fluid of the thermosyphon loop **301** to be heated using heat from the CPUs **505** and any other suitable heat sources. This causes evaporation of the working fluid from liquid phase in the downcomer **513** to a mixture of liquid and vapour in the outlet channel **515**. The two-phase fluid is condensed back to liquid by rejecting the heat to the water-side of the condenser **305**.

The outlet channel **515** is coupled to the condenser **305** so that the two-phase fluid is condensed back to the liquid phase by the condenser **305**. The condensed outlet water **511** will have a higher temperature than the inlet water **507** due to the heat exchanged with the thermosyphon working fluid. The condenser **305** can be an air-cooled condenser, a water-cooled condenser or any other suitable type of condenser.

FIG. **6** shows a thermosyphon loop **301** that can be provided within the cooling system **517** shown in FIG. **5**. The thermosyphon loop **301** comprises a heat exchanger apparatus **101**, a riser, **303**, a condenser **305** and a downcomer **307** which can be as shown in FIG. **3**.

The heat exchanger apparatus **101** comprises a porous layer **105** and a plurality of evaporator structures **107** which can be as described above. The heat exchanger apparatus **101** is coupled to a CPU **505** of a server **503**. The heat exchanger apparatus **101** is coupled to the CPU **505** via a thermal interface material **603**. The thermal interface material **603** comprises a material with high thermal conductivity so as to enable efficient heat transfer from the CPU **505** to the heat exchanger apparatus **101**.

The condenser **305** of the thermosyphon loop **301** is coupled to the outlet channel **515** of the cooling system as shown in FIG. **5**. The condenser **305** is coupled to the outlet channel via thermal interface material, **601**. The thermal interface material, **601** comprises a reworkable material with high thermal conductivity so as to enable efficient heat transfer from the condenser **305** to fluid in the outlet channel **515**. In this example the thermal interface material **601** is only provided on side of the condenser **305** that is coupled to the outlet channel. This enables the heat exchanger apparatus **101** to be removed from the cooling system **301** while the cooling system **301** is in use, so as to provide a hot-swappable system.

When the thermosyphon loop **301** is in use heat from the CPU **505** causes phase change of fluid within the heat

exchanger apparatus **101** of the thermosyphon loop **301**. Fluid in the two phase mixture is then provided to the condenser **305** where it is cooled by the water, or other fluid, passing through the outlet channel **515** as indicated by the arrows **609**.

It is to be appreciated that the server CPU **505** can be one of a plurality of server CPUs **505** as shown in FIG. **5**. Each of the server CPUs **505** can be thermally coupled to a different thermosyphon loop **301**. Fluid in the outlet channel **515** can be used to sequentially cool fluid in the condensers **305** of the plurality of thermosyphon loops **301**.

In the example of FIG. **6** the thermosyphon loop **301** and the thermal interface materials **603**, **601** provide a closed loop. This enables each of the thermosyphon loops **301** within the cooling system **517** to be independent of the other thermosyphon loops **301** within the cooling system **517**. This can enable the thermosyphon loops **301** to be removed and exchanged while the server rack and cooling system **517** are in use, thereby providing a hot-swappable modular cooling system **517**. This also reduces the risk of damage that could be caused by failure of any of the independent thermosyphon loops **301**.

In some examples the water or other fluid in the outlet of the condenser that is heated by plurality of thermosyphon loops **301** can be extracted from the cooling system **517** and used to provide heat to a heating network or for improving energy efficiency of a power source.

In this description the term coupled means operationally coupled and any number or combination of intervening elements can be provided between coupled components including no intervening elements.

The term "comprise" is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one Y or may comprise more than one Y. If it is intended to use 'comprise' with an exclusive meaning then it will be made clear in the context by referring to "comprising only one . . . " or by using "consisting".

In this description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'can' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example', 'can' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example as part of a working combination but does not necessarily have to be used in that other example.

Although examples have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the claims. For example. FIG. **3** shows the heat exchanger apparatus **101** in a passive cooling system **301**. It is to be appreciated that the heat exchanger apparatus **101** can be also implemented in a cooling system comprising one or more pumps. In such examples one or more pumps and condenser can be located in a dedicated space at the bottom of a server rack or other electronic device that requires cooling.

Features described in the preceding description may be used in combinations other than the combinations explicitly described above.

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain examples, those features may also be present in other examples whether described or not.

The term 'a' or 'the' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising a/the Y indicates that X may comprise only one Y or may comprise more than one Y unless the context clearly indicates the contrary. If it is intended to use 'a' or 'the' with an exclusive meaning then it will be made clear in the context. In some circumstances the use of 'at least one' or 'one or more' may be used to emphasis an inclusive meaning but the absence of these terms should not be taken to infer any exclusive meaning.

The presence of a feature (or combination of features) in a claim is a reference to that feature or (combination of features) itself and also to features that achieve substantially the same technical effect (equivalent features). The equivalent features include, for example, features that are variants and achieve substantially the same result in substantially the same way. The equivalent features include, for example, features that perform substantially the same function, in substantially the same way to achieve substantially the same result.

In this description, reference has been made to various examples using adjectives or adjectival phrases to describe characteristics of the examples. Such a description of a characteristic in relation to an example indicates that the characteristic is present in some examples exactly as described and is present in other examples substantially as described.

Whilst endeavoring in the foregoing specification to draw attention to those features believed to be of importance it should be understood that the Applicant may seek protection via the claims in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not emphasis has been placed thereon.

We claim:

1. A heat exchanger apparatus comprising:

a channel for fluid flow extending between an inlet and an outlet;

a porous layer dividing a first portion of the channel from a second portion of the channel, wherein the porous layer comprises a plurality of capillary pores configured to enable fluid to be transferred from the first portion of the channel to the second portion of the channel;

a plurality of evaporator structures located within the second portion of the channel wherein the evaporator structures comprise a wicking layer configured to enable evaporation of fluid from the surface of the evaporator structures; and

an ejector section configured to combine fluid from the first portion of the channel with fluid from the second portion of the channel and provide the combined fluid to the outlet.

2. The heat exchanger of claim **1**, wherein the porous layer is provided overlaying at least a subset of the evaporator structures.

3. The heat exchanger of claim 1, wherein the porous layer is configured to allow fluid to flow through the capillary pores from the first portion of the channel to the second portion of the channel via capillary action.

4. The heat exchanger of claim 1, wherein the porous layer comprises a thermally insulating material.

5. The heat exchanger of claim 1, wherein the porous layer is coupled to the wicking layer of the evaporator structures so that fluid can flow from the porous layer into the wicking structure.

6. The heat exchanger of claim 1, wherein the wicking layer comprises a plurality of capillary structures and the capillary structures have a smaller pore size than the capillary pores in the porous layer.

7. The heat exchanger of claim 1, wherein the evaporation of fluid from evaporation structures provides fluid in the second portion of the channel with a higher vapour content than fluid in the first portion of the channel.

8. The heat exchanger of claim 1, wherein the apparatus is configured so that the second portion of the channel can be provided in proximity to a heat source so as to enable heat to be transferred from the heat source to fluid in the second portion of the channel via the evaporator structures.

9. The heat exchanger of claim 1, wherein the evaporator structures comprise a plurality of fins that, at least partially, define flow paths through the second portion of the channel.

10. A cooling system comprising one or more heat exchangers, the at least one or more heat exchangers comprising:

a channel for fluid flow extending between an inlet and an outlet;

a porous layer dividing a first portion of the channel from a second portion of the channel, wherein the porous layer comprises a plurality of capillary pores configured to enable fluid to be transferred from the first portion of the channel to the second portion of the channel;

a plurality of evaporator structures located within the second portion of the channel wherein the evaporator structures comprise a wicking layer configured to enable evaporation of fluid from the surface of the evaporator structures; and

an ejector section configured to combine fluid from the first portion of the channel with fluid from the second portion of the channel and provide the combined fluid to the outlet.

11. The cooling system of claim 10, wherein the cooling system comprises one or more thermosyphon loops.

12. The cooling system of claim 11, wherein the one or more thermosyphon loops comprises a plurality of heat exchanger apparatus connected in series to cool a plurality of heat sources.

13. The cooling system of claim 12, comprising one or more liquid accumulators.

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