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(54) **HEAT EXCHANGERS AND METHODS OF FORMING HEAT EXCHANGERS**

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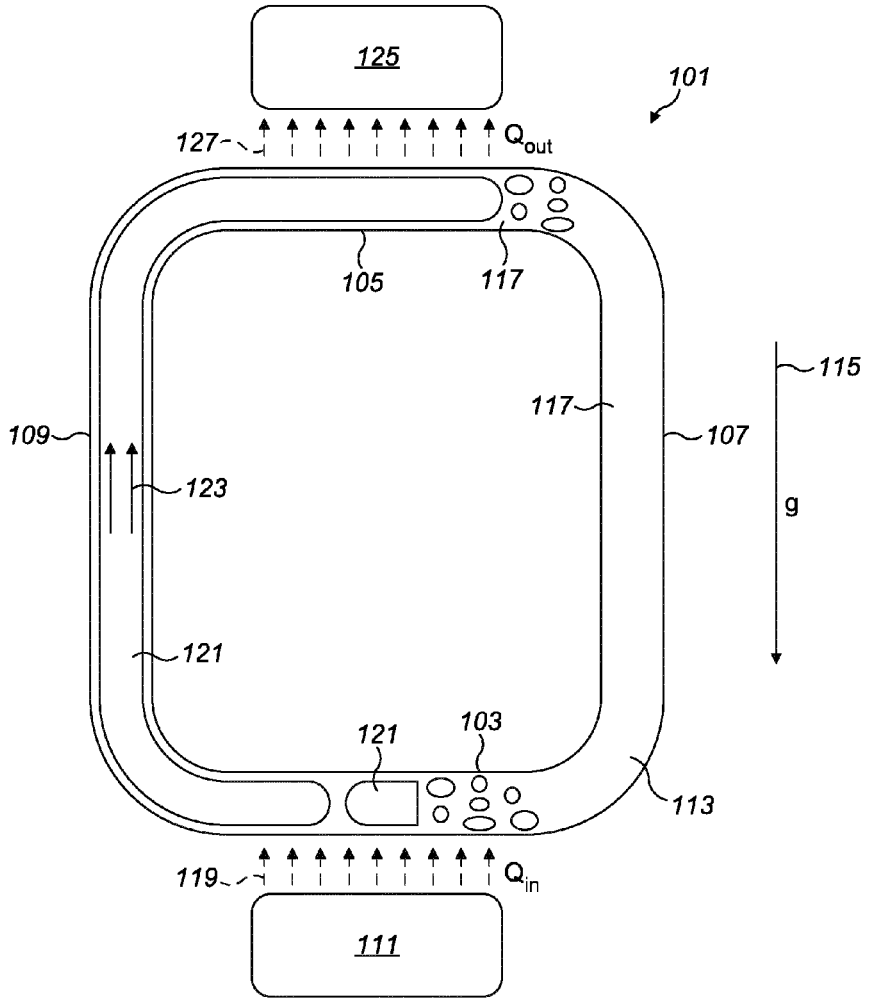
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(57) **ABSTRACT**

Examples of the disclosure relate to heat exchangers. The heat exchangers could be evaporators or condensers. The heat exchangers can comprise a plurality of structures extending from a base plate where adjacent structures are separated by at least a first distance. The heat exchangers can also comprise at least one cover plate positioned over ends of the plurality of structures so that the at least one cover plate is spaced from the ends of the plurality of structures by a second distance where the second distance is smaller than the first distance. The at least one cover plate is brazed to the plurality of structures by brazing material provided between the ends of the plurality of structures and the at least one cover plate. The brazing material is provided in a discontinuous configuration so that gaps are provided between portions of brazing material so that a brazing join is formed from brazing materials that has flowed into spacing between the at least one cover plate and the ends of the plurality of structures.



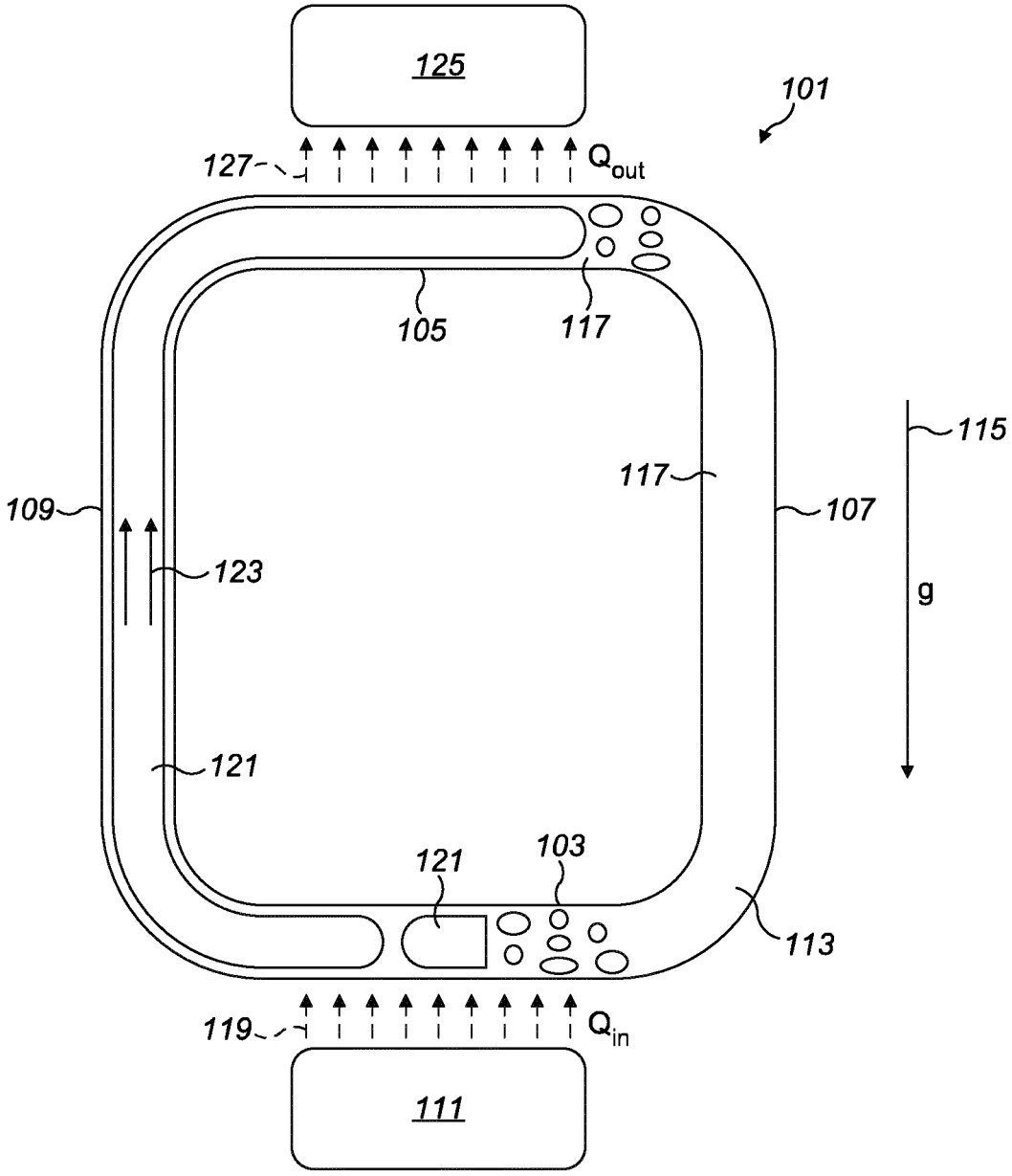

125
101
127
Q_{out}
105
117
115
117
109
107
123
g
121
121
103
113
119
Q_{in}
111

FIG. 1

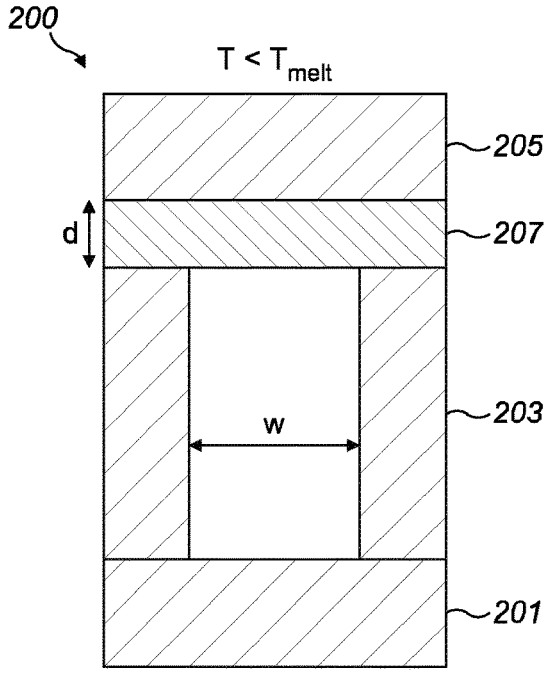


FIG. 2A

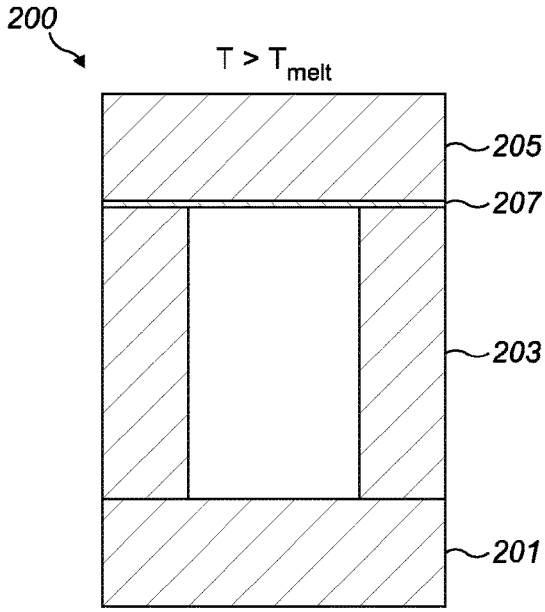


FIG. 2B

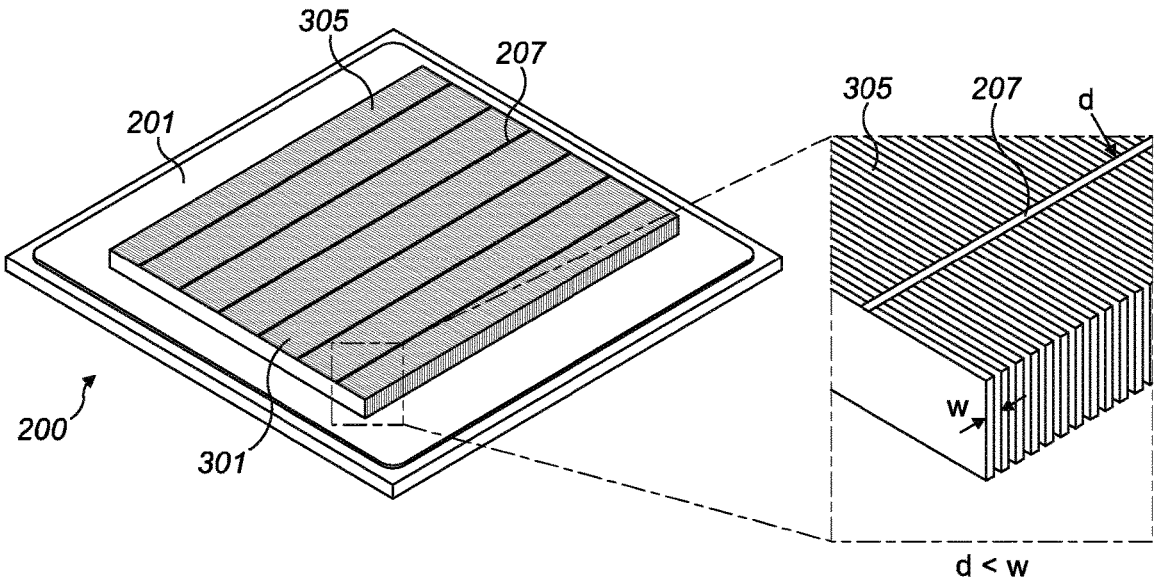


FIG. 3A

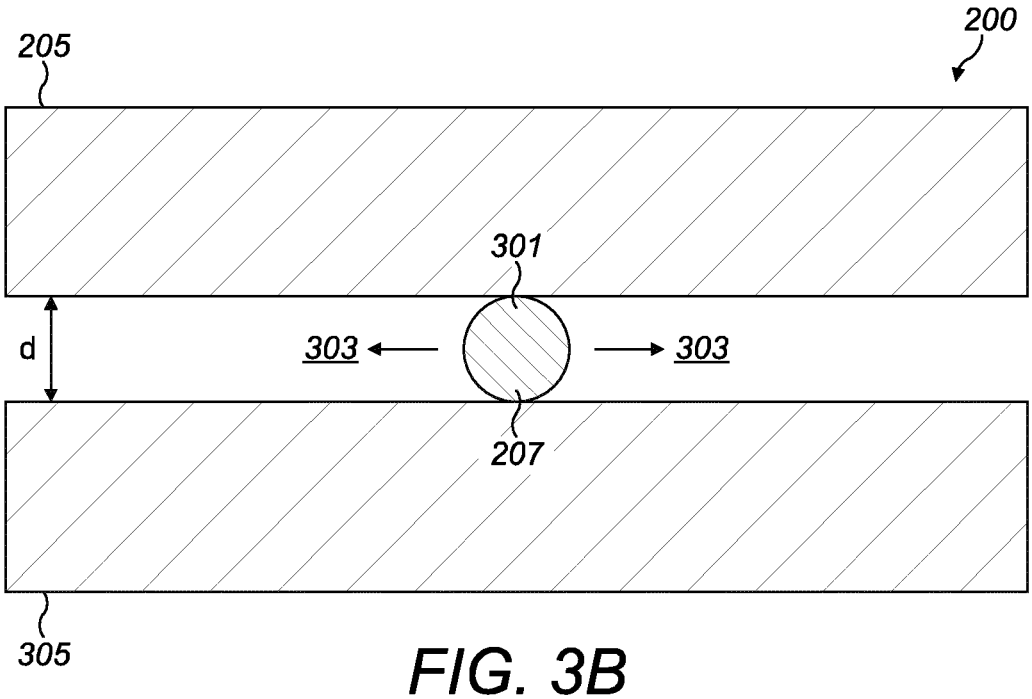

205
200
301
d
303
303
207
305

FIG. 3B

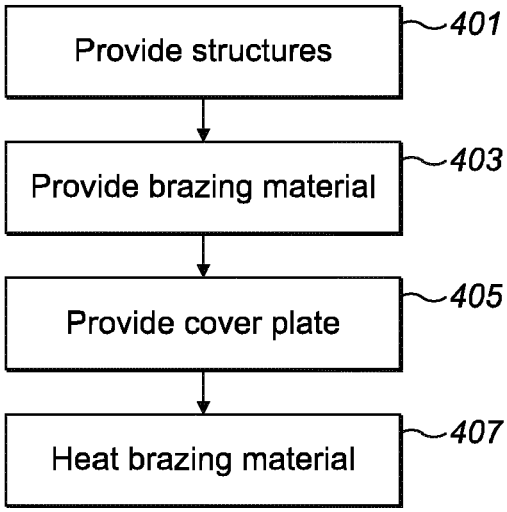

Provide structures
401
Provide brazing material
403
Provide cover plate
405
Heat brazing material
407

FIG. 4

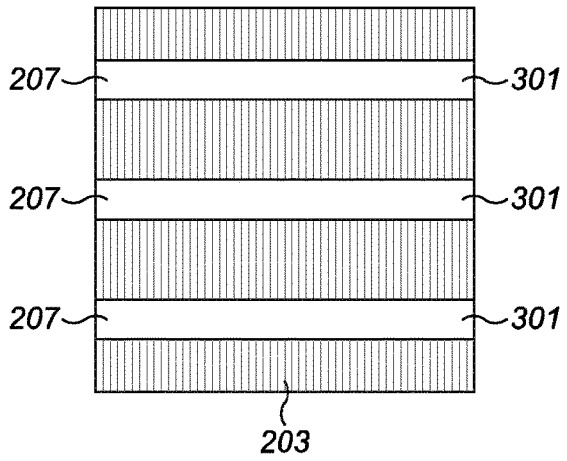


FIG. 5A

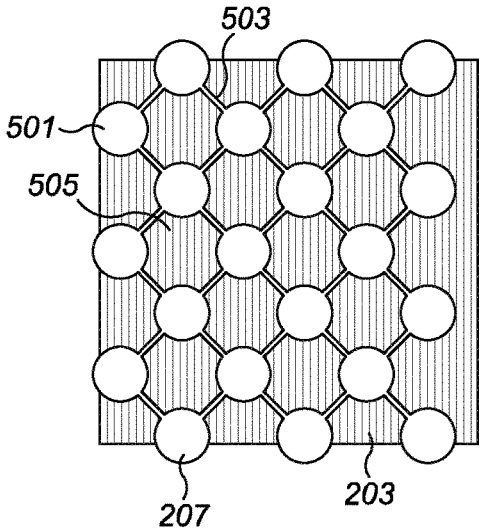


FIG. 5B

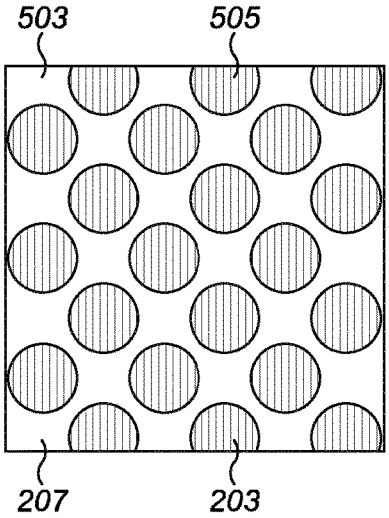


FIG. 5C

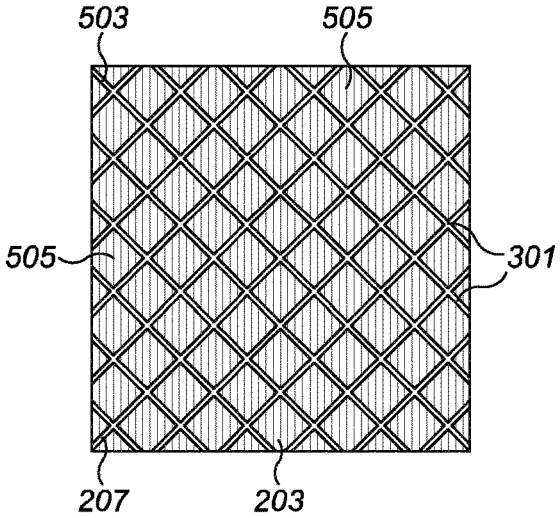


FIG. 5D

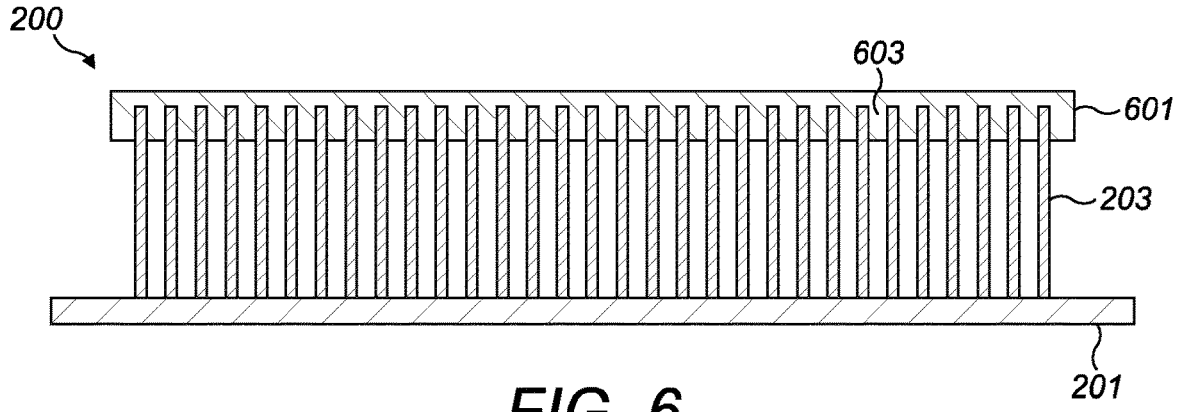


FIG. 6

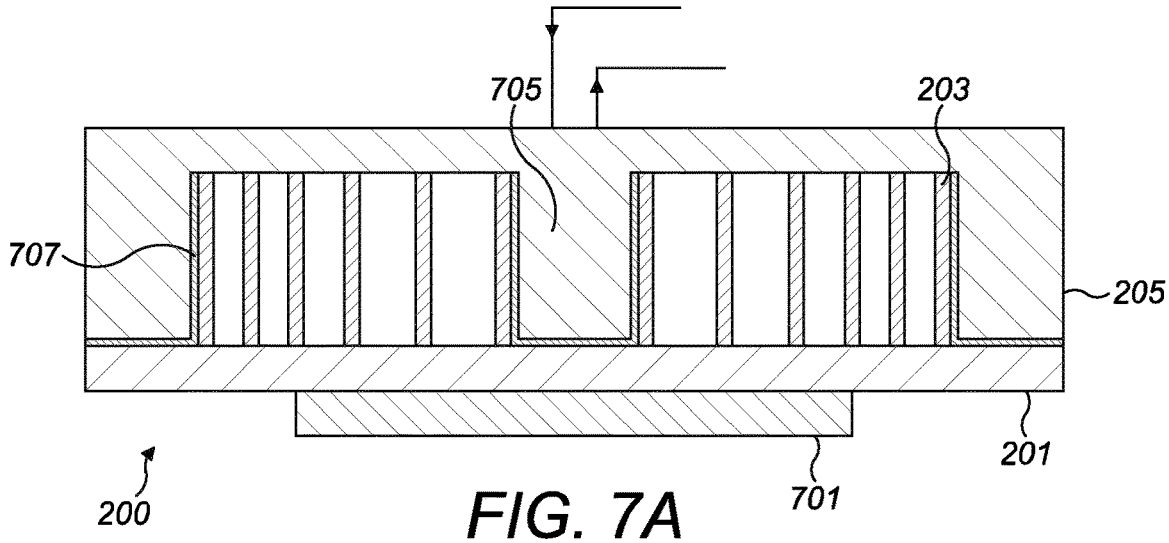


FIG. 7A

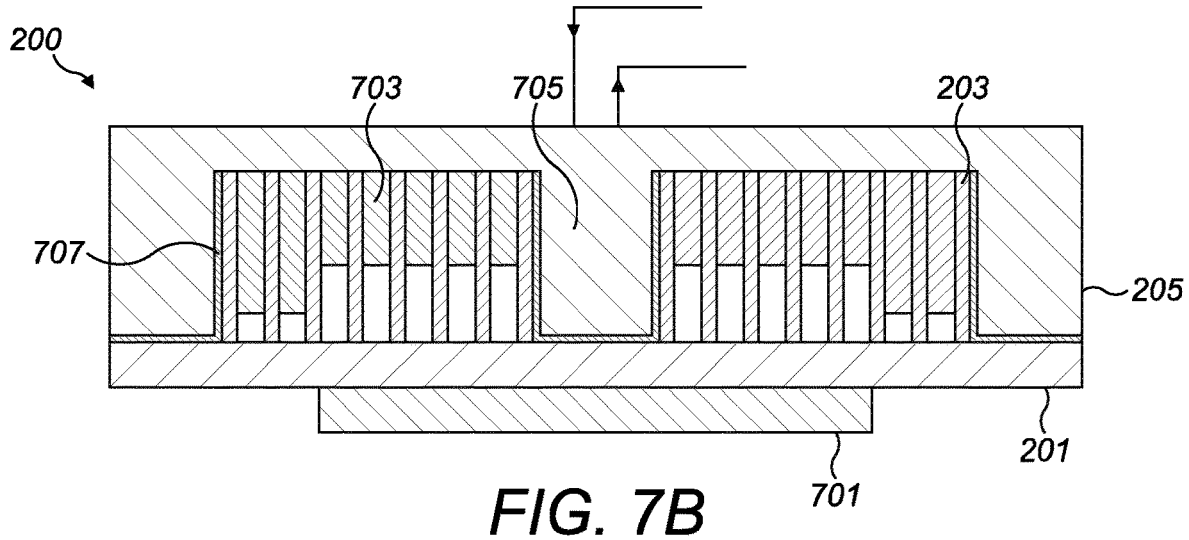


FIG. 7B

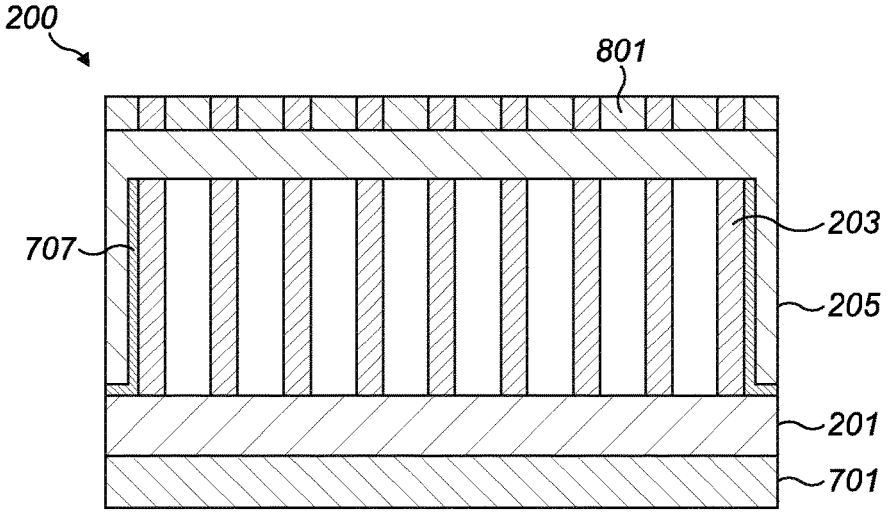


FIG. 8

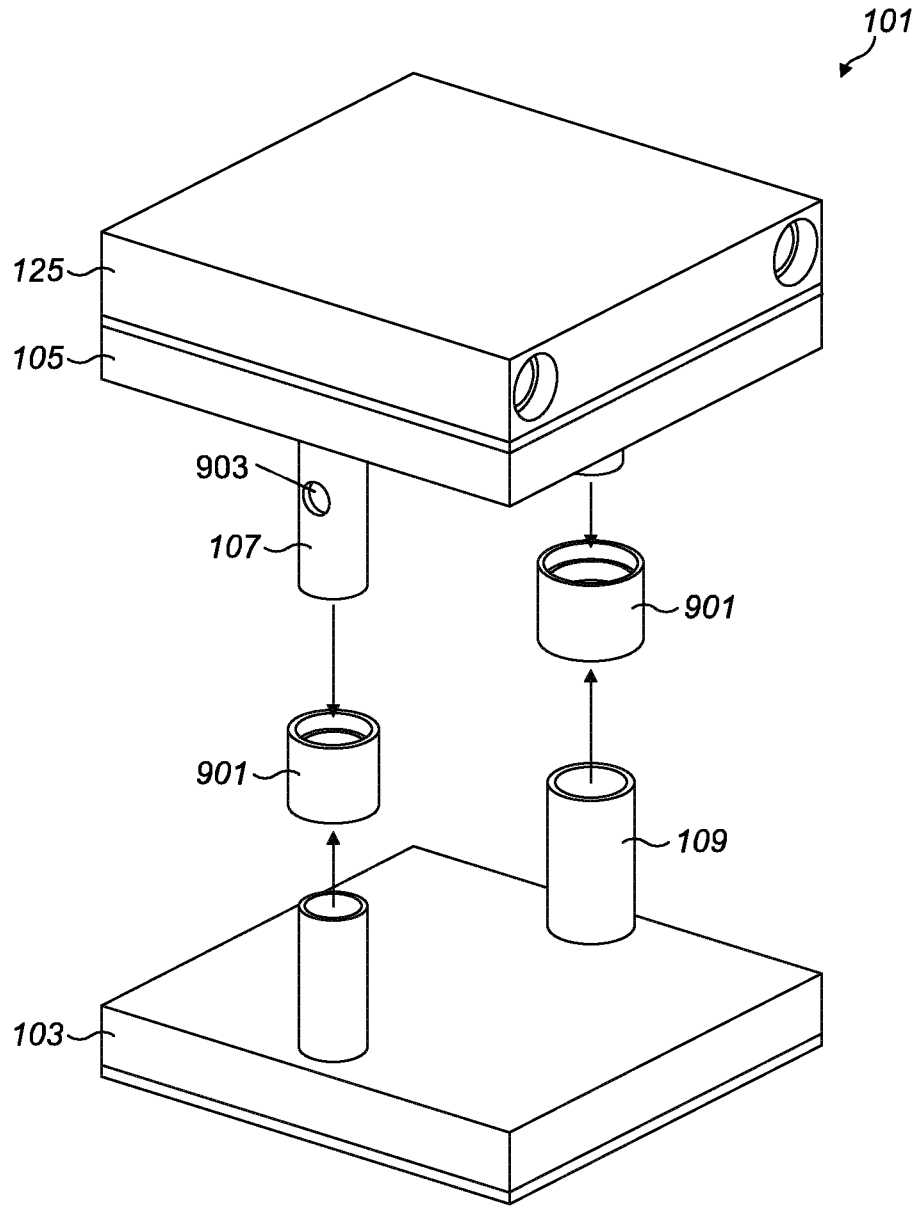


FIG. 9

HEAT EXCHANGERS AND METHODS OF FORMING HEAT EXCHANGERS

TECHNOLOGICAL FIELD

[0001] Examples of the disclosure relate to heat exchangers and methods of forming heat exchangers. Some relate to heat exchangers and methods of forming heat exchangers for use in two-phase cooling systems.

BACKGROUND

[0002] Heat exchangers such as evaporators and condensers are configured to enable heat transfer within a cooling system. The overall efficiency of the cooling system can be dependent upon the efficiency of the heat transfer occurring in the heat exchangers.

BRIEF SUMMARY

[0003] According to various, but not necessarily all, examples of the disclosure there may be provided a heat exchanger comprising: a plurality of structures extending from a base plate where adjacent structures are separated by at least a first distance; and at least one cover plate positioned over ends of the plurality of structures so that the at least one cover plate is spaced from the ends of the plurality of structures by a second distance where the second distance is smaller than the first distance; wherein the at least one cover plate is brazed to the plurality of structures by brazing material provided between the ends of the plurality of structures and the at least one cover plate; and wherein the brazing material is provided in a discontinuous configuration so that gaps are provided between portions of brazing material so that a brazing join is formed from brazing materials that has flowed into spacing between the at least one cover plate and the ends of the plurality of structures.

[0004] The brazing material may be provided in a thickness that is smaller than the first distance.

[0005] The first distance and the second distance may be selected so that Laplace pressure causes the brazing material to flow into gaps between the ends of the plurality of structures and the at least one cover plate.

[0006] The plurality of structures may extend substantially perpendicularly out of the base plate.

[0007] The plurality of structures may be evenly spaced across the base plate.

[0008] The plurality of structures may be spaced closer together at edges of the base plate than in a centre of the base plate.

[0009] The base plate may have a surface area that is larger than a heat source to which the heat exchanger is thermally coupled.

[0010] The heat exchanger may comprise a stiffener structure comprising a plurality projecting portions configured to extend between the plurality of structures so as to restrict bending of the plurality of structures.

[0011] At least some of the plurality of structures may extend through the at least one cover plate and further coupling means may be provided on the ends of the plurality of structures that extend through the at least one cover plate.

[0012] The plurality of structures may comprise fins.

[0013] The heat exchanger may comprise an evaporator or a condenser.

[0014] According to various, but not necessarily all, examples of the disclosure there may be provided a method comprising: providing a plurality of structures extending from a base plate where the plurality of structures are separated by at least a first distance; providing brazing material overlaying, at least some of the plurality of structures wherein the brazing material is provided in a discontinuous configuration so that gaps are provided between portions of brazing material; providing at least one cover plate over ends of the plurality of structures and the brazing material so that the at least one cover plate is spaced from the ends of the plurality of structures by a second distance where the second distance is smaller than the first distance; and heating the brazing material so that the brazing material flows into spacing between the at least one cover plate and the ends of the plurality of structures.

[0015] The brazing material may be provided in a thickness that is smaller than the first distance.

[0016] The first distance and the second distance may be selected so that Laplace pressure causes the brazing material to flow into gaps between the ends of the plurality of structures and the at least one cover plate.

[0017] According to various, but not necessarily all, examples of the disclosure there may be provided a heat exchanger comprising: a base plate; a plurality of structures extending out of the base plate; and at least one stiffener structure comprising a plurality projecting portions configured to extend between the plurality of structures so as reduce bending of the plurality of structures.

[0018] The heat exchanger may comprise a cover plate wherein the at least one stiffener structure is provided as part of the cover plate.

[0019] The base plate may be connected to first ends of the plurality of structures and at least one stiffener structure is connected to second ends of the plurality of structures.

[0020] Sides of the plurality of projecting portions of the stiffener structure may be brazed to sides of the plurality of structures.

[0021] The projecting portions of the stiffener structure may be coupled to all of the plurality of structures.

[0022] The projecting portions of the stiffener structure may be coupled to a subset of the plurality of structures.

[0023] According to various, but not necessarily all, examples of the disclosure there may be provided a heat exchanger comprising: a base plate; and a plurality of structures extending out of the base plate; wherein the heat exchanger is configured to provide larger channels for flow of working fluid towards in a central portion of the base plate compared to edges of the base plate.

[0024] The plurality of structures may be spaced closer together at the edges of the base plate than in a centre of the base plate.

[0025] The heat exchanger may comprise an inlet portion that provides a larger channel width in a central portion of the base plate compared to edges of the base plate.

[0026] The base plate may have a surface area that is larger than a heat source to which the heat exchanger is thermally coupled.

[0027] According to various, but not necessarily all, examples of the disclosure there may be provided a heat exchanger comprising: a base plate; a plurality of structures extending out of the base plate; and a cover plate; wherein at least some of the plurality of structures extend through the cover plate and coupling means is provided on ends of the structures that extend through the cover plate.

[0028] According to various, but not necessarily all, examples of the disclosure there may be provided a two-phase cooling system comprising one or more heat exchangers as described herein.

BRIEF DESCRIPTION

[0029] Some examples will now be described with reference to the accompanying drawings in which:

[0030] FIG. **1** shows a general schematic of example of passive two-phase cooling system;

[0031] FIGS. **2**A and **2**B show part of an evaporator;

[0032] FIGS. **3**A and **3**B show an evaporator being formed;

[0033] FIG. **4** shows an example method;

[0034] FIGS. **5**A to **5**D show examples for alternative configurations of brazing filler material structures;

[0035] FIG. **6** shows an example evaporator being formed;

[0036] FIGS. **7**A and **7**B show example evaporators;

[0037] FIG. **8** shows an example evaporator; and

[0038] FIG. **9** shows a schematic example and main components of passive two phase cooling system.

DETAILED DESCRIPTION

[0039] FIG. **1** schematically shows a two-phase cooling system **101** that can comprise heat exchangers such as evaporators **103** and condensers **105** according to examples of the disclosure.

[0040] In the example of FIG. **1** the two-phase cooling system **101** comprises a passive two-phase cooling system that is driven by gravity rather than a pump, requiring external work input to drive the flow. In the example of FIG. **1** the passive two-phase cooling system **101** comprises a thermosyphon loop. The example heat exchangers can be provided within other types of two-phase cooling system, such as heat pipes, vapor chambers and many others.

[0041] The thermosyphon loop shown in FIG. **1** comprises an evaporator **103**, a condenser **105**, a downcomer **107** and a riser **109**. A working fluid **113** is provided within the thermosyphon loop. When the thermosyphon loop is in use the working fluid **113** circulates through the components of the thermosyphon loop.

[0042] The evaporator **103** is provided at the bottom of the thermosyphon loop so that the working fluid flows down the downcomer **107** into the evaporator **103** under the force of gravity as indicated by the arrow **115**. The height of the two-phase cooling system **101** and inner diameter of the downcomer **107** can be selected so that the static head of the fluid within the downcomer **107** causes the fluid to flow through the evaporator **103**, riser **109** and condenser **105**. The working fluid **113** is normally in the liquid phase **117** when it is in the downcomer **107**. In particular the volume of the downcomer **107** filled by the working fluid **113** in the liquid phase **117** depends on the thermosyphon operating conditions and geometry.

[0043] The evaporator **103** comprises any means for transferring heat from a heat source **111** into the working fluid **113**. The evaporator **103** is thermally coupled to the heat source **111**. A thermal interface material could be used to enable the evaporator **103** to be thermally coupled to the heat source **111**. The heat source **111** could comprise an electronic device that generates unwanted heat during operation. The electronic device could be a server, router, network switch, storage device or any other suitable type of device. In some examples the heat sources can comprise a plurality of electronic devices comprised within a data centre, telecommunication equipment room, or network, a communication room, a computer room, a network room or any other suitable arrangement.

[0044] In other examples, the heat source **111** can be an intermediate fluid, therefore heat is exchanged between two working fluids (intermediate fluid and working fluid **113**). In these examples, the evaporator **103** is a heat exchanger with a metal wall separating the two streams. The wall can be also manufactured with a ceramic or other materials.

[0045] Heat is transferred from the heat source **111** to the working fluid **113** in the evaporator **103** as indicated by the arrows **119**. This heat transfer causes a partial evaporation of working fluid **113** within the evaporator **103** and converts the working fluid **113** from a liquid phase **117** into a mixture of liquid and vapour phase. In particular, the evaporator **103** causes some of the working fluid **113** to be converted into the vapour phase **121** while some remains in a liquid phase **117** so that the fluid expelled from the outlet of the evaporator **103** is a two-phase mixture with a defined value of vapor quality. The two-phase mixture can comprise droplets of vapour entrained within the liquid or other flow regimes depending on the design of the thermosyphon loop, heat load, heat rejection conditions, filling ratio and any other suitable parameter.

[0046] The evaporator **103** is coupled to the riser **109** so that the working fluid expelled from the evaporator **103** flows into the riser **109**. This working fluid comprises a two-phase mixture where the vapour phase **121** is less dense than the liquid phase **117**. The working fluid **113** within the thermosyphon loop rises through the riser **109**, as indicated by the arrows **123**. The passive flow in the thermosyphon loop is driven by the density difference between the working fluid **113** in the liquid phase in the downcomer **107** and the working fluid **113** in the two-phase mixture in the riser **109**.

[0047] The evaporator **103** can comprise structures that enable efficient transfer from the evaporator **103** into the working fluid **113**. For example, the evaporator **103** could comprise wick structures, micro-channels, arrays of fins, a serpentine arrangement of macro-/micro-channels or any suitable combination of such features. Examples of evaporators **103** comprising such structures are shown in FIGS. **2** and **3**, as well as in FIGS. **6** to **8**.

[0048] The condenser **105** is provided at the top of the thermosyphon loop. The condenser **105** is positioned above the evaporator **103** so that the working fluid **113** flows downwards from the condenser **105** to the evaporator **103** (via gravity force **115**) and upwards from the evaporator **103** to the condenser **105**.

[0049] The condenser **105** is coupled to the riser **109** so that the working fluid **113** in the two-phase mixture (vapour phase **121** and liquid phase **117**) flows from the riser **109** into the condenser **105**. The condenser **105** can comprise any means for cooling the working fluid **113**. For example, the condenser **105** could be air-cooled or liquid-cooled. A liquid-cooled condenser **105** could comprise a tube-in tube heat exchanger, a shell-and-tube heat exchanger a plate heat exchanger or any other suitable heat exchanger configuration or arrangement. An air-cooled condenser could comprise a louvered-fin flat tube heat exchanger, a tube-and-fin heat exchanger or any other suitable type of heat exchanger configuration or arrangement. Overall, the condenser **105**

can comprise any suitable heat exchanger geometry that enables heat to be removed efficiently from the working fluid **113**.

[0050] The condenser **105** is thermally coupled to a coolant **125**. A thermal interface material could be used to enable the condenser **105** to be thermally coupled to the coolant **125**. In other examples the coolant **125** can be directly integrated in the condenser **105** with a wall interface separating the stream of thermosyphon working fluid **113** from the stream of coolant **125**. The wall interface can comprise a highly conductive metal or metal alloy, such as copper, aluminum, brass, or any other suitable metal. In some examples the wall interface can comprise highly conductive ceramics such as Aluminum Nitride (AlN), or polymers such as filled polymer composites.

[0051] The condenser **105** enables heat to be transferred from the working fluid **113** to the coolant **125** as indicated by the arrows **127**. This heat transfer causes the working fluid **113** to condense, at least partly, back into the liquid phase **117**. The working fluid **113** at the outlet of the condenser **105** can be therefore in the liquid phase **117** or in the two-phase mixture (vapour phase **121** and liquid phase **117**).

[0052] The condenser **105** is coupled to the downcomer **107** so that the working fluid **113** can flow down the downcomer **107** by gravity and be returned to the inlet of the evaporator **103**.

[0053] FIGS. **2**A and **2**B show part of a heat exchanger **200** that could be used in the two-phase cooling system **101** of FIG. **1** or in any other suitable cooling system. The heat exchanger **200** could be an evaporator **103** or a condenser **105** or any other suitable type of heat exchanger. The heat exchanger **200** can be a macro-scale or micro-scale two-phase heat exchanger. The heat exchanger **200** can be a single-phase heat exchanger or a two-phase heat exchanger **200** or any other suitable type of heat exchanger **200**.

[0054] The example heat exchanger **200** comprises a base plate **201**, a plurality of structures **203** and at least one cover plate **205**. In order to achieve a more robust design the heat exchanger **200** comprises a mechanical bond between the tops of the structures **203** and the cover plate **205**. The components of the heat exchanger **200** are not shown to scale in FIGS. **2**A and **2**B. FIG. **2**A shows the heat exchanger **200** before the brazing material **207** is melted and FIG. **2**B shows the heat exchanger **200** after the brazing material **207** is melted. In FIGS. **2**A and **2**B only a section of the heat exchanger **200** is shown so only two structures **203** are shown. It is to be appreciated that a plurality of structures **203** would be configured to provide a plurality of channels for working fluid through the heat exchanger **200**.

[0055] The base plate **201** comprises a flat or substantially flat surface. The base plate **201** can comprise a thermally conductive material. When the heat exchanger **200** is in use as an evaporator **103** the base plate **201** can be thermally coupled to a heat source to enable heat to be transferred from the heat source into working fluid within the evaporator **103**.

[0056] The plurality of structures **203** extend out of the surface of the base plate **201**. The structures **203** can be machined, brazed, extruded, additively manufactured or obtained by any other suitable fabrication technique or combination of fabrication techniques. The structures **203**, at least partially, define flow paths for the working fluid through the heat exchanger **200**. In other examples the heat exchanger **200** could comprise a plurality of different types of structures **203** such as fins, plates or any other suitable structures.

[0057] In the example of FIGS. **2**A and **2**B the structures **203** comprise elongate structures that extend perpendicularly, or substantially perpendicularly, out of the base plate **201**. In the example shown in FIGS. **2**A and **2**B the structures **203** have rectangular cross sections. Other shapes of structures **203** can be provided in other examples of the disclosure.

[0058] In the example of FIGS. **2**A and **2**B the two adjacent structures **203** are separated by a first distance w. The first distance defines the width of the channel between the structures **203**. In some examples the heat exchanger **200** can be configured so that the plurality of structures **203** are evenly spaced across the base plate **201**. In such examples the different channels between different adjacent structures **203** would have the same width. In other examples the heat exchanger **200** can be configured so that the plurality of structures **203** have different spacing across the base plate **201**. For example, the structures **203** could be spaced further apart on regions of the base plate **201** that are closer to a heat source. This can provide larger channels and more fluid flow in the areas of the heat exchanger **200** which have a higher heat load. For example, the plurality of structures **203** can be spaced closer together at the edges of the base plate **201** than in the centre of the base plate **201**.

[0059] In some examples the footprint area of the base plate **201** can be larger than the area of the heat source, to improve heat spreading. In such examples an evaporator **103** having non-uniform channel width can help to provide uniform, or substantially uniform flow distribution in all the channels of the evaporator **103** and thus enhanced thermal performance.

[0060] The structures **203** can comprise any suitable thermally conductive material. The structures **203** can comprise the same material as the base plate **201** and the cover plate **205**. In other cases, the base plate **201** and structures **203** can comprise a different material than the one used for the cover plate **205**.

[0061] The cover plate **205** is positioned over ends of the plurality of structures **203**. The cover plate **205** is provided at the opposite end of the structures **203** to the base plate **201** in order to create a closed volume for the circulation of the working fluid **113**.

[0062] The cover plate **205** comprises a flat or substantially flat surface. In the example of FIGS. **2**A and **2**B only part of the cover plate **205** is shown. It is to be appreciated that the cover plate **205** could cover all of the plurality of structures **203** or other structures.

[0063] The cover plate **205** is brazed to the plurality of structures **203** by brazing material **207**. The brazing material **207** is provided between the ends of the plurality of structures **203** and the cover plate **205**. The brazing material **207** can comprise any suitable material that can be melted and solidified to form a rigid connection between the ends of the structures **203** and the cover plate **205**. In some examples the heat exchanger **200** can be further strengthened by brazing the four exterior surfaces of the cover pate **205** to the top part of the base plate **201**.

[0064] FIG. **2**A shows the heat exchanger **200** before the brazing material **207** has been melted and before the rigid brazing join has been formed. The cover plate **205** is spaced from the ends of the plurality of structures **203** by a second

distance d. The second distance d is smaller than the first distance w that defines the gaps between adjacent structures **203**.

[0065] In this case the brazing material also has a thickness d that is equal to the spacing between the ends of the structures **203** and the cover plate **205**. The thickness of the brazing material is therefore also smaller than the distance between adjacent structures **203**.

[0066] The brazing material **207** can be provided in a discontinuous configuration. The brazing material **207** is discontinuous so that, instead of being provided in a continuous sheet there are gaps provided between portions of brazing material **207**. For example, the brazing material **207** can be provided as a plurality of lines or a network of crossed lines or in any other suitable configuration. In the example shown in FIG. **2**A the discontinuities would extend into the page.

[0067] FIG. **2**B shows the heat exchanger **200** after the brazing material **207** has been melted to form a rigid join between the ends of the structures **203** and the cover plate **205**. When the brazing material **207** is melted it flows between the ends of the structures **203** and the cover plate **205** so that when the heat exchanger **200** is cooled again a rigid join is formed from the solidified brazing material **207**.

[0068] In examples of the disclosure the discontinuous configuration of the brazing material **207** causes the melted brazing material **207** to flow into the spacing between the cover plate **205** and the ends of the plurality of structures **203**. The brazing material **207** flows horizontally across the ends of the plurality of structures **203** rather than downwards into the channel between adjacent structures **203**. In the example shown in FIGS. **2**A and **2**B the melted brazing material **207** would flow into the page to form the brazing join as shown in FIG. **2**B.

[0069] In examples of the disclosure the brazing material **207** flows horizontally across the ends of the plurality of structures **203** rather than downwards into the channels between adjacent structures **203**. This means that the volume of the channels for flow of the working fluid **113** is maintained and is not decreased by unwanted brazing material **207** that has flowed into the channels. This can help the heat exchanger **200** to function efficiently.

[0070] The spacing d between the ends of the structures **203** and the cover plate **205** and the width of the channel w between adjacent channels can be selected to control the Laplace pressure. The Laplace pressure causes the brazing material **207** to flow horizontally into gaps between the ends of the plurality of structures **203** and at least one cover plate **205** rather than downwards into the channels between adjacent structures **203**. The brazing material **207** can flow by wicking between the spacing between the ends of the structures **203** and the cover plate **205**. The width of the channels w is larger than the spacing d between the ends of the structures **203** and the cover plate and the corresponding thickness of the un-melted brazing material **207**. As the Laplace pressure is inversely proportional to the thickness of the brazing material **207** this creates a larger pressure differential in the horizontal direction than in the downwards direction so that when the brazing material **207** is melted it will flow in the horizonal direction.

[0071] FIGS. **3**A to **3**B show an example heat exchanger **200** being formed. In this example the heat exchanger **200** is an evaporator **103** and the plurality of structures **203** comprise a plurality of evaporator fins **305**. Other types of heat exchanger **200** comprising other types of structures **203** could be formed using a similar process in other types of the disclosure.

[0072] FIG. **3**A shows brazing material **207** being provided on the ends of the plurality of evaporator fins **305**. FIG. **3**B shows a cross section of part of the evaporator **103** before the brazing material **207** is melted.

[0073] FIG. **3**A shows the base plate **201** and the plurality of evaporator fins **305** extending out of the base plate **201**. The cover plate **205** is not shown in FIG. **3**A.

[0074] In the example of FIG. **3**A the base plate **201** is a square, or substantially square plate. Other shapes of base plate **201** can be used in other examples of the disclosure.

[0075] The plurality of evaporator fins **305** extend perpendicularly, or substantially perpendicularly out of the base plate **201**. In the example of FIG. **3**A each of the evaporator fins **305** comprises a thin plate. The plate has a thickness that is several orders of magnitude smaller than the longest length of the plate (along the flow direction). The plates of the evaporator fins **305** are provided in a parallel or substantially parallel arrangement across the surface of base plate **201**. Other dimensions and shapes of plates of the evaporator fins **305** that define the flow paths can be used depending on the application and operating conditions.

[0076] Adjacent evaporator fins **305** are separated from each other by a first distance w. In the example of FIG. **3**A the evaporator fins **305** are evenly spaced across the surface of the base plate **201** so that each of the evaporator fins **305** are separated from adjacent evaporator fins **305** by the same first distance w. This creates a plurality of parallel, or substantially parallel channels across the surface of the base plate **201** where the channels have a width w.

[0077] The brazing material **207** is provided over the ends of the evaporator fins **305**. In the example of FIG. **3**A the brazing material **207** is provided in a plurality of wires **301**. The wires **301** extend across the ends of the evaporator fins **305**. In the example of FIG. **3**A the wires **301** extend in a direction that is perpendicular, or substantially perpendicular to the direction of the channels formed by the evaporator fins **305**.

[0078] The wires **301** of brazing material **207** are provided in a discontinuous configuration so that gaps are provided between the wires **301**. The gaps on top of the evaporator fins **305** provide space for the brazing material **207** to flow when the brazing material **207** is melted ensuring effective bonding between the evaporator fins **305** and cover plate **205**. In the example shown in FIG. **3**A the wires **301** of brazing material **207** are provided evenly spaced across the ends of the evaporator fins **305**. Other arrangements for the wires **301** could be used in other examples of the disclosure.

[0079] The wires **301** of brazing material **207** have a thickness d that is smaller than the width between adjacent pairs of evaporator fins **305**.

[0080] FIG. **3**B shows a cross section of part of the evaporator **103** before the brazing material **207** is melted. FIG. **3**B shows an end of one of the evaporator fins **305** and the wire **301** of brazing material **207** provided between the ends of the evaporator fin **305** and the cover plate **205**.

[0081] The cover plate **205** is provided over wire **301** of brazing material **207**. The cover plate **205** is spaced from the end of the evaporator fin **305** by a distance d due to the thickness of the wire **301** of brazing material **207**. In the example shown in FIG. **3**B the wire **301** has a circular, or

substantially circular cross section. Other shapes for the wires could be used in other examples of the disclosure.

[0082] When the brazing material **207** is melted the Laplace pressure causes the brazing material to flow in a horizontal direction between the cover plates **205** and the ends of the evaporator fins **305** as indicated by the arrows **303** in FIG. **3**B. This direction of flow enables a strong brazing join to be formed but prevents excess brazing material from flowing into the channels formed by the evaporator fins **305**.

[0083] FIG. **4** shows an example method that could be used to form heat exchangers **200** in examples of the disclosure. The heat exchanger **200** can be a macro-scale or micro-scale two-phase heat exchanger. The heat exchanger **200** can be for use in two-phase cooling systems **101**. The heat exchanger **200** can be an evaporator **103** or a condenser **105** or any other suitable type of heat exchanger **200**.

[0084] At block **401** the method comprises providing a plurality of structures **203** extending from a base plate **201** where the structures **203** are separated by at least a first distance w. The structures **203** could comprise any means for defining a flow path for working fluid **113** through the heat exchanger **200**. In some examples the plurality of structures **203** could comprise a plurality of evaporator fins **305** as shown in FIG. **3**A or in any other suitable type or configuration of structures **203**.

[0085] At block **403** the method comprises providing brazing material **207** overlaying, at least some of the structures **203**. The brazing material **207** can be provided in a discontinuous configuration so that gaps are provided between portions of brazing material **207**. The brazing material **207** could be provided in a plurality of wires **301** as shown in FIG. **3**A or in any other suitable configuration.

[0086] The brazing material **207** is provided in a thickness d that is smaller than the first distance w between pairs of adjacent structures **203**.

[0087] At block **405** the method comprises providing at least one cover plate **205** over ends of the plurality of structures **203**. At least one cover plate **205** is also provided over the brazing material **207** so that the brazing material **207** is positioned between the ends of the structures **203** and the cover plate **205**. The cover plate is spaced from the ends of the plurality of structures **203** by a second distance d where the second distance is smaller than the first distance w. The second distance d can be the same as, or slightly larger than, the thickness of the brazing material **207**.

[0088] The method also comprises, at block **407**, heating the brazing material **207**. The brazing material **207** is heated to a temperature above the melting point so that the molten brazing material **207** flows into spacing between the cover plate **205** and the ends of the plurality of structures **203**.

[0089] The distance w between pairs of adjacent structures **203** and the thickness d of the brazing material **207** are selected so that, when the brazing material **207** is melted, Laplace pressure causes the brazing material **207** to flow into gaps between the ends of the plurality of structures **203** and at least one cover plate **205**. This prevents the brazing material **207** from flowing into the channels formed by the structures **203**. This feature helps to maximize, or substantially maximise, the effective heat transfer area and reduce the total pressure drops within the heat exchanger **200**.

[0090] In the above described example, the brazing material **207** is provided in a thickness d that is smaller than the first distance w between pairs of adjacent structures **203**. In other examples the brazing material **207** could be provided in a thickness d that is initially larger than the first distance w between pairs of adjacent structures **203**. In such examples, when the brazing material **207** is heated, the initial Laplace pressure would cause the molten brazing material **207** to initially flow into the gaps between pairs of adjacent structures **203**. However, once the brazing material **207** has flowed to a point where the thickness is less than the first distance w between pairs of adjacent structures **203** then the Laplace pressure would drive the flow of the brazing material **207** into the gap between the ends of the structures **203** and the cover plate **205**. Flow into the gaps between pairs of adjacent structures **203** would be halted and reversed to maximize, or substantially maximise, the effective heat transfer area and reduce the total pressure drops within the heat exchanger **200**. At these cases the Laplace pressure difference between the meniscus in the gap between adjacent structures **203** and the ends of the structures **203** and the cover plate **205** would drive the flow of the brazing material **207**.

[0091] FIGS. **5**A to **5**D show different example configurations of brazing material **207** that could be used in examples of the disclosure. In these examples the brazing material **207** is provided in a discontinuous configuration rather than in a continuous sheet. The discontinuous configuration ensures that there are gaps between portions of the brazing material **207**. These gaps provide a spacing between the cover plate **205** and the ends of the structures **203** into which the molten brazing material **207** can flow.

[0092] The thickness of the brazing material **207** can be selected so that Laplace pressure of the brazing material **207** will cause flow of the brazing material **207** horizontally across the ends of the structures **203**. The area covered by the brazing material **207** and the discontinuous configuration used for the brazing material **207** can be selected to provide sufficient volume of brazing material **207** so that a secure and rigid brazing join can be formed.

[0093] In the example of FIG. **5**A the brazing material **207** is provided in a plurality of wires **301**. The plurality of wires **301** can have a circular, or substantially circular, cross section. The plurality of wires **301** can extend perpendicularly to the channels formed by the plurality of structures **203**.

[0094] The wires **301** are provided in an even spacing across the tops of the structures **203** in the example of FIG. **5**A. The number and spacing of wires **301** can be selected so as to control the volume of brazing material **207** that is used.

[0095] In the example of FIG. **5**B the brazing material **207** is provided in a plurality of dots **501**. The dots **501** are provided in an interconnected mesh **503**. The interconnected mesh comprises gaps **505** between the dots **501** into which the molten brazing material **207** can flow. The number of dots **501** and the size of the dots **501** can be selected so as to control the volume of brazing material **207** that is used.

[0096] The brazing material **207** shown in FIG. **5**C is also provided in an interconnected mesh **503**. In this example the interconnected mesh **503** comprises a plurality of circular gaps **505**. The circular gaps **505** provide spacing into which the molten brazing material **207** can flow. Other shapes for the gaps **505** could be used in other examples of the disclosure. The number of gaps **505** and the size of the gaps **505** can be selected so as to control the volume of brazing material **207** that is used.

[0097] FIG. **5**D shows another example interconnected mesh **503** of brazing material **207**. In this example the interconnected mesh **503** can be formed from a plurality of intersecting wires **301**. In this example the interconnected mesh **503** provides a plurality of rectangular gaps **505** for the molten brazing material **207** to flow into. The number of wires **301** within the interconnected mesh **503** can be selected so as to control the volume of brazing material **207** that is used.

[0098] In the examples shown in FIGS. **4** to **5**D the base plate **201** has a substantially square shape. Other shapes could be used in other examples. In some examples the base plate **201** can have a surface area that is larger than the heat source to which the base plate **201** and an evaporator **103** are thermally coupled. This can help to distribute heat across the base plate **201** and can provide better thermal performance.

[0099] In some examples the heat exchanger **200** can comprise additional components that are not shown in FIGS. **2** to **5**D. In some examples the heat exchanger **200** can comprise a stiffener structure that is configured to restrict bending of the structures **203**. The stiffener structure can comprise a plurality of projecting portions that extend between the plurality of structures **203** to hold the structures **203** in place.

[0100] In some examples the heat exchanger **200** can be configured so that at least some of the structures **203** extend through the cover plate **205**. This can provide a larger surface for the brazing between the structures **203** and the cover plate **205**. Further coupling means can be provided on the ends of the structures **203** that extend through the cover plate **205**. The further coupling means can provide further coupling of the structure **203** to the cover plate **205** in addition to the brazing join. This can provide for a more rigid heat exchanger **200** and can enable the heat exchanger **200** to withstand handle high internal operating pressures.

[0101] FIG. **6** shows an example heat exchanger **200** being formed comprising a stiffener structure **601**. In this example the heat exchanger **200** is an evaporator **103** with a plurality of structures **203**. The stiffener structure **601** is configured to strengthen the heat exchanger **200** and reduce deformation of the heat exchanger **200** during use. The stiffener structure **601** can be provided in heat exchanger **200** as shown in FIGS. **2** to **5**D and in FIGS. **7**A to **8** or in any other suitable type of heat exchanger **200**.

[0102] The heat exchanger **200** shown in FIG. **6** comprises a base plate **201** and a plurality of structures **203** which can be as described above.

[0103] The stiffener structure **601** can be provided as part of the cover plate **205** or as an additional component between the ends of the structures **203** and the cover plate **205**. In the example shown in FIG. **6** the base plate **201** is connected to first ends of the plurality of structures **203** and the stiffener structure **601** is connected to second ends of the plurality of structures **203**.

[0104] The stiffener structure **601** comprises a plurality of projecting portions **603** that extend between the plurality of structures **203** to hold the structures **203** in place. The projecting portions **603** can be configured to hole the ends of the structures **203** in place. The projecting portions **603** have a much shorter length compared to the structures **203** so that the projecting portions **603** do not project too far into the channels formed by adjacent pairs of structures **203**. This helps to maintain the size of the channels so that sufficient working fluid **113** can flow through the channels when the heat exchanger **200** is in use.

[0105] In the example of FIG. **6** the projection portions **603** of the stiffener structure **601** form an interdigitated structure with the ends of the structures **203**. The projection portions **603** are sized and shaped so that they fit tightly into the gaps between the ends of the structures **203**. The projection portions **603** grip the sides of the structures **203** to hold the structures **203** in place. In some examples the plurality of projecting portions **603** of the stiffener structure **601** can be brazed to sides of the plurality of structures **203**. This can help to prevent movement of the structures **203** relative to the stiffener structure **601** and thus helps to prevent deformation of the heat exchanger **200**.

[0106] In the example of FIG. **6** all structures **203** are coupled to projecting portions **603** of the stiffener structure **601**. In other examples the projecting portions **603** of the stiffener structure **601** can be coupled to a subset of the plurality of structures **203**. Where the projecting portions **603** are coupled to just a subset of the plurality of structures **203** the subset can be selected so as to reduce the deformation of the heat exchanger **200**. For example, the structures **203** at the centre of the heat exchanger **200** could be the ones that are most likely to be deformed during use and so the projecting portions **603** can be configured to be coupled to the structures **203** at the centre of the heat exchanger **200**.

[0107] In the example of FIG. **6** the stiffener structure **601** is provided as a single component that is coupled to all structures **203**. Different arrangements for the stiffener structure **601** can be provided in other examples of the disclosure. For instance, a plurality of different stiffener structures **601** can be provided coupled to different subsets of the structures **203**.

[0108] FIGS. **7**A and **7**B show examples of different geometries that can be used for heat exchangers **200**. FIGS. **7**A and **7**B show a completed heat exchanger **200**. In these examples the heat exchanger **200** is an evaporator **103** with a plurality of structures **203**. The heat exchanger **200** could be formed using any of the methods described above. These heat exchangers **200** are configured to provide uniform flow, or substantially uniform flow of the working fluid **113** across the heat exchanger **200** to improve thermal performance. The features shown in FIGS. **7**A and **7**B can be provided in combination with other features of heat exchangers **200** in any of FIGS. **2** to **6** or FIG. **8**.

[0109] In the examples of FIGS. **7**A and **7**B the heat exchanger **200** comprises a base plate **201** and a plurality of structures **203** extending out of the base plate **201**. A cover plate **205** is provided over the structures **203**. In the examples of FIGS. **7**A and **7**B the heat exchangers **200** are configured to provide larger channels for flow of working fluid **113** towards the central portion of the base plate **201** compared to edges of the base plate **201**. This can help providing a uniform flow distribution of the working fluid.

[0110] The base plate **201** is thermally coupled to a heat source **701**. A thermal interface material can be provided between the heat source **701** and the base plate **201** for the thermal coupling. In the examples of FIGS. **7**A and **7**B the base plates **201** are larger than the heat sources **701**. Having the larger base plates **201** improve heat spreading and increase the effective heat transfer area which helps to reduce the thermal resistance of the heat exchanger **200**.

[0111] In the examples of FIGS. **7**A and **7**B the heat sources **701** are positioned in a central part of the base plates **201**. The channels defined by the structures **203** have different widths in order to provide uniform, or substantially uniform, flow distribution across the heat exchanger **200**. The channels that are closer to the heat source **701** have larger sizes than the channels that are further away. The widths of the channels that are used can be designed to achieve uniform or substantially uniform, flow distribution while maintaining the mechanical integrity of the heat exchanger **200**.

[0112] In the example of FIG. **7**A the different channel sizes are obtained by having different spacings between the structures **203**. The spacings between adjacent pairs of structures **203** is larger in the centre of the base plate **201** than it is at the edges. The structures **203** are spaced closer together at the edges of the base plate **201** than in the centre of the base plate **201**. This creates channels having larger widths at the centre of the base plate **201** and channels having narrower widths at the edges of the base plate **201**.

[0113] In the example of FIG. **7**B the different channel sizes are obtained by providing an inlet portion **703** that provides a larger channel width in a central portion of the base plate **201** compared to edges of the base plate **201**. The inlet portion **703** could be directly machined in the cover plate **205**.

[0114] In this example the inlet portion **703** defines an inlet for the heat exchanger **200**. The inlet portion **703** shown in FIG. **7**B has two different lengths. A first length is provided towards the centre of the base plate **201** and a second length is provided at the edges of the base plate **201**. The first length is shorter than the second length so that the inlet is larger at the centre of the base plate **201** than it is at the edges. It is to be appreciated that other configurations of the inlet portion **703** can be used in other examples of the disclosure.

[0115] In both of the examples shown in FIGS. **7**A and **7**B the heat exchangers **200** are provided into two parts. In these examples the cover plates **205** comprise a central section **705** that divide the heat exchangers **200** into the different parts.

[0116] The cover plates **205** can be bonded to the base plates **201** and the structures **203** by brazing joins **707**. In the example shown in FIGS. **7**A and **7**B the brazing joins **707** can be formed along edges of the structures **203** that are at the edges of the base plates **201**. Brazing joins **707** are also formed between the central section **705** of the cover plates **205** and the structures **203** that are adjacent to the central section **705**. This arrangement of the brazing joins **707** help to provide a better bonding between the base plates **201** and the cover plates **205** and helps to reduce deformation of the heat exchangers **200** during use.

[0117] FIG. **8** shows another example heat exchanger **200**. In this example the heat exchanger **200** is an evaporator **103** with a plurality of structures **203**. The features shown in FIG. **8** can be provided in combination with other features of heat exchangers **200** in any of FIGS. **2** to **7**B.

[0118] The heat exchanger **200** comprises a base plate **201**, a plurality of structures **203** extending out of the base plate **201** and a cover plate **205**. At least some of the plurality of structures **203** extend through the cover plate **205**. The base plate **201** is thermally coupled to a heat source **701**. The cover plate **205** is joined to the base plate **201** and the structures **203** by a brazing join **707**.

[0119] Coupling means **801** are provided on the ends of the structures **203** that extend through the cover plate **205**. The coupling means **801** can comprise brazing material or any other suitable means.

[0120] The coupling means **801** can provide additional strength in addition to the brazing join **707** between the cover plate **205** and the structures **203** and/or the base plate **201**. The additional coupling means **801** can help to prevent deformation of the heat exchanger **200** during use.

[0121] FIG. **9** show formation of an example two-phase cooling system **101** comprising an evaporator **103** and a condenser **105**. The evaporator **103** and condenser **105** are heat exchangers **200** that can be as shown in any of FIGS. **2** to **8** or can comprise any combination of the features shown in FIGS. **2** to **8**.

[0122] The evaporator **103** can be provided within an additional frame before being installed in a server or other system for use. The additional frame can be rigid frame formed from plastic or any other suitable materials. The rigid frame can prevent people from directly accessing the evaporator **103** so as to prevent the evaporator **103** from becoming damaged. The additional frame can also act as a thermal insulator to avoid unwanted air flow impacting the evaporator **103**.

[0123] In order to form the two-phase cooling system **101**, the evaporator **103** and the condenser **105** can be vacuum brazed. The vacuum brazing of the evaporator **103** mechanically couples the cover plate **205** to the base plate **201** and evaporator fins **305**. The vacuum brazing of the condenser **105** mechanically couples the two cover plates **205** to a base plate **201** or any other suitable components. The base plate **201** of the condenser **105** could comprise a double-sided fin plate or any other suitable type of plate.

[0124] The evaporator **103** and the condenser **105** are then connected to a riser **109** and a downcomer **107** via junctions **901**, as indicated by the arrows. The junctions **901** form a closed loop for the two-phase cooling system **101**. The junctions **901** can have the same inlet diameters as the downcomer **107** and the riser **109**. This helps to prevent pressure drops within the two-phase cooling system **101** and helps to maximize, or substantially maximize, the passive flow circulation.

[0125] The various components of the two-phase cooling system **101** can be connected together via any suitable means. In the example of FIG. **9** the evaporator **103** and the condenser **105** are connected to the riser **109** the downcomer **107** by laser spot welding around the internal perimeters of the junctions **901**.

[0126] In the example shown in FIG. **9** the two-phase cooling system **101** also comprises a charging port **903**. The charging port **903** enables working fluid **113** to be provided into the two-phase cooling system **101**. The charging port **903** is provided in the downcomer **107**. In this example the charging port **903** is provided at the top of the downcomer **107** close to the condenser **105**.

[0127] 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".

[0128] 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.

[0129] 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.

[0130] Features described in the preceding description may be used in combinations other than the combinations explicitly described above.

[0131] Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

[0132] Although features have been described with reference to certain examples, those features may also be present in other examples whether described or not.

[0133] 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.

[0134] 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.

[0135] 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.

[0136] 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.

1. A heat exchanger comprising:

a plurality of structures extending from a base plate where adjacent structures are separated by at least a first distance; and

at least one cover plate positioned over ends of the plurality of structures so that the at least one cover plate is spaced from the ends of the plurality of structures by a second distance where the second distance is smaller than the first distance;

wherein the at least one cover plate is brazed to the plurality of structures by brazing material provided between the ends of the plurality of structures and the at least one cover plate; and

wherein the brazing material is provided in a discontinuous configuration so that gaps are provided between portions of brazing material so that a brazing join is formed from brazing materials that has flowed into spacing between the at least one cover plate and the ends of the plurality of structures.

2. The heat exchanger of claim **1**, wherein the brazing material is provided in a thickness that is smaller than the first distance.

3. The heat exchanger of claim **1**, wherein the first distance and the second distance are selected so that Laplace pressure causes the brazing material to flow into gaps between the ends of the plurality of structures and the at least one cover plate.

4. The heat exchanger of claim **1**, wherein the plurality of structures extend substantially perpendicularly out of the base plate.

5. The heat exchanger of claim **1**, wherein the plurality of structures are spaced closer together at edges of the base plate than in a center of the base plate.

6. The heat exchanger of claim **1**, comprising a stiffener structure comprising a plurality projecting portions configured to extend between the plurality of structures so as to restrict bending of the plurality of structures.

7. The heat exchanger of claim **1**, wherein at least some of the plurality of structures extend through the at least one cover plate and further coupling devices provided on the ends of the plurality of structures that extend through the at least one cover plate.

8. The heat exchanger of claim **1**, wherein the plurality of structures comprises fins.

9. The heat exchanger of claim **1**, wherein the heat exchanger comprises an evaporator or a condenser.

10. A method comprising:

providing a plurality of structures extending from a base plate where the plurality of structures are separated by at least a first distance;

providing brazing material overlaying, at least some of the plurality of structures wherein the brazing material is provided in a discontinuous configuration so that gaps are provided between portions of brazing material;

providing at least one cover plate over ends of the plurality of structures and the brazing material so that the at least one cover plate is spaced from the ends of the plurality of structures by a second distance where the second distance is smaller than the first distance; and

heating the brazing material so that the brazing material flows into spacing between the at least one cover plate and the ends of the plurality of structures.

11. The method of claim **10**, wherein the brazing material is provided in a thickness that is smaller than the first distance.

12. The method as claimed in any of claims of claim **10**, wherein the first distance and the second distance are selected so that Laplace pressure causes the brazing material to flow into gaps between the ends of the plurality of structures and the at least one cover plate.

13. A heat exchanger comprising:

a base plate;

a plurality of structures extending out of the base plate; and

at least one stiffener structure comprising a plurality projecting portions configured to extend between the plurality of structures so as reduce bending of the plurality of structures.

14. The heat exchanger of claim **13**, comprising a cover plate wherein the at least one stiffener structure is provided as part of the cover plate.

15. The heat exchanger of claim **13**,

wherein the heat exchanger is configured to provide larger channels for flow of working fluid towards in a central portion of the base plate compared to edges of the base plate.

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