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(54) Title: THERMOSIPHON WITH MULTIPORT TUBE AND FLOW ARRANGEMENT

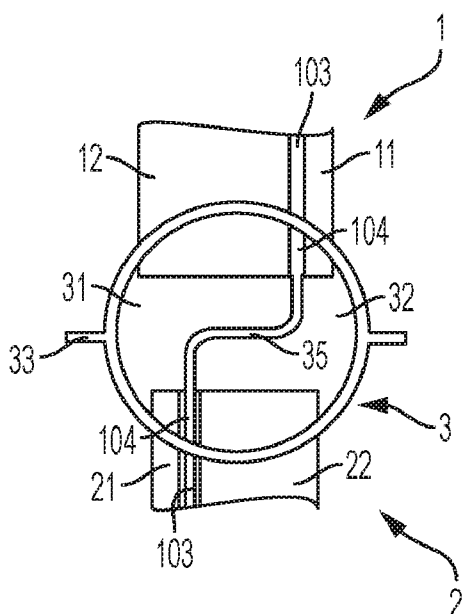


FIG. 6

(57) Abstract: A thermosiphon device includes one or more flat multiport tube structures having at least one section that defines a plurality of flow channels and at least one web that extends from the section in a plane of the flat multiport tube structures. The flow channels may function as condensing channels, e.g., in a counterflow device, or as evaporation channels. A multiport tube structure may include two sections that each define a plurality of flow channels and the two sections may be joined by a web that extends between the sections in the plane of the multiport tube structure. The sections may function as condensing channels, as evaporation channels, or one section may function as a set of evaporation channel and the other section may function as a set of condensing channels. Multiport tube sections may alternately function as a vapor supply path or liquid return path.



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## **THERMOSIPHON WITH MULTIPORT TUBE AND FLOW ARRANGEMENT**

### **BACKGROUND OF THE INVENTION**

#### 5 1) Field of Invention

This invention relates generally to thermosiphon devices and other heat transfer devices that employ a two-phase fluid for cooling.

#### 2) Description of Related Art

10 Thermosiphon devices are widely used for cooling systems, such as integrated circuits and other computer circuitry. For example, U.S. Patent Publication 2013/0104592 discloses a thermosiphon cooler used to cool electronic components located in a cabinet or other enclosure.

### **SUMMARY OF THE INVENTION**

One aspect of the invention provides a thermosiphon device including an  
15 evaporator section arranged to receive heat and evaporate a liquid, and a condenser section arranged to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid. At least one flat multiport tube structure may be employed in the device and include one or more functional sections of the device, such as evaporator and condenser channels. For example, a flat multiport tube structure may  
20 have a first section defining one or more flow channels, a second section defining one or more flow channels, and a web that extends between the first and second sections in a plane of the multiport tube structure. Thus, the web may connect the first and second sections together while providing at least some degree of thermal isolation between the two. For example, the web may include one or more gaps (e.g., areas where the web is  
25 removed) to help limit thermal transfer between the first and second sections, help reduce weight or cost, etc.

The thermal isolation and/or physical separation of the first and second sections provided by the web may allow the sections to perform different, or the same, functions

in the thermosiphon device. In some embodiments, the first section may define one or more evaporation channels, and the second section may define one or more evaporation channels, one or more condensing channels, or a liquid return path of the evaporator section. Alternately, or in addition, the first section may define one or more condensing channels, and the second section may define one or more evaporation channels, one or more condensing channels, or a vapor supply path of the condenser section. As a result, different functional portions of the thermosiphon device may be formed as part of a single multiport tube structure, helping to ease assembly, simplify device design, and/or enhance device operation. Where multiple tube structures are used, the tube structures may provide a variety of different functions. Thus, the multiport tube structure may allow for greater flexibility in design since various functional features can be incorporated into tube structure or structures used in the device.

In some devices, the evaporator section may include at least one evaporation channel arranged to receive heat and evaporate a liquid in the at least one evaporation channel and a liquid return path for delivering condensed liquid to the at least one evaporation channel. In one embodiment, the evaporation channels and liquid return path may be combined into a multiport tube structure, e.g., the at least one evaporation channel and the liquid return path may be part of a flat multiport tube structure in which the first section defines the at least one evaporation channel and the second section defines the liquid return path. Similarly, a condenser section may include at least one condensing channel arranged to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid and a vapor supply path for delivering evaporated liquid to the at least one condensing channel. The at least one condensing channel and the vapor supply path may be part of a flat multiport tube structure in which the second section defines at least one condensing channel and the first section defines the vapor supply path. At least one manifold may fluidly connect the at least one evaporation channel with the vapor supply path, and fluidly connect the at least one condensing channel with the liquid return path. For example, a manifold may include an outer wall that defines an interior cavity and a separation wall positioned in the interior cavity to separate the interior cavity into a vapor chamber and a liquid chamber. The separation wall may be positioned in the manifold such that the at least one evaporation

channel and the vapor supply path are in fluid communication with the vapor chamber, and the at least one condensing channel and the liquid return path are in fluid communication with the liquid chamber. Two or more multiport tube structures may be provided as part of the evaporator or condenser section, e.g., to increase a heat capacity  
5 of the system.

In another embodiment, a single multiport tube structure may define portions of both the condenser and evaporator sections. For example, a single flat multiport tube structure may have a first section that defines at least one evaporation channel and a vapor supply path, and a second section that defines a liquid return path and at least one  
10 condensing channel. As a result, a single tube structure may form a complete thermosiphon device, and a plurality of such flat multiport tube structures may be provided in a thermosiphon device, if desired.

In some embodiments, a flat multiport tube structure may include one or more lateral webs that extend outwardly from the first or second section in a plane of the flat  
15 multiport tube structure. The lateral web(s) may provide thermal transfer structure (e.g., exchange heat with a surrounding environment), or provide protection for portions of the thermosiphon device. In addition, or alternately, the flat multiport tube structure may include three or more sections that define flow channels, and the sections may be connected such that adjacent sections have a web extending between the sections. This  
20 may allow a multiport tube structure to incorporate several different functional elements. For example, a first section of the multiport tube structure may define a plurality of condenser channels, the second section may define the vapor supply path, and the third section may define a plurality of condenser channels.

In another aspect of the invention, a thermosiphon device may include one or  
25 more flat multiport tube structures having a first section that defines one or more flow channels, and a web that extends laterally away from the first section in a plane of the multiport tube structure. The first section may define a plurality of evaporation channels or a plurality of condenser channels. The web may be useful in defining an insertion depth of an end of the first section into a manifold or other structure to which the  
30 multiport tube structure is fluidly coupled. For example, the web may act as a stop to define the insertion depth, which may be important to control or influence flow of liquid

or vapor from or into the first section. In one case, a liquid return path may need to be positioned below a set of evaporation channels in a manifold to ensure that liquid enters the liquid return path rather than the evaporation channels. In such a case, the web on a multiport tube that defines the evaporation channels may cut or otherwise formed to

5 define a gap that sets a proper insertion depth of the first section into a manifold when the web contacts the manifold. In some cases, a multiport tube structure may have first and second webs that extend laterally away from opposite sides of the first section in a plane of the multiport tube structure, e.g., to enlarge a heat transfer area. Multiport tube structures having this arrangement may be employed as part of the evaporator section,

10 e.g., to provide evaporation channels, and/or as part of a condenser section, e.g., to provide condenser channels. When employed to provide condenser channels, the condenser section may operate in a counterflow mode (where vapor moves generally upwardly in the channels while condensed liquid travels generally downwardly) or in a loop mode (where vapor and condensed liquid move generally in a same direction).

15 Such multiport tube structures may also be used for other purposes, such as fluid connecting conduits or other pathways that are not designed or intended to transfer significant amounts of heat with respect to a fluid in the conduit.

These and other aspects of the invention will be apparent from the following description. Also, it should be appreciated that different aspects of the invention may be

20 combined in a variety of different ways.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate select embodiments of the present invention and, together with the description, serve to explain the principles of the inventions. In the drawings:

25 FIG. 1 is a perspective view of a thermosiphon device in an illustrative embodiment that incorporates aspects of the invention;

FIG. 2 shows a thermosiphon device in another illustrative embodiment having a bent configuration;

FIG. 3 shows a close up view of the FIG. 2 embodiment;

FIG. 4 shows an illustrative embodiment of a multiport tube structure having a connecting web;

FIG. 5 shows a modified version of the FIG. 4 embodiment;

FIG. 6 shows an end view of a manifold coupled to condenser and evaporator sections including multiport tube structures;

FIG. 7 shows a perspective view of the manifold in FIG. 6;

FIG. 8 shows a separation wall in one embodiment;

FIG. 9 shows a separation wall in another embodiment;

FIG. 10 shows an end view of a manifold incorporating the separation wall of FIG. 8;

FIG. 11 shows a multiport tube structure having a connecting web and tooth;

FIG. 12 shows an end view of a manifold incorporating the separation wall of FIG. 9;

FIG. 13 shows a section of a manifold arranged to receive the multiport tube structure of FIG. 11;

FIG. 14 shows a separation wall in another embodiment that includes a barb or clip with a laterally extending element;

FIG. 15 shows an end view of a manifold incorporating the separation wall of FIG. 14;

FIG. 16 shows the manifold of FIG. 15 with the multiport tube structures positioned for attachment to the manifold;

FIG. 17 shows the manifold of FIG. 16 with spacer elements in place;

FIG. 18 shows an end view of a manifold incorporating another separation wall embodiment;

FIGs. 19-22 show embodiments of a multiport tube structure incorporating thermal transfer structure;

FIG. 23 shows an illustrative embodiment of a multiport tube structure having a three sections joined by connecting webs and having lateral webs;

FIG. 24 shows a thermosiphon device incorporating the multiport tube structure of FIG. 23;

FIG. 25 shows an end view of a manifold of the FIG. 24 embodiment along with a cap structure;

FIG. 26 shows the manifold of the FIG. 24 embodiment;

FIG. 27 and 28 show an alternate end cap arrangement;

5 FIG. 29 shows a thermosiphon device in which a multiport tube structure defines portions of both an evaporator and condenser section;

FIG. 30 shows a thermosiphon device similar to that of FIG. 29 but having a bent configuration;

10 FIG. 31 shows a multiport tube structure for use in the FIGs. 29 and 30 embodiments;

FIG. 32 shows a thermosiphon device like that of FIG. 30 and having multiple multiport tube structures;

FIG. 33 shows a manifold of the FIG. 32 embodiment;

15 FIG. 34 shows a modified version of the device of FIG. 29 that omits conduits between manifolds;

FIG. 35 shows a manifold arrangement for the embodiment of FIG. 34;

FIG. 36 shows a thermosiphon device including multiport tube structures of the condensing section arranged for counterflow operation;

FIG. 37 shows a side view of the device of FIG. 36;

20 FIG. 38 shows a multiport tube structure for use in the FIG. 36 embodiment;

FIG. 39 shows the manifold and a multiport tube structure of the FIG. 36 embodiment;

FIG. 40 shows a multiport tube structure having lateral webs flush with a surface of the channel section;

25 FIG. 41 shows a multiport tube structure having lateral webs with a bent portion;

FIG. 42 shows a multiport tube structures having thermal transfer structure arranged between the structures;

FIG. 43 shows a multiport tube structure having gaps in the webs at an end of the structure;

30 FIG. 44 shows a thermosiphon device in which a multiport tube structure shown in FIG. 43;



FIG. 45 shows a thermosiphon device similar to that of FIG. 45 but omitting a lower turnaround;

FIG. 46 shows a side view of the device of FIG. 45;

FIG. 47 shows a thermosiphon device in which multiport tube structures define  
5 portions of both the evaporator and condenser sections;

FIG. 48 shows a thermal transfer structure arrangement for use in the FIG. 47 device;

FIG. 49 shows a modified version of the FIG. 47 device in which an upper turnaround manifold is replaced with bent tube sections;

10 FIG. 50 shows a modified version of the FIG. 49 device in which a lower turnaround manifold is replaced with bent tube sections;

FIG. 51 shows a thermosiphon device in which multiport tube structures define a condenser section;

FIG. 52 shows a side view of the FIG. 51 embodiment;

15 FIG. 53 shows the evaporator section and vapor supply path of the FIG. 51 device;

FIG. 54 shows a manifold of the FIG. 51 device;

FIG. 55 shows a multiport tube structure including the condenser channels of the FIG. 51 device;

FIG. 56 shows a base plate for the FIG. 51 device;

20 FIG. 57 shows a thermosiphon device similar to the FIG. 51 device but oriented in a vertical direction;

FIG. 58 shows a thermosiphon device having multiple devices like that shown in FIG. 57;

25 FIG. 59 shows a thermosiphon device similar to the FIG. 58 device and having a turnaround for the evaporator section;

FIG. 59A shows a thermosiphon device similar to the FIG. 59 device and has condenser section manifolds coupled in fluid communication;

FIG. 60 shows a thermosiphon device including counterflow condenser channels and an evaporator section including a turnaround;

30 FIG. 61 shows a thermosiphon device in which multiport tube structures include condensing and evaporation channels;

- FIG. 62 shows the FIG. 61 device with manifolds removed;
- FIG. 63 shows a multiport tube structure for use in the FIG. 61 device;
- FIG. 64 shows a thermosiphon device similar to the device of FIG. 61 and having only evaporator and condenser channel of each multiport tube structure fluidly connected;
- 5        FIG. 65 shows a multiport tube structure for use in the FIG. 64 device;
- FIG. 66 shows a thermosiphon device including counterflow condenser channels arranged in a multiport tube structure;
- FIG. 67 shows a multiport tube structure for use in the FIG. 66 device;
- FIG. 68 shows the FIG. 66 device in a vertical orientation;
- 10       FIG. 69 shows a manifold arrangement including plugs to control liquid flow;
- FIG. 70 shows a modified version of the FIG. 66 device with condensing channels arranged at a non-perpendicular angle to a plane of the manifold;
- FIG. 71 shows the FIG. 70 device in a vertical orientation;
- FIG. 72 shows a base plate for the FIG. 66 device;
- 15       FIG. 73 shows a thermosiphon device including counterflow condenser channels arranged in a multiport tube structure and a multipart manifold;
- FIG. 74 shows a multiport tube structure for use in the FIG. 73 device;
- FIG. 75 shows a manifold sheet for the FIG. 73 device;
- FIG. 76 shows the FIG. 73 device in a vertical orientation;
- 20       FIG. 77 shows the FIG. 73 device in an alternate vertical orientation;
- FIG. 78 shows an alternate manifold structure for the FIG. 73 device;
- FIG. 79 shows a base plate for the FIG. 78 device;
- FIG. 80 shows an alternate manifold arrangement for the FIG. 73 device;
- FIG. 81 shows a modified version of the FIG. 66 device with manifolds attached via
- 25       a multiport tube conduit;
- FIG. 82 shows a close up view of a portion of the FIG. 81 device;
- FIG. 83 shows a multiport tube conduit for use in the FIG. 81 device;
- FIG. 84 shows a close up view of a multiport tube conduit engagement with manifolds in the FIG. 81 device;
- 30       FIG. 85 shows an alternate liquid trapping arrangement including internal threads;
- FIG. 86 shows a coil element for use in liquid trapping in a manifold;

FIG. 87 shows a thermosiphon device having multiple, vertically oriented multiport tube structures including counterflow condenser channels;

FIG. 88 shows a circular manifold of the FIG. 87 device;

FIG. 89 shows a plug for use in the manifold of the FIG. 87 device;

5        FIG. 90 shows an alternate manifold arrangement for the FIG. 87 device including a wicking element;

FIG. 91 shows a thermosiphon device similar to the FIG. 87 device and having a manifold with a cylindrical chamber;

10       FIG. 92 shows an alternate manifold arrangement for the FIG. 91 device including a wicking element;

FIG. 93 shows alternate manifold arrangement for the FIG. 87 device including a plurality of cavities in the manifold bottom wall;

FIG. 94 shows a thermosiphon device with multiple, vertically oriented multiport tube structures including counterflow condenser channels and a serpentine manifold; and

15       FIG. 95 shows the FIG. 94 device in a vertical orientation;

#### DETAILED DESCRIPTION

Aspects of the invention are not limited in application to the details of construction and the arrangement of components set forth in the following description or  
20       illustrated in the drawings. Other embodiments may be employed and aspects of the invention may be practiced or be carried out in various ways. Also, aspects of the invention may be used alone or in any suitable combination with each other. Thus, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

25       FIG. 1 shows an illustrative embodiment of a thermosiphon device 10, e.g., used to cool electronics devices in a closed cabinet or other enclosure 6. That is, as is understood by those of skill in the art, one or more evaporator sections 2 of the device 10 may be positioned in a sealed enclosure 6 along with electronics or other heat-generating devices to be cooled. One or more condensing sections 1 may be positioned outside of  
30       the sealed enclosure 6 and dissipate heat received from the evaporator section(s) 2, e.g., to air in an environment outside of the sealed enclosure 6. A flange 33 on a manifold 3

or elsewhere in the device 10 may be engaged with an opening of the sealed enclosure, thereby sealing the enclosure 6 and defining a dividing point between portions inside of the enclosure 6 and an environment outside of the enclosure. By providing the evaporator section(s) 2 inside the sealed enclosure 6 and the condenser section(s) 1 outside of the enclosure 6, devices in the enclosure 6 may be cooled while being contained in an environment protected from external conditions, e.g., protected from dirt, dust, contaminants, moisture, etc. Of course, use of a thermosiphon device with a sealed enclosure is not required, e.g., the device may be used in a completely open system in which heat generating devices to be cooled are thermally coupled to one or more evaporator section(s) 2 of the device 10. Also, the embodiment of FIG. 1 shows the thermosiphon device 10 arranged at a relatively shallow angle to the horizontal, but the device 10 may be oriented in different ways, e.g., vertically or other angles to the horizontal, and may be arranged to operate in a variety of different positions as discussed in more detail below. Also, the device 10 need not be flat as in FIG. 1, but may be arranged in a bent configuration such as shown in FIG. 2 or in other ways.

FIG. 3 shows a close up view of a portion of the thermosiphon device 10 of FIG. 2. In simplified form, the thermosiphon device 10 operates to cool heat generating devices by receiving heat at the evaporator section(s) 2 such that liquid in evaporation channels 22 boils or otherwise vaporizes. Heat may be received at the evaporation channels 22 by warm air (heated by the heat generating devices) flowing across a thermal transfer structure 23 that is thermally coupled to the evaporation channels 22 or in other ways, such as by a direct conductive path, one or more heat pipes, a liquid heat exchanger, etc. Vapor flows upwardly from the evaporation channels 22 into a manifold 3, and then into a vapor supply path 11 of a condenser section 1. The vapor continues to flow upwardly in the vapor supply path 11 until reaching a turnaround 14 (see FIG. 2) of the condenser section 1. At this point, the vapor flows downwardly into one or more condensing channels 12 of the condenser section 1, where the vapor condenses to a liquid and flows downwardly into the manifold 3. Heat removed from the vapor during condensation may be transferred to thermal transfer structure 13 coupled to the condensing channels 12, e.g., one or more fins conductively coupled to the condenser section 1 adjacent the condensing channels 12. In turn, heat may be removed from the

thermal transfer structure 13 by cool air flowing across the structure 13, by a liquid bath, a liquid heat exchanger, refrigerant coils, or other arrangement. The condensed liquid flows downwardly from the condensing channels 12 into the manifold 3 and then into a liquid return path 21 of an evaporator section 2 until reaching a turnaround 24 (see FIG. 2) of the evaporator section 2. The liquid then enters an evaporator channel 22 and the process is repeated.

In accordance with an aspect of the invention, the condenser section 1 and/or evaporator section 2 may be arranged as a flat multiport tube structure in which functionally different channel sections are attached to each other by a flat web that extends between the channel sections in the plane of the multiport tube structure. For example, the evaporator section may include one or more flat multiport tube structures that each have at least one evaporation channel section joined to a liquid return path section by a flat web that extends in a plane of the multiport tube structure. Alternately, or in addition, the condenser section may include one or more flat multiport tube structures that each have at least one condensing channel section joined to a vapor supply path section by a flat web that extends in a plane of the multiport tube structure. By having the different sections joined by a flat web, heat transfer between the sections may be minimized, particularly if the web is made very thin, discontinuous and/or of a material having a relatively low thermal conductivity. Reduced heat transfer may provide advantages, such as helping to ensure proper thermal performance of the thermosiphon device 10 and suitable vapor and liquid flow. For example, reduced heat transfer between a liquid return path section and an evaporation channel section may help maintain working fluid in liquid form in the liquid return path, thereby helping ensure proper flow circulation in the thermosiphon device. Similar is true for the condensing channel section and the vapor supply path, i.e., reduced heat transfer may help maintain working fluid in vapor form in the vapor supply path. Moreover, by combining different functional sections of the evaporator and/or condenser sections into a single part, manufacture and assembly can be simplified.

FIGs. 4 and 5 show illustrative embodiments of a flat multiport tube structure that may be employed as part of an evaporator or condenser section in accordance with aspects of the invention. In FIG. 4, the multiport tube 100 includes a first section 101

and a second section 102 that are joined by a flat web 103 that extends between the sections 101, 102 in a plane of the multiport tube 100. The first section 101 in this embodiment includes multiple flow channels, and could function as a set of evaporation channels 22 or condensing channels 12 or other flow conduit. The second section 102 includes a single channel, and could function as a liquid return path 21 or vapor supply path 11 or other flow conduit. Of course, it will be understood that any suitable number of channels may be employed in the first and/or second sections 101, 102. The web 103 may have any suitable width, thickness and/or length, and may be made of any suitable material, which may be different than the material used to form the first and/or second sections 101, 102. For example, a wider and/or thinner web 103 may help reduce heat transfer between the first and second sections 101, 102. As another example, portions of the web 103 may be removed, e.g., punched out, to provide a gap between the first and second sections 101, 102 while still maintaining a mechanical connection between the sections 101, 102. FIG. 5 shows an arrangement in which a gap 104 is provided by removal of a portion of the web 103. While in the FIG. 5 embodiment a portion of the web 103 at an end of the multiport tube 100 is removed, other portions of the web 103 may be removed, such as portions positioned anywhere along a length of the web 103. Thus, one or more gaps 104 may be provided in the web 103, whether to reduce weight, help control heat transfer, reduce cost, and/or other purposes. Also, as discussed more below, a web 103 is not limited to a single flat element that extends between the first and second sections 101, 102 at a center point in the thickness dimension of the multiport tube structure 100 as shown in FIGs. 4 and 5. Instead, for example, the web 103 may be positioned so as to be flush with one or both side surfaces of the first and second sections 101, 102, e.g., so that the first and second sections 101, 102 and the web 103 define a continuous flat, planar surface. Also, two or more webs 103 may be provided, if desired, e.g., with one web 103 positioned flush with a top side surface of the first and second sections 101, 102 and another web 103 positioned flush with a bottom side surface of the first and second sections 101, 102. Where two or more webs 103 are provided and if the webs 103 define a potential flow channel, the flow channel is not employed by the device 10, e.g., the flow channel may contain only air, insulation or other material that is not working fluid for the device 10. An arrangement in which the multiport tube

structure 100 includes webs 103 positioned flush at both side surfaces of the first and second sections 101, 102 may be convenient for manufacture, e.g., because the multiport tube structure 100 may initially be made as a conventional multiport tube, and a portion of the tube that defines one or more flow channels may be arranged to function as the web 103 section, e.g., portions of the tube at the web section may be notched, removed, otherwise altered or simply not employed as a flow channel for the device. Moreover, the web(s) 103 need not be completely flat as shown, but may be corrugated, have a surface texture or be arranged in other ways.

In accordance with another aspect of the invention, providing a gap 104 in a web 103 near an end of a multiport tube 100 may also help define a relationship between the multiport tube 100 and a manifold 3 or other structure to which the multiport tube 100 is attached. For example, FIG. 6 shows an illustrative embodiment of a device 10 that includes a condenser section 1 and an evaporator section 2 that include a multiport tube like that shown in FIG. 5. The manifold ends of the multiport tube structure of the condenser and evaporator sections 1, 2 are inserted into openings of the outer wall of the manifold 3 so that the gap 104 is positioned in the manifold 3. A separation wall 35 in the manifold 3 divides the internal space of the manifold 3 into a vapor chamber 32 and a liquid chamber 31, and ends of the separation wall 35 extend into the gaps 104 of the multiport tubes 100. As a result, the evaporation channels 22 and the vapor supply path 11 are fluidly connected to the vapor chamber 32, and the condensing channels 12 and the liquid return path 21 are fluidly connected to the liquid chamber 31. FIG. 7 shows a perspective view of the manifold 3 without the condenser and evaporator sections 1, 2 engaged with the manifold 3. As can be seen, the outer wall 34 of the manifold 3 has openings 331, 332, 333, 334 to receive portions of the manifold end of the condenser and evaporator sections 1, 2. That is, the openings 331 are arranged to receive a first section 101 of a multiport tube 100 that defines the condensing channels 12, the openings 332 are arranged to receive a second section 102 of a multiport tube 100 that defines the vapor supply path 11, the openings 333 are arranged to receive a first section 101 of a multiport tube 100 that defines the evaporation channels 22, and the openings 334 are arranged to receive a second section 102 of a multiport tube 100 that defines the liquid return path 21. The openings 331 and 332 for each multiport tube 100 are separated by a

solid portion of the outer wall 34 which contacts a leading end of the web 103 of each multiport tube 100 so as to limit the extent to which the manifold end of the multiport tube 100 can be inserted into the manifold 3. Thus, the insertion depth of each multiport tube structure 100 can be relatively easily defined by establishing a desired length for the gap 104, i.e., the multiport tube 100 can be inserted into the manifold 3 until the web 103 contacts the outer wall 43 of the manifold 3.

While the separation wall 35 in the FIGs. 6 and 7 embodiment is arranged as a plate having an S shape with straight ends, the separation wall 35 can be arranged in other ways. For example, FIG. 8 shows a separation wall 35 that includes a folded barb or hairpin clip 351 at ends of the wall 35. FIG. 9 shows another separation wall 35 that includes a folded barb or hairpin clip 351 at ends of the wall 35, but the wall 35 in this case has a different overall shape, e.g., a lazy Z shape. Of course, other shapes for a separation wall 35 are possible. FIG. 10 shows an embodiment similar to that in FIGs. 6 and 7, but employing a separation wall 35 like that in FIG. 8. As can be seen, the barb or clip 351 at ends of the wall 35 engage with the multiport tube structures 100 at the gap 104 so that the multiport tube structures 100 are held in place by friction with the barb or clip 351. This may help hold the multiport tube structures 100 in place in preparation for brazing or other process to securely join the multiport tube structures 100 with the manifold 3.

In another aspect of the invention, a multiport tube structure 100 may include a tooth or other engagement feature to help secure the multiport tube structure 100 in place with respect to a manifold 3 or other element. For example, FIG. 11 shows an illustrative embodiment that includes a tooth 105 formed in the gap 104 at the manifold end of a multiport tube structure 100. In this case, the tooth 105 is formed by removing a section of the web 103 to form both the gap 104 and the tooth 105, but other arrangements are possible, such as welding or otherwise attaching a tooth, barb, tab or other engagement element to the multiport tube structure 100. As can be seen in FIG. 12, the tooth 105 may engage a portion of a separation wall 35 or other component so that the manifold end of the multiport tube structure 100 is captured in engagement with the manifold 3 or other component. In this embodiment, the separation wall 35 is arranged like that shown in FIG. 9, and a distal end of the hairpin clip 351 is captured on



a proximal side of the tooth 105 so that the multiport tube structure 100 is held in place. As a result, the manifold end of each multiport tube structure 100 may be inserted into the manifold 3 until the clip 351 is captured at the proximal end of the tooth 105, ensuring the multiport tube structure 100 is properly positioned in the manifold 3. As  
5 can be seen in FIG. 13, openings 331 in the manifold 3 may be arranged to receive the tooth 105, e.g., to have a relatively small slit extending from the main opening 331 to allow the tooth 105 to pass through.

As noted above, the separation wall 35 and clips or barbs 351 may be arranged in other ways. FIG. 14 shows another illustrative embodiment in which the clips or barbs  
10 351 include a laterally extending portion at a distal end. As can be seen in FIG. 15, a tooth 105 and gap 104 of a multiport tube 100 may be arranged so that the laterally extending portion of the clip or barb 351 is captured on a proximal side of the tooth 105, thereby latching the multiport tube structure 100 in engagement with the manifold 3. As also shown in this embodiment, the gap 104 is made relatively long so that the web 13  
15 does not contact the outer wall 34 of the manifold 3 when the multiport tube structure 100 is properly positioned relative to the manifold 3 with the laterally extending portion of the clip or barb 351 in contact with the tooth 105. Instead, the gap 104 is sized so that jig or spacer elements 106 can be received into the gap 104 at a location outside of the manifold inner space, as can be seen in FIGs. 16 and 17. The spacer elements 106 in this  
20 embodiment are arranged as rectangular bars that may be arranged to define the position of multiple multiport tube structures 100 relative to a manifold 3. After brazing or other attachment of the multiport tube structures 100 to the manifold 3 is complete, the spacer elements 106 may be removed, or the elements 106 may be secured in place as well.

FIG. 18 shows another arrangement for a separation wall 35 that in this  
25 embodiment is made of two parts 35a, 35b that are joined together. One or more openings 35c may be provided in the separation wall 35, e.g., along a section where the parts 35a, 35b are joined together, so that liquid or vapor (in this case liquid) may pass from the condenser section 1 to the evaporator section 2.

As mentioned above, a multiport tube structure 100 may have thermal transfer  
30 structure, such as fins, pins, studs or other structure to aid in heat transfer between a portion of the multiport tube structure 100 and a surrounding environment. For example,

FIG. 19 shows a cross sectional view of a multiport tube structure 100 that includes first and second sections 101, 102 joined by a web 103. Here again, the web 103 is shown extending between first and second sections 101, 102 at a midpoint of a thickness of the first and second sections 101, 102, but such an arrangement is not required. Instead, the web 103 may be positioned at either side surface of the first and second sections 101, 102, may have a thickness equal to the first and second sections 101, 102, may extend at an angle relative to the plane of the multiport tube structure 100 (e.g., so as to extend the thermal pathway of the web 103 while not increasing an overall width of the structure 100), may be corrugated or have another non-flat shape, and others. Thermal transfer structure, such as fins 13, 23, are in thermal contact with the second section 102, which may function as condensing channels 12 or evaporating channels 22. So as to reduce heat transfer with respect to the first section 101, the thermal transfer structure 13, 23 stops short of, and does not contact, the first section 101. FIG. 20 shows a similar arrangement, except that the first section 101 is made thinner than the second section 102, or at least has a surface nearest the thermal transfer structure 12, 23 that is offset from the plane of the surface of the second section 102 to which the thermal transfer structure is attached. This way, a gap is present between the thermal transfer structure 13, 23 and the first section 101, allowing the thermal transfer structure 13, 23 to have a larger size and yet still avoid contact with the first section 101. FIG. 21 shows an arrangement similar to FIG. 19 except that the multiport tube structure 100 includes a flat web 107 that extends outwardly from the second section 102 in a plane of the multiport tube structure 100. This web 107 may serve as thermal transfer structure, e.g., a fin to transfer heat with respect to a surrounding environment, and/or may help protect the thermal transfer structure 13, 23. That is, the thermal transfer structure 13, 23 may be relatively fragile such that portions of the thermal transfer structure 13, 23 can be bent or otherwise damaged with contact. The web 107 may help prevent such contact. FIG. 22 shows another arrangement similar to FIG. 21, except that the multiport tube 100 includes a pair of flat webs 107 that extend away from the second section 102 in a plane of the multiport tube 100. In this embodiment, the webs 107 are positioned so as to be flush with a respective side surface of the first and second sections 101, 102, but could

be arranged in other ways. Also, the thermal transfer structure 13, 23 may be thermally connected to one of the flat webs 107, which may aid in thermal transfer.

While in the embodiments above, the multiport tubes 100 included only first and second sections 101, 102 arranged to carry fluid, embodiments are not limited in this regard. For example, FIG. 23 shows a multiport tube structure 100 that includes second and third sections 102, 108 that are joined to a first section 101 by respective webs 103. As noted above, such an arrangement may be useful where at least some degree of thermal isolation between the first section 101 and the second and third sections 102, 108 is desired. It should also be understood that each section 101, 102, 108 may include any suitable number of channels, e.g., 1, 2, 3, 5, 10, 20, etc. This embodiment also includes flat webs 107 that extend outwardly from the second and third sections 102, 108. These webs 107 may aid in thermal transfer, provide strength and/or perform other functions.

FIG. 24 shows an illustrative embodiment that employs a multiport tube structure 100 like that in FIG. 23 in the condenser section 1. In this example, the first section 101 of the multiport tube structure 100 functions as a vapor supply path 11 and provides working vapor to a turnaround 14 (which may be a tubular manifold that connects to multiple multiport tube structures 100). The vapor is then distributed to the second and third sections 102, 108 which function as condensing channels 12. Condensed working fluid, i.e., liquid, passes downwardly into liquid chambers 31 of the manifold 3 and to a liquid return path 21 of the evaporator section 2. The liquid is delivered to a turnaround 24 (which may be a tubular manifold that connects to multiple evaporation channels 22 and liquid return paths 21), which supplies evaporator channels 22 with working fluid in liquid form. Heat received by the working fluid evaporates the liquid, and the vapor travels upwardly to a vapor chamber 32 of the manifold and to the first section 101. The evaporation channels 22 and liquid return path 21 may be arranged in any suitable way, e.g., may include one or more multiport tube structures like that in FIG. 5, a single flow channel conduit, etc.

FIG. 25 shows a close up view of the manifold 3 of the FIG. 24 embodiment. As described above, the internal space of the manifold 3 is divided into three chambers, i.e., a vapor chamber 32 and two liquid chambers 31. Since in this embodiment the liquid return path 21 is connected only to the liquid chamber 31 on the right in FIG. 25, some

provision must be made to fluidly connect the two liquid chambers 31. In accordance with an aspect of the invention, the manifold includes an end cap 5 that includes an inner plate 54 with first and second openings 55 and an outer plate 56. The inner plate 54 is attached inside the manifold 3 so as to sealingly engage the ends of the separation walls 35 and the inner side of the manifold outer wall 34 so as to isolate the vapor chamber 32 from the liquid chambers 31. The outer plate 56 is then attached to the end of the outer wall 34 of the manifold 3. Since the inner plate 54 is inset from the end of the manifold 3, a space is provided between the outer plate 56 and the inner plate 54 so that the openings 55 are fluidly connected to each other, thereby fluidly connecting the liquid chambers 31. In embodiments where a liquid return path 21 is connected to both liquid chambers 31, the openings 55 may be eliminated. In such a case, a relatively small opening may be provided in the inner plate 54 to allow fluid communication between the vapor chamber 32 and the space between the outer plate 56 and the inner plate 54. This opening allows for equalization of pressure in the space between the outer plate 56 and the inner plate 54 and the vapor chamber 32, which can help prevent bowing of the inner plate 54 due to pressure in the vapor chamber 32. This can help ensure the inner plate 54 maintains a suitable seal with the separation wall(s) 35.

FIG. 26 shows a close up view of the manifold in the FIG. 24 embodiment. The separation walls 35 are inset from the end of the outer wall 34 of the manifold 3 by a distance that approximately defines the offset between the inner and outer plates 54, 56. That is, the inner plate 54 fits inside of the outer wall 34 and contacts the ends of the separation plates 35 so that the inner plate 54 is inset relative to the end of the outer wall 34. Thus, when the outer plate 56 is attached to the end of the outer wall 34, the outer plate 56 is separated from the inner plate 54 so that a chamber is defined between the inner and outer plates 54, 56. This chamber provides the fluid communication between the openings 55. The manifold is also shown as having openings 331, 332, 333, 334. Much like in the FIG. 7 embodiment, these openings respectively receive the first section 101 and second and third sections 102, 108 of the condenser section 1, the liquid return path 21 and the evaporation channels 22.

FIGs. 27 and 28 show an alternate embodiment for an end cap 5. In an embodiment where the separation wall(s) 35 in a manifold 3 extend so as to be flush with

the end of the outer wall 34 of the manifold 3, the end cap 5 may be arranged differently from that described above. Specifically, if the separation wall(s) 35 are not inset from the end of the outer wall 34, the end cap 5 may be arranged to provide a flow path between the openings 55. In the illustrative embodiment of FIGs. 27 and 28, the inner plate 54 has a larger diameter than in the above embodiment (e.g., equal or greater than the diameter of the manifold 3), and the outer plate is arranged to include a cylindrical wall element 56 and a flat plate 57. As can be seen in FIG. 28, the inner plate 54 may be attached to the cylindrical wall element 56 so that the inner plate 54 is spaced from the flat plate 57. The inner plate 54 can then be attached to the ends of the outer wall 34 and the separation wall(s) 35 to close the manifold 3. In an embodiment where the openings 55 are eliminated, the inner plate 54 may have a small opening to allow fluid communication between the vapor chamber 32 and the space between the flat plate 57 and the inner plate 54, as discussed above.

In another illustrative embodiment, both a condenser section and an evaporator section may be made from a single multiport tube structure. Moreover, the condenser section may include a vapor supply path separate from one or more condensing channels, and the evaporator section may include a liquid return path that is separate from one or more evaporation channels. For example, FIG. 29 shows a thermosiphon device 10 that includes a multiport tube structure 100 that defines the condenser section 1 and the evaporator section 2. FIG. 30 shows essentially the same arrangement except that the multiport tube structure 100 is bent to form an angled device 10. FIG. 31 shows a perspective view of a multiport tube structure 100 that may be used to form the devices 10 in FIGs. 29 and 30. The first section 101 includes three channels in this embodiment and may form the vapor supply path 11 and the evaporator section 22. The second section 102 includes five channels in this embodiment and may form the condensing channels 12 and the liquid return path 21. Of course, other numbers of channels may be used as desired. The first and second sections 101, 102 are joined by a web 103 that extends in a plane of the multiport tube structure 100, and may be solid, include one or more gaps 104 (not shown) along its length, etc. As can be seen in FIGs. 29 and 30, thermal transfer structure 13, 23 is thermally coupled to portions of the first section 101 that defines the evaporation channels 22 and to portions of the second section 102 that

defines the condensing channels 12. As described above, the thermal transfer structure 13, 23 may enhance heat transfer for the sections to which the structure 13, 23 is thermally coupled. The multiport tube structure 100 may include outer webs 107 that extend outwardly in the plane of the multiport tube structure 100 from the first and second sections 101, 102. These webs 107 may help transfer heat and/or provide protection for the thermal transfer structure 13, 23. The web 107 shown on the left in FIG. 31 includes a bumper section 107a that extends in a thickness direction of the multiport tube structure 100 and may help protect thermal transfer structure 13, 23. Of course, the webs 107 may be eliminated, altered in size and/or thickness and/or material, notched or selectively removed in sections, etc.

At opposite ends of the multiport tube structure 100, the first and second sections 101, 102 are fluidly coupled by turnarounds that are defined by manifolds 141, 142 for the condenser section 1 and manifolds 241, 242 for the evaporator section 2. The manifolds 141, 142 and 241, 242 may be fluidly coupled to each other by one or more conduits 143 so that vapor or liquid can pass.

FIG. 32 shows a perspective view of a thermosiphon device 10 arranged like that in FIG. 30, but has a plurality of multiport tube structures 100 arranged in parallel and communicating with the manifolds 141, 142 and 241, 242. Thermal transfer structure 23 may be thermally coupled to adjacent pairs of evaporation channels 22 and may be arranged to allow for air or other fluid flow between the multiport tube structures 100. Thermal transfer structure 13 may be similarly arranged for the condenser section 1, but cannot be seen in FIG. 32.

FIG. 33 shows one of the manifolds 141 of the FIG. 32 embodiment and illustrates how the manifold 141 may include a plurality of openings 143 to receive a manifold end of a multiport tube structure 100, and openings 144 that connect to a conduit 143 (such as a pipe) that provides fluid coupling between the manifold 141 and the manifold 142. The other manifolds 142, 241 and 242 may be similarly arranged.

FIG. 34 shows an arrangement similar to that in FIG. 29, except that conduits 143 that provide fluid coupling between the manifolds 141, 142 and 241, 242 are eliminated. Instead, the manifolds 141, 142 and 241, 242 are butted up against each other so that the manifolds 141, 142 and 241, 242 may communicate directly through the openings 144.

FIG. 35 illustrates how the manifolds 141, 142 may be joined together such that the openings 144 in each manifold are aligned to provide fluid communication between the manifolds 141, 142. While the embodiment of FIG. 34 has a flat or planar arrangement, the manifold arrangement may be employed in a bent configuration like that in FIG. 30 or other device 10 configurations. Of course, one potential benefit of the arrangement in FIG. 29 as compared to the FIG. 34 embodiment is that the vapor conducting portions (the evaporation channels 22 and vapor supply path 11) may be further distanced from, and better thermally separated from, the liquid conducting portions (the condensing channels 12 and liquid return path 21).

In accordance with another aspect of the invention, a thermosiphon device may have an evaporator section or condenser section that includes a flat multiport tube structure having a section defining a plurality of adjacent flow channels and one or more flat webs that extend away from the flow channels in a plane of the multiport tube structure. For example, FIGs. 36 and 37 show a thermosiphon device 10 that has a plurality of multiport tube structures 100 that form the condenser section 1 and a plurality of multiport tube structures 100 that define evaporation channels 22 for the evaporator section 2. The multiport tube structures 100 may have an arrangement like that shown in FIG. 38 in which a first section 101 includes one or more flow channels, e.g., to define condensing channels or evaporation channels, and one or more flat webs 107 that extend outwardly from the flow channels in a plane of the multiport tube structure 100. The webs 107 may function as thermal transfer structure, e.g., to transfer heat with respect to working fluid in the flow channels. The multiport tube structures 100 of the condenser section 1 may each have a manifold end fluidly coupled with a manifold 3, e.g., to receive working fluid vapor and deliver condensed working fluid liquid. An upper end of the multiport tube structures 100 may be fluidly coupled to a turnaround 14, such as a tubular manifold. The multiport tube structures 100 of the evaporator section 2 in this embodiment are rotated 90 degrees about a vertical axis relative to the multiport tube structures 100 of the condenser section 1 and also have a manifold end fluidly coupled to the manifold 3, e.g., to deliver working fluid vapor to the manifold 3. The webs 107 of the multiport tube structures 100 of the evaporator section 2, along with a surface of the first section 101, may provide a surface to which heat

generating components such as electronic devices, can be mounted so that heat can be transferred to the webs 107, and thus to the working fluid in the evaporation channels 22. In this embodiment, a pair of liquid return path conduits 21 fluidly couple the manifold 3 and a turnaround 24 (e.g., a tubular manifold) so that condensed working fluid is  
5 delivered to the turnaround 24 and thus to the evaporation channels 22. The liquid return path conduits 21 may be arranged as a multiport tube structure 100 as well, or may be single lumen conduit with no web. In this embodiment, the condensing channels 12 operate as a counterflow device in which vapor travels upwardly through the condensing channels 12 while condensed liquid travels downwardly in the condensing channels 12.  
10 However, a dedicated vapor supply path could be provided, if desired, e.g., in a way similar to embodiments described above or otherwise.

One advantage to using a multiport tube structure 100 for the evaporator and/or condenser sections 2, 1 is that the web(s) 107 may be used to define an insertion depth of the multiport tube structure 100 with respect to a manifold. For example, FIG. 39 shows  
15 the manifold 3 of the FIG. 36 embodiment with a plurality of openings 331 to receive the first section 101 of a respective multiport tube structure 100. While the first section 101 is received into the opening 331, one or more webs 107 of the multiport tube structure 100 may contact the outer wall 34 of the manifold 3 and function as a stop to define the insertion depth of the first section 101 into the manifold 3. This function can be  
20 particularly useful when assembling a thermosiphon device 10 and ensuring that certain portions of the device 10, such as a set of evaporation channels 22, are inserted further into a manifold 3 than other portions of the device 10, such as a liquid return path 21. This relative relationship of the evaporation channels 22 and liquid return path 21 can be seen in FIG. 37 and helps ensure that liquid flows downwardly into the liquid return path  
25 21 rather than the evaporation channels 22. As a result, assembly of the device 10 can be simplified since the multiport tube structures 100 may be inserted into a manifold until a stop is contacted and then secured in position.

While FIG. 38 shows one illustrative embodiment for a multiport tube structure 100 and outer web arrangement, other arrangements are possible. For example, FIG. 40  
30 shows another configuration in which a pair of webs 107 are positioned so as to be flush with one side surface of the first section 101. Such a configuration may be useful, for



example, when attaching a heat generating component, heat plate or other structure to the multiport tube structure 100. Other arrangements are possible too, including a multiport tube structure 100 with webs 107 extending from both side surfaces of the first section 101, etc. FIG. 41 shows another arrangement in which webs 107 have portions that  
5 extend outwardly from the first section 101 in the plane of the first section 101, and have upwardly extending portions arranged perpendicular to the plane of the multiport tube structure 100. Such an arrangement may increase the surface area of the webs 107 while reducing the overall width of the multiport tube structure 100, and could be used for the evaporation channels 22 in the FIG. 36 embodiment. FIG. 42 shows yet another  
10 arrangement for a multiport tube structure 100 in which the webs 107 have a thickness equal to the first section 101. Thus, the webs 107 are flush with both side surfaces of the first section 101. One possibility for such an arrangement is to provide thermal transfer structure 13, 23, such as one or more fins, that are thermally coupled to the webs 107 and first sections 101 of adjacent multiport tube structures 100. FIG. 43 shows yet another  
15 arrangement in which webs 107 define a gap 104 near an end of the first section 101. As can be appreciated in FIG. 44, the gaps 104 may help define an insertion distance for the first section 101 into a manifold 3 while the additional surface area of the webs 107 may aid in heat transfer.

While the arrangement in FIG. 44 shows the liquid return path 21 and  
20 evaporation channels 22 in communication with a turnaround 24, other arrangements are possible such as that shown in FIGs. 45 and 46. In this embodiment, the liquid return path 21 and evaporation channels 22 are formed from bent multiport tube structures 100 so as to obviate the need for a turnaround manifold 24. That is, the multiport tube structures 100 include a bend where the lower end of the liquid return path 21  
25 communicates with the evaporation channels 22. In some cases, any web 107 may be removed from the liquid return path section of the multiport tube structure 100, e.g., to reduce heat transfer. Note in FIG. 46 that the multiport tube structure 100 is bent so that the evaporator channel section extends further into the manifold 3 than the liquid return path section. This helps ensure liquid flows into the liquid return path and not the  
30 evaporation channels.

FIG. 47 shows another illustrative embodiment of a thermosiphon device 10 that employs one or more flat multiport tube structures having a section with a plurality of adjacent flow channels and one or more flat webs that extend away from the flow channels in a plane of the multiport tube structure. In this illustrative embodiment, each flat multiport tube structure 100 defines a set of evaporation channels 22 and a vapor supply path 11, or a set of condensing channels 12 and a liquid return path 21. That is, each multiport tube structure 100 defines a portion of a condenser section 1 and an evaporator section 2. Opposite ends of the multiport tube structures 100 are fluidly coupled to turnarounds 14 and 24, so that vapor flowing upwardly in the vapor supply path 11 of one or more multiport tube structures 100 can enter the turnaround 14 and into the condensing channels 12 of one or more multiport tube structures 100, and so that liquid flowing downwardly in a liquid return path 21 can enter the turnaround 24 and into evaporation channels 22 of one or more multiport tube structures 100. The multiport tube structures 100 may have a cross section like that in FIG. 38, 40, 42, 43, or others. A flange 33 may provide a separation between the condenser and evaporator sections 1, 2, e.g., so that warm air at the evaporator sections 2 is kept away from the condenser sections 1. Thermal transfer structure 13 may be thermally coupled to portions of the multiport tube structures 100 that define condensing channels 12, and thermal transfer structure 23 may be thermally coupled to portions of the multiport tube structures 100 that define evaporation channels 22. However, portions of the multiport tube structures 100 that define a liquid return path or vapor supply path may be free of thermal transfer structure, and in some embodiments portions of a web 107 may be removed from these portions as well to reduce heat transfer. While in this embodiment multiport tube structures 100 that define evaporation channels 22/vapor supply path 11 are interdigitated with multiport tube structures 100 that define condensing channels 12/liquid return path 21, other arrangements are possible, such as clustering multiport tube structures 100 that define evaporation channels 22/vapor supply path 11, or that define condensing channels 12/liquid return path 21 in groups of two or more.

FIG. 48 shows one technique for arranging thermal transfer structure 13, 23 like that shown in FIG. 47. Thermal transfer structure 13 (or 23) may be sandwiched between two adjacent multiport tube structures 100, e.g., squeezed in physical contact

between webs 107 or other portions of the multiport tube structures 100. The thermal transfer structure 13 may include a cladded side 13a and a non-cladded side 13b so that during a brazing, soldering or other similar process, the cladded side 13a is bonded to the adjacent multiport tube structure 100 but the non-cladded side 13b is not bonded to the adjacent multiport tube structure 100. As a result, the thermal transfer structure 13 may better transfer heat with the multiport tube structure 100 on the cladded side 13a than on the non-cladded side 13b.

FIG. 49 shows another thermosiphon device 10 that is arranged similarly to that in FIG. 47, but the upper turnaround 14 is omitted. In its place, the multiport tube structures 100 are bent to provide a turnaround 14 that fluidly connects a vapor supply path section 11 of each multiport tube structure 100 with a condensing channel 21 section of the structure 100. FIG. 50 shows yet another embodiment similar to the FIG. 49 embodiment but with the lower turnaround 24 removed. Instead, the multiport tube structures 100 are bent to provide turnarounds 24 for each section that defines a liquid return path and a section that defines a set of evaporation channels. Since flow in this arrangement will follow a closed loop, a manifold 3 is provided so that liquid returned in the final liquid return path 21 at the extreme right in FIG. 49 can return to the manifold 3 and enter the evaporation channels 22 of the multiport tube structure 100 at the extreme left in FIG. 49. A fill tube 38 is provided to allow the device 10 to be filled with working fluid in liquid form prior to being put into service.

FIG. 51 shows another embodiment of a thermosiphon device 10 that includes a multiport tube structure 100 in an evaporator or condenser section. In this embodiment, the condenser section 1 includes a plurality of multiport tube structures 100 that each defines a set of condensing channels 12 and includes webs 107 extending upwardly and downwardly in the plane of the multiport tube structure 100. The condensing channels 12 are provided with working fluid vapor by a vapor supply path 11 that leads from a set of evaporation channels 22 of the evaporation section 2. As can be seen in FIG. 52, since one end of the condensing channels 12 is positioned higher than the opposite end, condensed working fluid flows into a liquid return path 21 and then to the evaporation channels 22. All of the liquid return path 21, the evaporation channels 22 and the vapor supply path 11 may be formed from a multiport tube structure 100 which may or may not

have a web 107. As shown in FIG. 53, sections of web 107 may be provided for the vapor supply path 11 and the liquid return path 21 so as to define an insertion depth of the tube ends into a respective manifold 3. As can be seen in FIG. 51, manifolds 3 may be employed to fluidly couple the vapor supply path 11 and the liquid return path 21 to the condensing channels 12. FIG. 54 shows a manifold 3 which may include an opening 331 to couple with the section of the multiport tube structure 100 defining condensing channels 12 and an opening 332 to couple with the vapor supply path 11 or the liquid return path 21. The manifolds 3 are needed in this embodiment because the multiport tube structures 100 that define the condensing channels 12 may have a size and/or number of flow channels that is different from the size and/or number of flow channels in the multiport tube structure 100 that defines the liquid return path 21, the evaporation channels 22 and the vapor supply path 11. FIG. 55 shows an end view of a multiport tube structure 100 having a section that defines a plurality of flow channels for the condensing channels 12 and webs 107 extending outwardly from the section in the plane of the multiport tube structure 100. Of course, other numbers of flow channels may be employed. FIG. 56 shows a base plate 25 that may be used with the thermosiphon device 10. In this embodiment, the base plate 25 includes a plurality of grooves 251 that may each receive a set of evaporation channels 22, e.g., which may be welded or otherwise bonded in place to thermally couple the channels 22 with the base plate 25. The base plate 25 may itself be coupled with a heat source, such as one or more heat generating devices and transfer heat to the evaporation channels 22.

FIG. 57 shows an illustrative embodiment of a thermosiphon device 10 similar to that in FIG. 51, except that the device 10 is shown oriented in a more vertical direction than the FIG. 51 embodiment. Similar to the FIG. 51 embodiment, the FIG. 57 embodiment includes a multiport tube structure 100 that defines a plurality of condensing channels 12 and which may have a cross section like that in FIG. 38, 40, 42, 43, or others. Like the FIG. 51 embodiment, all of the liquid return path 21, the evaporation channels 22 and the vapor supply path 11 may be formed from a multiport tube structure 100 which may or may not have a web 107. As shown in FIG. 58, multiple ones of the thermosiphon devices 10 in FIG. 57 may be ganged together into a single thermosiphon device 10, and as can be seen in FIG. 59, the liquid return paths 21

and evaporation channels 22 may be coupled to a common turnaround 24, which may be a tubular manifold. Alternately, or in addition, the manifolds 3 that couple the condensing channels 12 to the vapor supply path 11 and/or the liquid return path 21 may be coupled together by a common manifold 130 as seen in FIG. 59A. Such an arrangement may help balance liquid and vapor flow amongst the parallel units.

FIG. 60 shows another illustrative embodiment of a thermosiphon device 10 that includes a condenser section 1 that operates in a counterflow-type operation (like that in the device 10 of FIG. 36). However, somewhat differently from FIG. 36, the condenser channels 12 of each flat multiport tube structure 100 are fluidly coupled by a manifold 3 at a bottom end and a turnaround 14 at a top end. The multiport tube structures 100 may or may not have a web 107. Also in this embodiment, the evaporator section includes evaporator channels 22 and liquid supply paths 21 that are provided by a plurality of multiport tube structures 100 that may have a cross section like that in FIG. 31. Thus, sections of the multiport tube structures 100 that define the evaporation channels 22 may be joined to sections that define the liquid return path 21 by a web 103. Outer webs 107 and other features may be provided or not.

In another aspect of the invention, a thermosiphon device may include at least one multiport tube structure that defines at least one evaporation channel and at least one condensing channel. The at least one condensing channel may be joined to the at least one evaporation channel by a web that extends between the at least one condensing channel and the at least one evaporation channel in a plane of the multiport tube structure. For example, FIG. 61 shows a thermosiphon device 10 that includes a plurality of multiport tube structures 100 that each includes a plurality of evaporation channels 22 (defined by a first section 101) and a plurality of condensing channels 12 (defined by a second section 102) joined by a web 103. An outer web 107 is also provided in this embodiment that extends outwardly from the second section 102 in a plane of the multiport tube structure 100. Ends of the first and second sections 101, 102 are fluidly coupled to a respective manifold 3. In this embodiment, five multiport tube structures 100 are shown, but more or fewer multiport tube structures 100 could be used. Upper and lower manifolds 3 on opposite sides of the device 10 are fluidly coupled by conduits 37, which may be formed as a multiport tube structure 100, e.g., having a cross

section like that in FIG. 38. As described above, the use of a multiport tube structure 100 for a conduit 37 may help define an insertion depth into the manifolds 3 easier. The first section 101 of each multiport tube structure 100 may be thermally coupled to a base plate 25, e.g., so as to receive heat from the base plate 25. As will be understood, working fluid liquid that is evaporated in the evaporation channel 22 may flow to a lower manifold 3, then flow upwardly through a conduit 37, into an upper manifold 3 and into a condensing channel 21. Condensed working fluid liquid may flow in an opposite direction. The device 10 may be relatively tolerant of tilting or rotation in different directions, i.e., the device 10 may continue to operate properly even when tilted or rotated to limited degrees about various axes parallel to the plane of the base plate 25. This may make the device 10 suitable for a variety of applications or in applications where the device 10 moves in different directions, such as on an airplane.

FIG. 62 shows the device 10 with the manifolds 3 and conduits 37 removed for clarity. As can be seen in FIG. 62 and in FIG. 63, the multiport tube structures 100 may have a cross section in which the web 103 is relatively wide and in which the first section 101 (defining the evaporation channels 22) has fewer flow channels than the second section 102 (defining the condensing channels 12). Of course, other arrangements are possible, including more and few flow channels for either section 101, 102, a web 103 with different dimensions (width, thickness, length) or material, a web 103 with gaps or removed sections, etc. Also, the web 103 and/or web 107 may help define an insertion depth for the first and second sections 101, 102 into a respective manifold 3, as discussed above.

FIG. 64 shows another embodiment of a thermosiphon device 10 that is similar to that in FIG. 61 except that the first and second sections 101, 102 of each multiport tube structure 100 are fluidly coupled by a pair of manifolds 3 and the multiport tube structures 100 are not fluidly coupled together. Another difference is that the cross section of the multiport tube structures 100 is different, as can be seen in FIG. 65. In this example, the web 103 is relatively narrow, and both the first and second sections 101, 102 (defining the evaporation channels 22 and condensing channels 12, respectively) have more flow channels. The manifolds 3 may have slot-like openings to respectively receive the first and second sections 101, 102, and the web 103 may define an insertion

depth for both sections 101, 102 in to the manifold. In contrast to the FIG. 61 embodiment, the FIG. 64 embodiment may be more tolerant of rotation of the device about axes that extend along a length of the multiport tube structures 100. This is because working fluid cannot flow from one multiport tube structure 100 to another.

5 In accordance with another aspect of the invention, a thermosiphon may include a condenser section with a plurality of sets of condensing channels arranged to operate in a counterflow mode. That is, the condensing channels may receive vaporized working fluid at a bottom end, conduct a flow of vapor upwardly in the channels, transfer heat from evaporated liquid to a surrounding environment to condense the vapor to form a  
10 liquid, and conduct the flow of condensed liquid back to the bottom end of the channels. At least two of the plurality of sets of condensing channels may be part of a flat multiport tube structure in which the one set of condensing channels is joined to the another set of condensing channels by a flat web that extends between the sets of condensing channels in a plane of the multiport tube structure. For example, FIG. 66 shows a thermosiphon  
15 device 10 that includes a plurality of sets of condensing channels 12 that are fluidly coupled at a bottom end to a manifold 3. The manifold 3 may be thermally coupled to a base plate 25, e.g., to receive heat to vaporize working fluid liquid in the manifold 3. The vapor then enters the condensing channels 12, is condensed, and returns to the manifold 3.

20 This embodiment includes multiport tube structures 100 that each have three sets of condensing channels 12 (defined by first, second and third sections each with multiple flow channels), as can be seen in FIG. 67. The sets of condensing channels 12 are joined to an adjacent set by a web 103 that extends in a plane of the multiport tube structure 100. The web 103 can not only aid in heat transfer, but also define an insertion depth of  
25 a bottom end of the condensing channels 12 into the manifold 3 and assist in simplifying manufacture of the device 10, e.g., by allowing three condensing channel sets to be mated with the manifold at one time. The upper end of the condensing channels 12 may be closed by crimping, a cap, or other arrangement.

30 While the embodiment in FIG. 66 is shown operating in a horizontal position, the device 10 may operate in other orientations, including orientations in which the device 10 is rotated about an axis parallel to the length of the multiport tube structures 100. For

example, FIG. 68 shows the manifold 3 oriented in a vertical position, e.g., in which the base plate 25 is oriented vertically. The manifold 3 includes bends 301 that are arranged to form a trap 302 that prevents each manifold segment 3 engaged with a multiport tube structure 100 from completely draining of working fluid liquid. As a result, the device

5 10 can continue to operate properly even when tilted up to 90 degrees relative to the horizontal about an axis parallel to the length of the multiport tube structures 100. While the FIG. 66 embodiment includes bends 301 arranged to form a trap 302, trapping liquid in manifold sections can be achieved in other ways. For example, FIG. 69 shows U-bends 301 in a manifold 3 that have a plug 303 positioned at one end of each bend 301.

10 The plug 303 has an opening at one side so that the plug 303 functions to trap liquid in the manifold section up to the level of the opening in the plug. 303.

While the FIG. 66 embodiment shows the condenser channel sets extending upwardly generally perpendicularly to the base plate 25, other arrangements are possible. For example, FIG. 70 shows a modification of the FIG. 66 embodiment in which the

15 condensing channels 12 are arranged at an angle  $\theta$  relative to the vertical with the base plate 25 arranged horizontally. This arrangement allows the device 10 to operate in the horizontal orientation shown in FIG. 70, and a vertical orientation shown in FIG. 71 in which the base plate 25 is vertical, and other tilt angles between the horizontal and vertical. That is, the inclination angle of the condensing channels 12 ensures that the

20 condensing channels 12 drain condensed liquid even when the device 10 is in the vertical position. Accordingly, the FIG. 70 arrangement is adapted for a variety of different orientations. Note that FIG. 72 shows a perspective view of the base plate 25 having grooves 251 to receive manifold sections 3 which may be thermally coupled to the base plate 25. The base plate 25 is not required, and can be omitted, or can be altered in size,

25 shape and/or material. If the base plate 25 is omitted, the orientation of the device 10 may be referenced based on a plane of the manifold 3, e.g., a plane that passes through manifold sections engaged with condensing channel sets.

FIG. 73 shows another thermosiphon device 10 that can be operated in a variety of different orientations. This embodiment also includes a plurality of multiport tube

30 structures 100 that each includes four sets of condensing channels 12 that are fluidly coupled at a bottom end to a manifold 3. A perspective view of a multiport tube



structure 100 is shown in FIG. 74. The manifold 3 in this embodiment (see FIG. 75) includes a sheet with convex features having openings 331 to receive a condensing channel section of the multiport tube structure 100. The manifold sheet 3 is coupled to a base plate 25, which has channels 251 that correspond to the convex features. Together  
5 the sheet and the base plate 25 form a manifold with flow channels for working fluid. The FIG. 73 embodiment can operate in a horizontal orientation shown in FIG. 73, as well as a vertical orientation shown in FIG. 76. The device 10 operates in this orientation, in part, because the channels 251 are shaped and cooperate with the manifold sheet 3 so as to provide a cavity 252 adjacent the end of each condensing channel set to  
10 receive and hold liquid working fluid. (Without the cavities 252, the condensing channels 12 might flood with liquid, decreasing their effectiveness.) The device 10 can even operate when flipped over in a vertical orientation shown in FIG. 77. Again, the channels 251 are shaped and cooperate with the manifold sheet 3 to define a cavity 253 to receive and hold liquid, allowing the device to operate. While in these embodiments,  
15 the condensing channels 12 extend generally perpendicularly relative to the base plate 25, the condensing channel sets may extend at other angles relative to the plane of the base plate 25. Also, the base plate 25 may be arranged in other ways, e.g., as shown in FIGs. 78 and 79. In this embodiment, the base plate 25 is formed from a sheet that is bent to form the channels 251 and other structure of the base plate 25. FIG. 80 shows  
20 another modification in which the base plate 25 includes a single cavity 251 that spans multiple convex features of the manifold sheet 3. To aid in desirably moving liquid working fluid in the cavity 251, a wicking element 255 is provided, e.g., to help distribute fluid by wicking and/or to increase a surface area of the working fluid and enhance boiling.

25 FIG. 81 shows a thermosiphon device 10 that is similar to that in FIG. 66 with the major difference being that the manifold sections 3 are fluidly coupled by conduits 304 rather than bends 301. A close up view of the conduits 304 is shown in FIG. 82, and the conduits 304 may be arranged as shown in FIG. 83, e.g., as a multiport tube structure 100 with a first section 101 defining one or more flow channels and a pair of webs 107  
30 extending outwardly from the first section 101. The webs 107 may help define an insertion depth of the conduits 304 into the manifold sections 3. FIG. 84 shows a close

up view of a conduit 304 and how the webs 107 define an insertion depth **D** into a manifold section 3. This insertion depth **D** may help trap working fluid liquid in manifold sections 3 when the device is tilted, e.g., to a vertical position as shown in FIG. 84, thereby helping keep the device 10 in efficient operation even in a tilted orientation.

5           FIG. 85 shows another arrangement to help trap liquid in a manifold 3. In this embodiment, the inner wall of the manifold 3 includes an internal thread feature 307 that helps trap liquid in the manifold 3, e.g., in the thread grooves. Thus, the thread feature 307 may help keep a manifold section from completely draining, thereby making working fluid liquid available for evaporation and heat transfer. In another illustrative  
10           embodiment, the internal thread feature 307 may be provided by a coil element, such as that shown in FIG. 86, rather than a thread groove formed in the inner wall of the manifold 3. The coil element may be brazed or otherwise secured in place, or held by friction or interference fit in the manifold 3. A brazed, adhered or other similar  
15           connection may aid in preventing liquid flow in any space between the coil element and the inner wall of the manifold 3. The additional surface area of the thread or coil feature exposed to the liquid may enhance heat transfer.

          FIG. 87 shows another thermosiphon device 10 that is similar in operation to the FIG. 66 embodiment in that a plurality of condensing channel sets operate in a counterflow mode. However, in this embodiment, the manifold 3 has a circular tube, and  
20           the condensing channels are arranged in a multiport tube structure like that shown in FIG. 38. Also, the manifold 3 includes a plurality of plugs 303 that help trap working fluid liquid in desired areas of the manifold 3, e.g., at or near the condensing channels 12 of each multiport tube structure 100. FIG. 88 shows the manifold 3 alone with plugs 303 positioned between each opening 331 to receive a corresponding manifold end of a  
25           multiport tube structure 100. FIG. 89 shows a plug 303 with an opening 303a. The plug 303 is positioned in the manifold 3 so that the opening 303a is positioned to control a depth of liquid in the manifold in adjacent sections. In an alternative embodiment shown in FIG. 90, the plugs 303 may be replaced with a wicking element 255 that functions to encourage flow of liquid in the manifold 3.

30           FIG. 91 shows another illustrative embodiment of a thermosiphon device 10 that operates similarly to that in FIG. 87, except that the circular manifold 3 is replaced with

a manifold 3 having a cylindrical chamber shape. As can be seen in FIG. 92, the manifold 3 may include a wicking element 255 to encourage and spread flow of the liquid working fluid in the manifold 3. Alternately, as shown in FIG. 93, the manifold 3 may include a plurality of cavities 306 at a bottom of the manifold 3 to hold working fluid liquid. The cavities 306 may increase a surface area exposed to the liquid, thereby enhancing heat transfer. The working fluid liquid level in the manifold 3 may be maintained above a top level of the cavities 306 to ensure that the cavities 306 are all filled with liquid.

FIG. 94 shows yet another embodiment of a thermosiphon device 10 that includes a plurality of multiport tube structures with sections to define sets of condensing channels 12. In this case, each multiport tube structure 100 has three sections that define condensing channels 12, and adjacent sections are joined by a web 103. The manifold 3 is arranged as a bent tube and includes one or more plugs 303 with openings 303a positioned to trap liquid in desired sections of the manifold at a desired level. As in other embodiments, the manifold 3 has openings to receive a manifold end of each condenser channel set, and the webs 107 and/or 103 may help define an insertion depth of the manifold ends into the manifold. Plugs 303 may be positioned in the manifold 3 between each condensing channel set, and may be arranged to trap liquid so that the device 10 can operate properly even when tilted through a wide variety of angles and in a wide variety of directions. In fact, the device 10 may operate in a vertical orientation as shown in FIG. 94, at a horizontal orientation shown in FIG. 95, or other orientations in between.

The embodiments provided herein are not intended to be exhaustive or to limit the invention to a precise form disclosed, and many modifications and variations are possible in light of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Although the above description contains many specifications, these should not be construed as limitations on the scope of the invention, but rather as an exemplification of alternative embodiments thereof.

The indefinite articles “a” and “an,” as used herein in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean “at least one.”

5       The phrase “and/or,” as used herein in the specification and in the claims, should be understood to mean “either or both” of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with “and/or” should be construed in the same fashion, i.e., “one or more” of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the “and/or” clause, whether related or  
10       unrelated to those elements specifically identified.

      The use of “including,” “comprising,” “having,” “containing,” “involving,” and/or variations thereof herein, is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

      It should also be understood that, unless clearly indicated to the contrary, in any  
15       methods claimed herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited to the order in which the steps or acts of the method are recited.

      While aspects of the invention have been described with reference to various illustrative embodiments, such aspects are not limited to the embodiments described.  
20       Thus, it is evident that many alternatives, modifications, and variations of the embodiments described will be apparent to those skilled in the art. Accordingly, embodiments as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit of aspects of the invention.

## CLAIMS

1. A thermosiphon device including:  
an evaporator section arranged to receive heat and evaporate a liquid; and  
5 a condenser section arranged to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid;  
the device comprising at least one flat multiport tube structure having a first section defining one or more flow channels, a second section defining one or more flow channels, and a web that extends between the first and second sections in a plane of the  
10 multiport tube structure,  
wherein the first section defines one or more evaporation channels, and the second section defines one or more evaporation channels, one or more condensing channels, or a liquid return path of the evaporator section, OR the first section defines one or more condensing channels, and the second section defines one or more  
15 evaporation channels, one or more condensing channels, or a vapor supply path of the condenser section.
2. The device of claim 1, wherein the evaporator section includes at least one evaporation channel arranged to receive heat and evaporate a liquid in the at least one  
20 evaporation channel and a liquid return path for delivering condensed liquid to the at least one evaporation channel; and  
the condenser section includes at least one condensing channel arranged to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid and a vapor supply path for delivering evaporated liquid to the at least  
25 one condensing channel;  
wherein the at least one evaporation channel and the liquid return path are part of a flat multiport tube structure in which the first section defines the at least one evaporation channel and the second section defines the liquid return path, and the at least one condensing channel and the vapor supply path are part of a flat multiport tube  
30 structure in which the second section defines at least one condensing channel and the first section defines the vapor supply path.

3. The device of claim 2, further comprising at least one manifold fluidly connecting the at least one evaporation channel with the vapor supply path and fluidly connecting the at least one condensing channel with the liquid return path.

5

4. The device of claim 3, wherein the manifold includes an outer wall that defines an interior cavity and a separation wall positioned in the interior cavity to separate the interior cavity into a vapor chamber and a liquid chamber.

10

5. The device of claim 4, wherein the outer wall includes separate respective openings to receive a manifold end of the first section defining the at least one evaporation channel, the second section defining the liquid return path, the second section defining the at least one condensing channel and the first section defining the vapor supply path.

15

6. The device of claim 5, wherein the separation wall is positioned in the manifold such that the at least one evaporation channel is in fluid communication with the vapor chamber and the liquid return path is in fluid communication with the liquid chamber.

20

7. The device of claim 6, wherein the separation wall is positioned such that the at least one condensing channel is in fluid communication with the liquid chamber and the vapor supply path is in fluid communication with the vapor chamber.

25

8. The device of claim 5, wherein the device includes a plurality of flat multiport tube structures that each include a first section that defines at least one evaporation channel and a second section defines the liquid return path, and a plurality of flat multiport tube structures that each include a second section that defines at least one condensing channel and a first section defines the vapor supply path.

30

9. The device of claim 8, wherein the separation wall is positioned such that the evaporation channels are in fluid communication with the vapor chamber and the liquid return paths are in fluid communication with the liquid chamber.

5           10. The device of claim 9, wherein the separation wall is positioned such that the condensing channels are in fluid communication with the liquid chamber and the vapor supply paths are in fluid communication with the vapor chamber.

10           11. The device of claim 2, wherein a single flat multiport tube structure includes the first section that defines the at least one evaporation channel and the vapor supply path, and the second section that defines the liquid return path and the at least one condensing channel.

15           12. The device of claim 11, comprising a plurality of flat multiport tube structures that each include a first section that defines at least one evaporation channel and a vapor supply path, and a second section that defines a liquid return path and at least one condensing channel.

20           13. The device of claim 1, wherein the flat multiport tube structure includes a lateral web that extends outwardly from the first or second section in a plane of the flat multiport tube structure.

            14. The device of claim 1, wherein the first section defines a plurality of evaporator channels and the second section defines the liquid return path.

25           15. The device of claim 1, wherein the first section defines a plurality of condenser channels and the second section defines the vapor supply path.

30           16. The device of claim 1, wherein the first section defines a plurality of condenser channels and the second section defines a plurality of condenser channels.

17. The device of claim 1, wherein the first section defines a plurality of evaporation channels and the second section defines a plurality of condenser channels.

18. The device of claim 1, wherein the first section defines a plurality of  
5 condenser channels and the second section defines the vapor supply path, wherein the multiport tube structure further comprises a third section that defines a plurality of condenser channels and a second web that extends between the second and third sections in a plane of the multiport tube structure.

10 19. The device of claim 18, wherein the multiport tube structure further comprises a lateral web that that extends outwardly from the first or third section in a plane of the flat multiport tube structure.

20. The device of claim 18, further comprising a plurality of the multiport tube  
15 structures, an upper manifold that fluidly couples upper ends of the first, second and third sections of the multiport tube structures, and a lower manifold that fluidly couples lower ends of the first, second and third sections of the multiport tube structures.

21. The device of claim 20, further comprising a pair of separation walls  
20 positioned in the manifold to define a vapor chamber and two liquid chambers and such that the second section is in fluid communication with the vapor chamber and the first and third sections are in fluid communication with a respective liquid chamber.

22. The device of claim 21, wherein the evaporator section includes a plurality of  
25 evaporation channels in fluid communication with the vapor chamber and a liquid return path in fluid communication with a liquid chamber.

23. The device of claim 22, further comprising an end cap engaged with the manifold so as to provide fluid communication between the liquid chambers.

30



24. The device of claim 1, further comprising a plurality of multiport tube structures where in each first section defines a plurality of evaporation channels and each second section defines a plurality of condenser channels, the device further comprising a manifold that fluidly couples the first and second section of each multiport tube structure.

25. The device of claim 24, further comprising a plurality of manifolds, each manifold fluidly connecting the first and second sections of a multiport tube structure together.

26. The device of claim 24, wherein the flat multiport tube structures each further include an outer web that extends from the second section in a plane of the flat multiport tube structure.

27. The device of claim 24, further comprising a base plate to which the first sections are thermally connected.

28. The device of claim 1, wherein the first section defines a plurality of condenser channels and the second section defines a plurality of condenser channels, the device further comprising a manifold fluidly coupled to a manifold end of the first and second sections and arranged to provide working fluid vapor to the condenser channels and to receive condensed working fluid liquid from the condenser channels.

29. The device of claim 1, further comprising a manifold fluidly connected to a manifold end of the first and second sections, and wherein a portion of the web at the manifold end acts as a stop to limit an insertion depth of the manifold end into the manifold.

30. A thermosiphon cooling device including:  
an evaporator section arranged to receive heat and evaporate a liquid; and

a condenser section arranged to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid;

the device comprising at least one flat multiport tube structure having a first section defining one or more flow channels, and a web that extends laterally away from the first section in a plane of the multiport tube structure,

wherein the first section defines a plurality of evaporation channels or a plurality of condenser channels.

31. The device of claim 30, wherein the first section defines a plurality of evaporation channels, the device further comprising a manifold fluidly coupling the plurality of evaporation channels and the condenser section.

32. The device of claim 30, wherein the first section defines a plurality of condensing channels, the device further comprising a manifold fluidly coupling the plurality of condensing channels and the evaporator section.

33. The device of claim 30, comprising first and second webs that extend laterally away from opposite sides of the first section in a plane of the multiport tube structure.

20

34. The device of claim 30, further comprising a manifold fluidly coupled to a manifold end of the first section, wherein a portion of the web at the manifold end acts as stop to limit an insertion depth of the manifold end into the manifold.

35. The device of claim 30, comprising a plurality of multiport tube structures that each include a first section defining a plurality of condensing channels, the device further comprising a manifold fluidly coupling manifold ends of the first sections of the plurality of multiport tube structures and the evaporator section.

36. The device of claim 35, further comprising a turnaround fluidly coupling upper ends of the first sections of the plurality of multiport tube structures.

37. The device of claim 36, wherein the evaporator section includes a plurality of evaporator channels and a liquid return path.

5           38. The device of claim 37, wherein the evaporator section includes a plurality of multiport tube structures that each include a first section defining a plurality of evaporation channels, a manifold end of the multiport tube structures being fluidly coupled to the manifold.

10           39. The device of claim 30, comprising a first multiport tube structure having a first section defining a plurality of evaporation channels of the evaporator section and a vapor supply path of the condenser section, and a second multiport tube structure having a first section defining a plurality of condensing channels of the condenser section and a liquid return path of the evaporator section.

15           40. The device of claim 39, comprising thermal transfer structure attached to the first multiport tube structure only at a portion of the first section that functions as a plurality of evaporation channels, and thermal transfer structure attached to the second multiport tube structure only at a portion of the first section that functions as a plurality  
20 of condenser channels.

          41. The device of claim 39, comprising an upper turnaround that fluidly couples an upper end of the first multiport tube structure to an upper end of the second multiport tube structure, and a lower turnaround that couples a lower end of the first multiport tube  
25 structure to a lower end of the second multiport tube structure.

          42. The device of claim 41, wherein the upper or lower turnaround is formed by a manifold or a bend in the multiport tube structures.

30           43. The device of claim 30, wherein the first section defines a plurality of condensing channels, and the evaporator section includes a multiport tube structure that

defines a plurality of evaporation channels, the device further comprising a vapor supply path and a liquid return path fluidly coupling the plurality of condensing channels and the plurality of evaporation channels.

5           44. The device of claim 43, wherein the vapor supply path, liquid return path and the plurality of evaporation channels are formed as part a single multiport tube structure.

          45. The device of claim 43, further comprising manifolds fluidly coupled to the first section at opposite ends of the multiport tube structure.

10

          46. A thermosiphon cooling device including:

          a condenser section including a plurality of sets of condensing channels arranged to operate in a counterflow mode to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid; and

15           at least one conduit fluidly connected to the plurality of sets of condensing channels arranged to provide working fluid vapor to the plurality of sets of condensing channels and to receive condensed working fluid liquid from the plurality of sets of condensing channels,

          wherein at least one of the plurality of sets of condensing channels is part of a flat  
20 multiport tube structure that has a web that extends from a set of condensing channels in a plane of the multiport tube structure.

          47. The device of claim 46, further comprising an evaporator section including at least one evaporation channel arranged to receive heat and evaporate a liquid in the at  
25 least one evaporation channel.

          48. The device of claim 47, further comprising a liquid return path for delivering condensed liquid to the at least one evaporation channel.

30           49. The device of claim 48, wherein the liquid return path and the at least one evaporation channel are fluidly coupled to the at least one conduit.

50. The device of claim 49, wherein the at least one evaporator section includes a multiport tube structure having a first portion defining a plurality of evaporation channels and including a web that extends from the first portion in a plane of the multiport tube structure.

51. The device of claim 50, wherein the web extends between the first section and a second section of the multiport tube structure that defines the liquid return path.

52. The device of claim 46, wherein at least two of the plurality of sets of condensing channels are part of a flat multiport tube structure in which the one set of condensing channels is joined to the another set of condensing channels by a flat web that extends between the sets of condensing channels in a plane of the multiport tube structure.

53. The device of claim 52, wherein at least three of the plurality of sets of condensing channels are part of a flat multiport tube structure in which adjacent pairs of the sets of condensing channels are joined by a flat web that extends between the sets of condensing channels.

54. The device of claim 46, wherein the at least one conduit includes multiple manifold sections that are fluidly coupled together, each manifold section being fluidly coupled to a corresponding set of condensing channels.

55. The device of claim 54, further comprising a trap or plug between manifold sections to resist liquid flow from one manifold section to another manifold section.

56. The device of claim 46, wherein adjacent manifold sections are fluidly coupled by a conduit having a flat tube section and webs extending outwardly from opposite ends of the flat tube section.

57. The device of claim 46, wherein the plurality of sets of condensing channels are arranged at an angle between 0 and 90 degrees relative to a plane of the at least one conduit.

5 58. The device of claim 46, wherein the at least one conduit includes a base plate having a plurality of channels and a sheet that is attached to the base plate so as to close the plurality of channels.

59. The device of claim 58, wherein the channels and the sheet are formed to  
10 define cavities adjacent a set of condensing channels with the device oriented in a vertical orientation.

60. The device of claim 46, wherein at least one of the plurality of sets of condensing channels is part of a flat multiport tube structure that has a first section  
15 defining a plurality of condensing channels and first and second flat webs that extend away from the first section in a plane of the multiport tube structure on opposite sides of the first section.

61. The device of claim 60, wherein the at least one conduit includes a  
20 cylindrical chamber having a top with an opening to receive a manifold end of the first section of the flat multiport tube structure.

62. The device of claim 61, further comprising a plurality of flat multiport tube structures arranged vertically and having a manifold end of the first section engaged with  
25 an opening at the top of the cylindrical chamber.

63. The device of claim 46, wherein the at least one conduit includes a tubular manifold having an opening to receive a manifold end of the first section of the flat multiport tube structure.

30

64. A thermosiphon cooling device including:

an evaporator section including at least one evaporation channel arranged to receive heat and evaporate a liquid in the at least one evaporation channel and a liquid return path for delivering condensed liquid to the at least one evaporation channel;

5 a condenser section including at least first and second sets of condensing channels arranged to transfer heat from evaporated liquid to a surrounding environment to condense the evaporated liquid, and a vapor supply path for delivering evaporated liquid to the at least one condensing channel; and

a manifold fluidly connecting the evaporator section and the condenser section,  
10 wherein the manifold includes first and second liquid chambers that are fluidly coupled to the first and second sets of condensing channels, respectively, and a vapor chamber fluidly coupled to the vapor supply path, and wherein the manifold includes an end cap that fluidly couples the first and second liquid chambers.

15 65. The device of claim 64, wherein the first liquid chamber is fluidly coupled to the liquid return path.

66. The device of claim 64, wherein the condenser section is formed as a flat multiport tube structure that includes the first and second sets of condensing channels  
20 positioned on opposite sides of at least one vapor supply channel that defines the vapor supply path, wherein the first and second sets of condensing channels are each connected to the at least one vapor supply channel by a respective connecting web.

67. The device of claim 66, wherein the manifold includes an outer wall with  
25 first, second and third openings, wherein the first set of condensing channels is received in the first opening, the second set of condensing channels is received into the second opening and the at least one vapor supply channel is received into the third opening.

68. The device of claim 66, wherein the condenser section includes a plurality of  
30 flat multiport tube structures that each include the first and second sets of condensing channels positioned on opposite sides of at least one vapor supply channel.

69. The device of claim 64, wherein the end cap includes an inner plate with a first opening in fluid communication with the first liquid chamber and a second opening in fluid communication with the second liquid chamber, and an outer plate to sealingly  
5 close the manifold, wherein the inner and outer plates are offset to define a chamber that fluidly couples the first and second openings.

70. The device of claim 69, further comprising first and second separation plates in the manifold that separate an internal space of the manifold into the first and second  
10 liquid chambers and the vapor chamber, wherein ends of the first and second separation plates are in sealing engagement with the inner plate.



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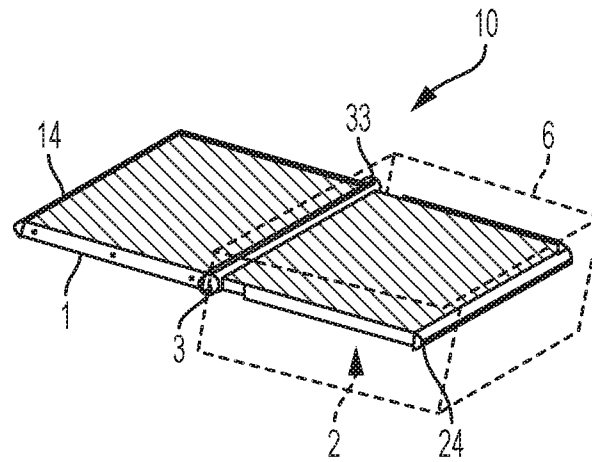


FIG. 1

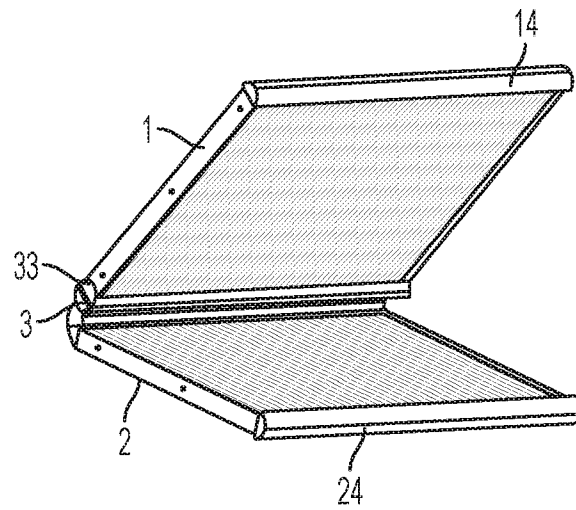


FIG. 2

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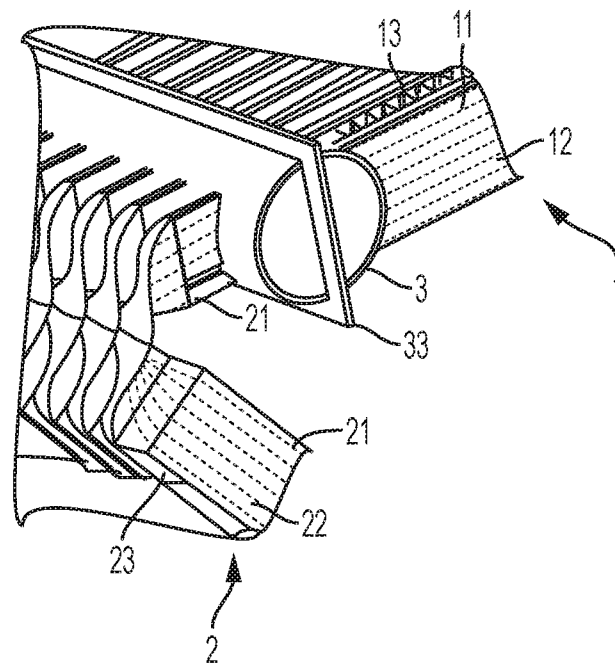


FIG. 3

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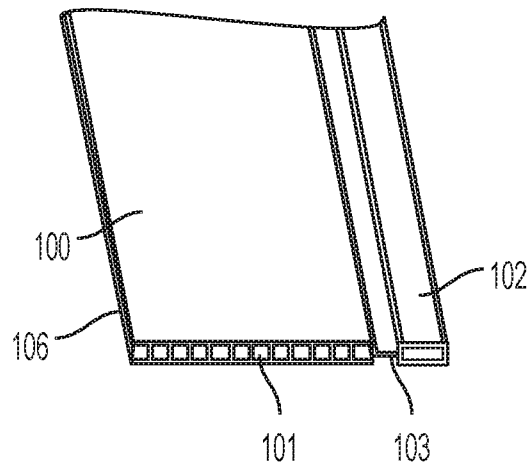


FIG. 4

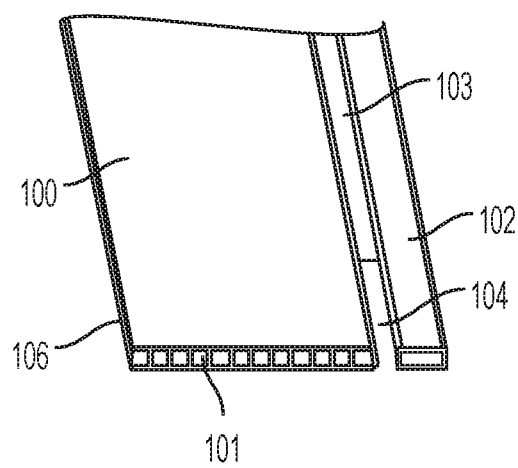


FIG. 5

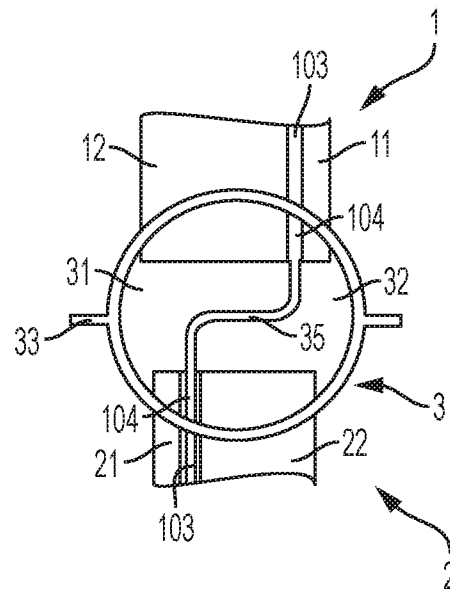


FIG. 6

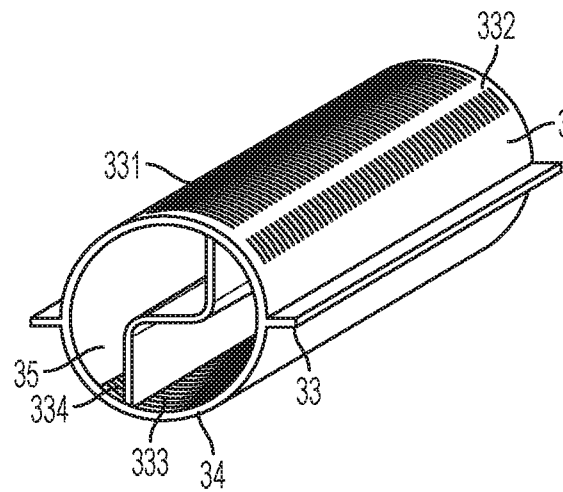


FIG. 7

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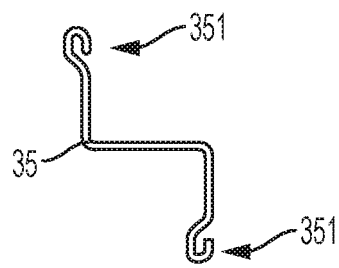


FIG. 8

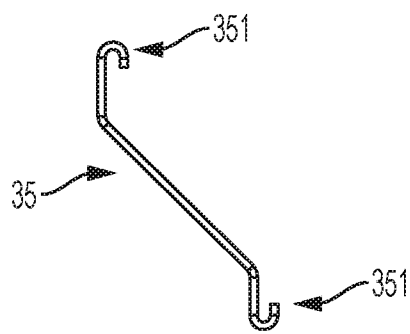


FIG. 9

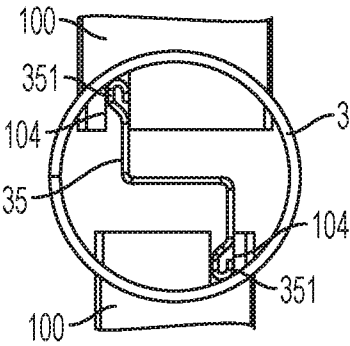


FIG. 10

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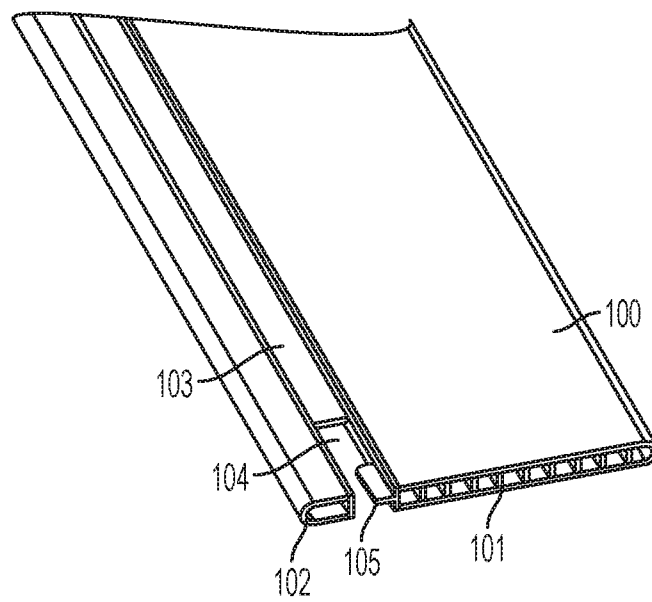


FIG. 11

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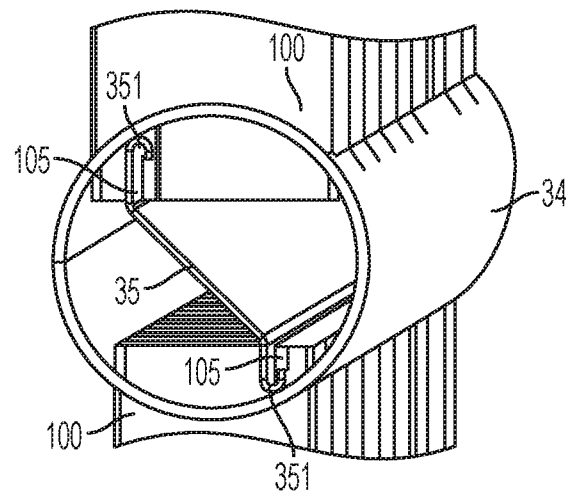


FIG. 12

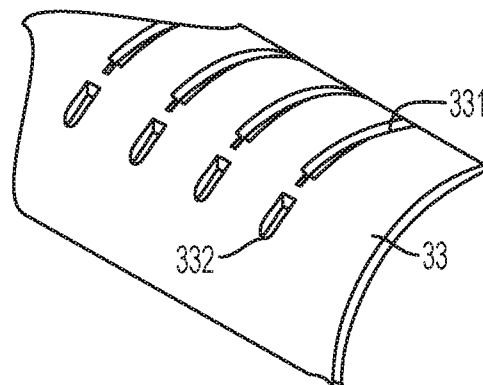


FIG. 13



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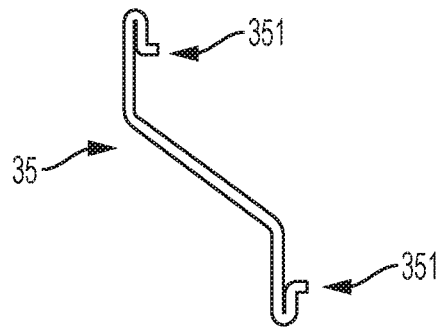


FIG. 14

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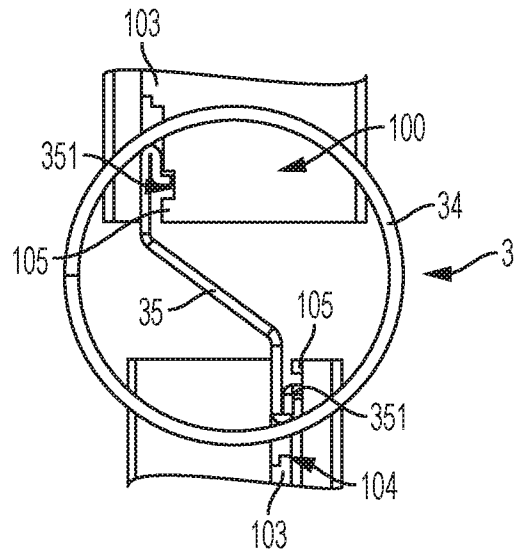


FIG. 15

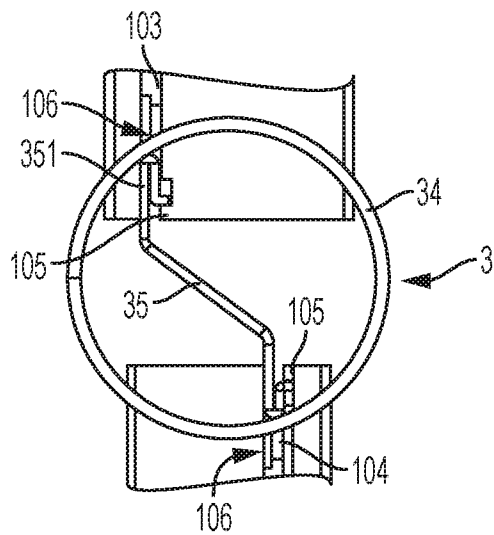


FIG. 16

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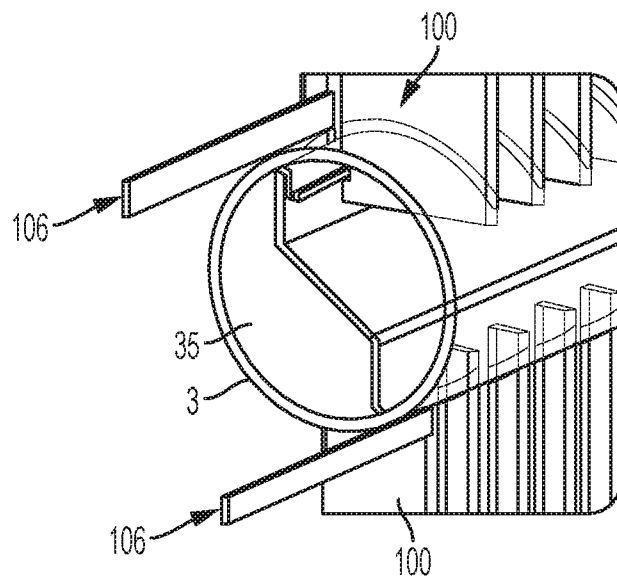


FIG. 17

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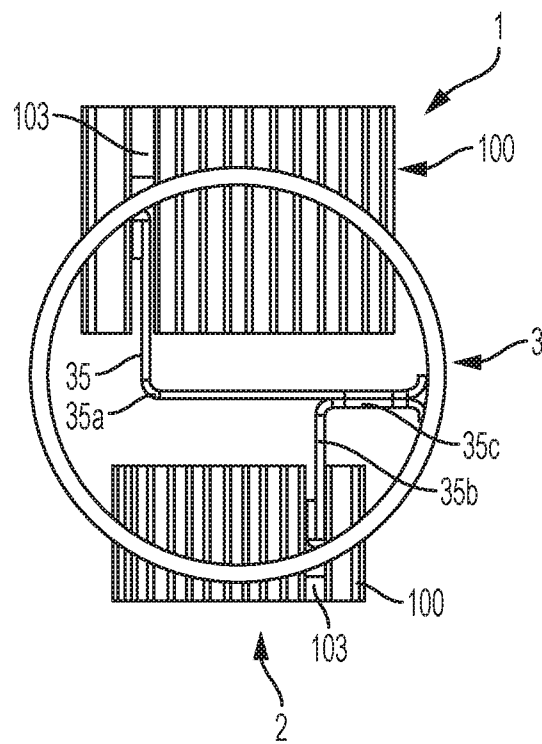


FIG. 18

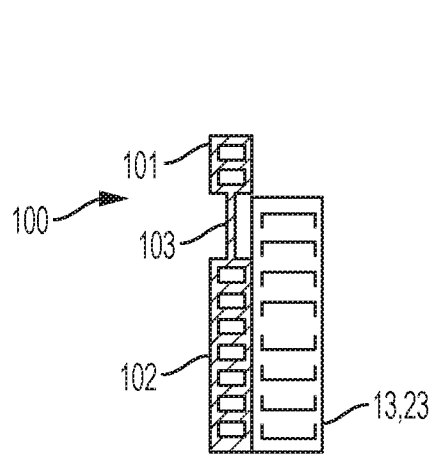


FIG. 19

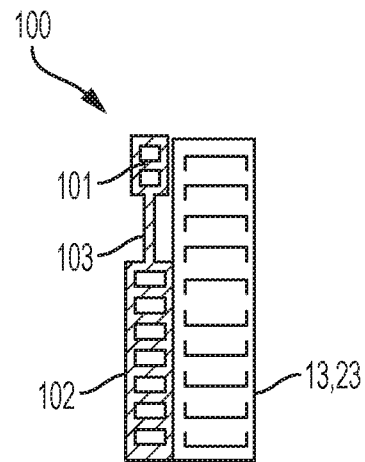


FIG. 20

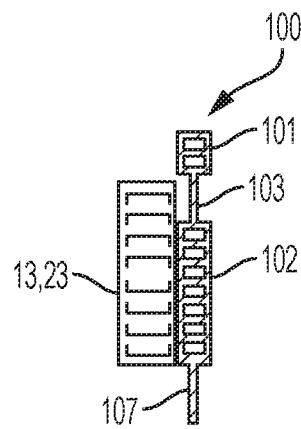


FIG. 21

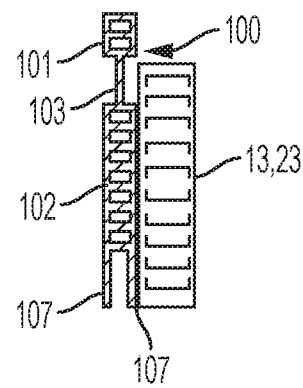


FIG. 22

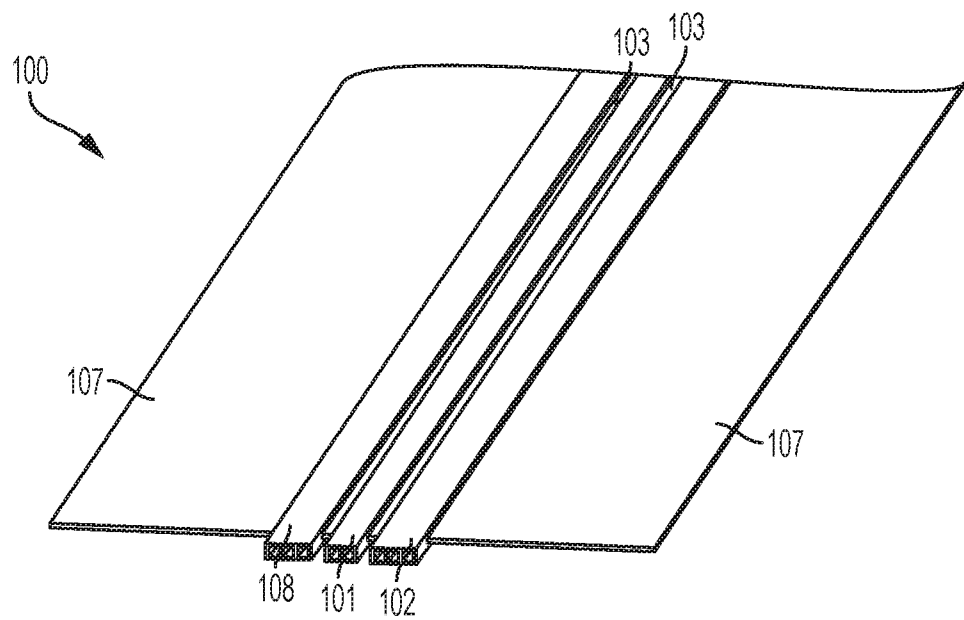


FIG. 23

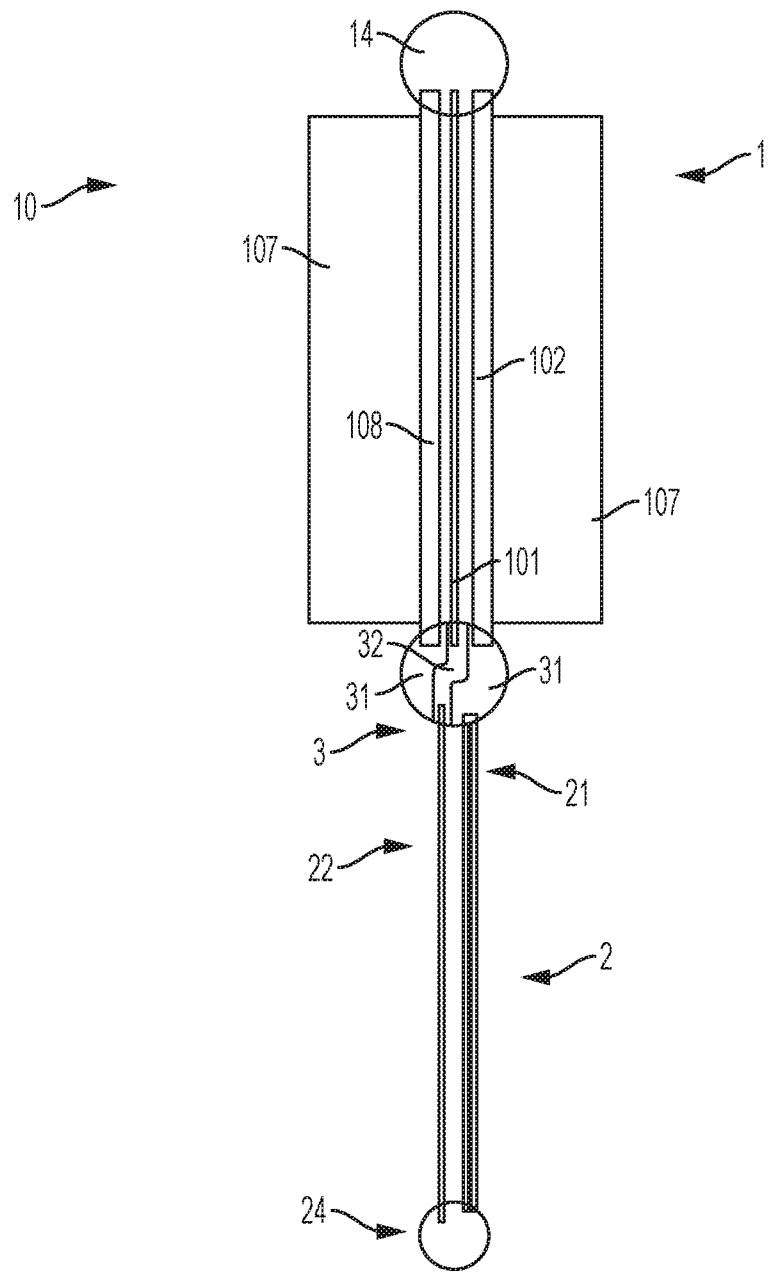


FIG. 24

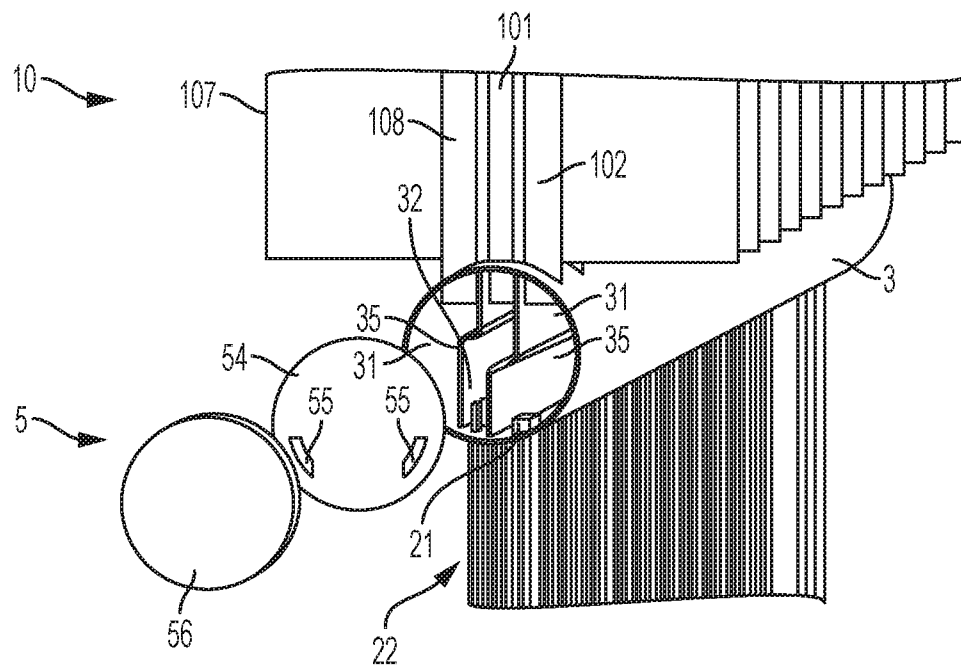


FIG. 25



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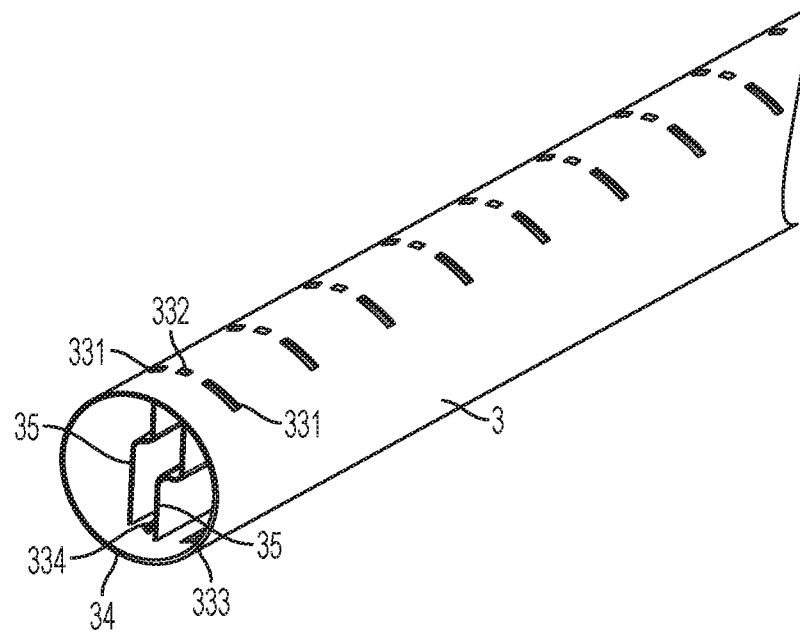


FIG. 26

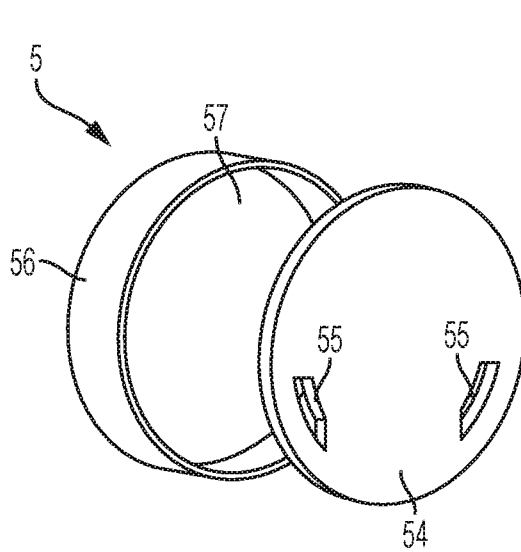


FIG. 27

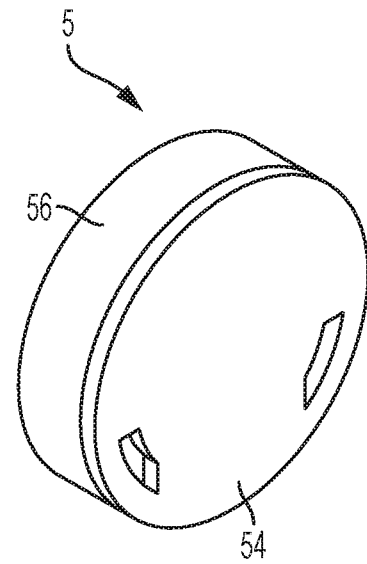


FIG. 28

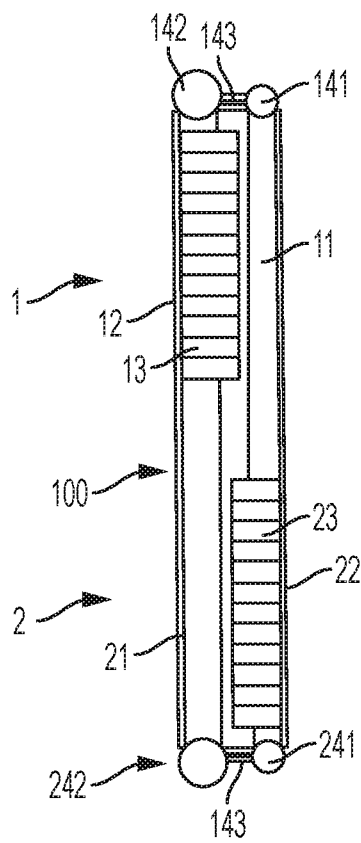


FIG. 29

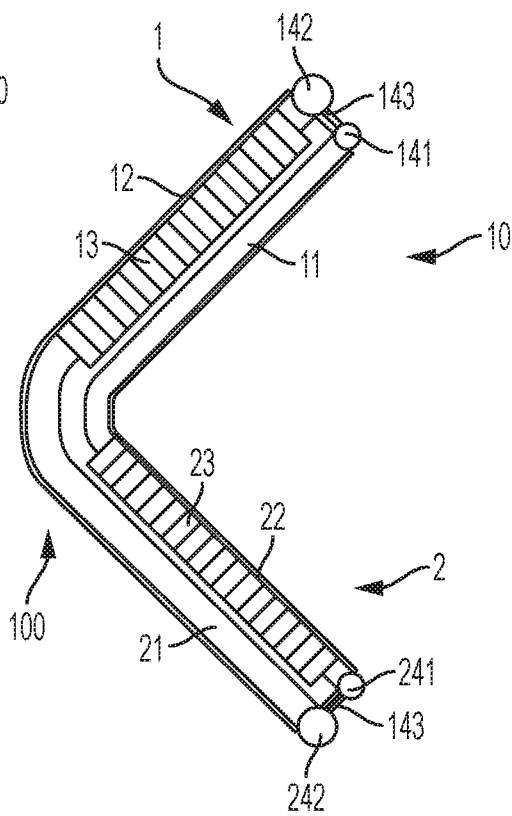


FIG. 30

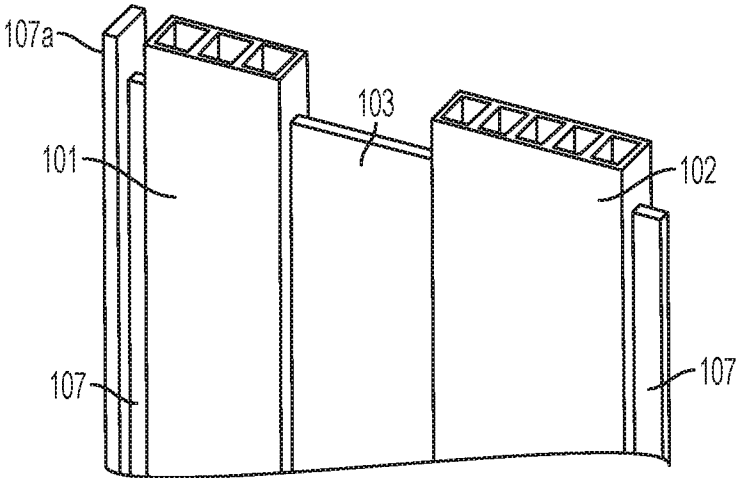


FIG. 31

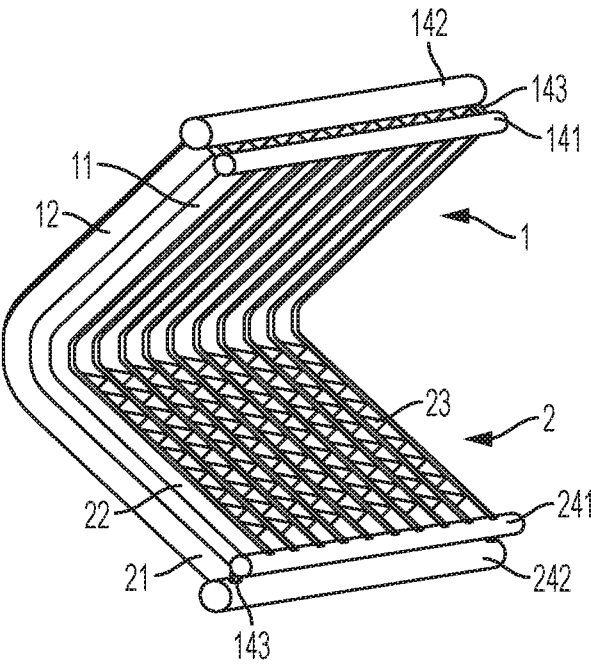


FIG. 32

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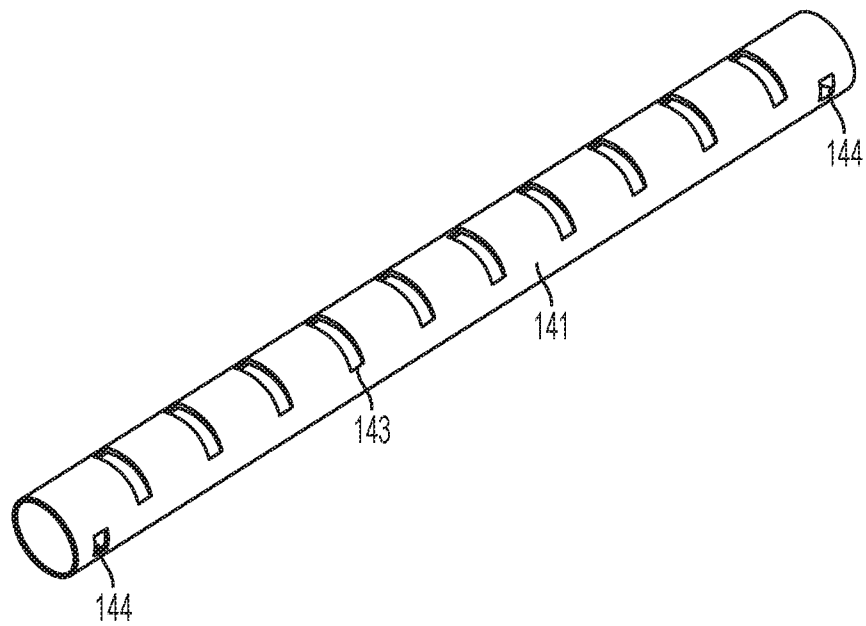


FIG. 33

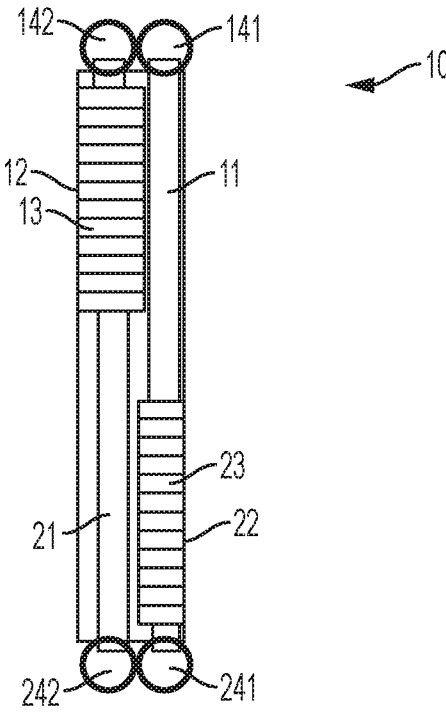


FIG. 34

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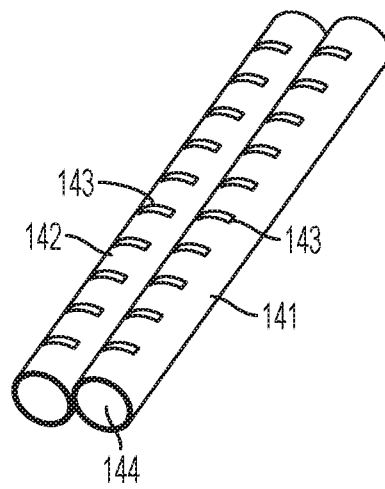


FIG. 35



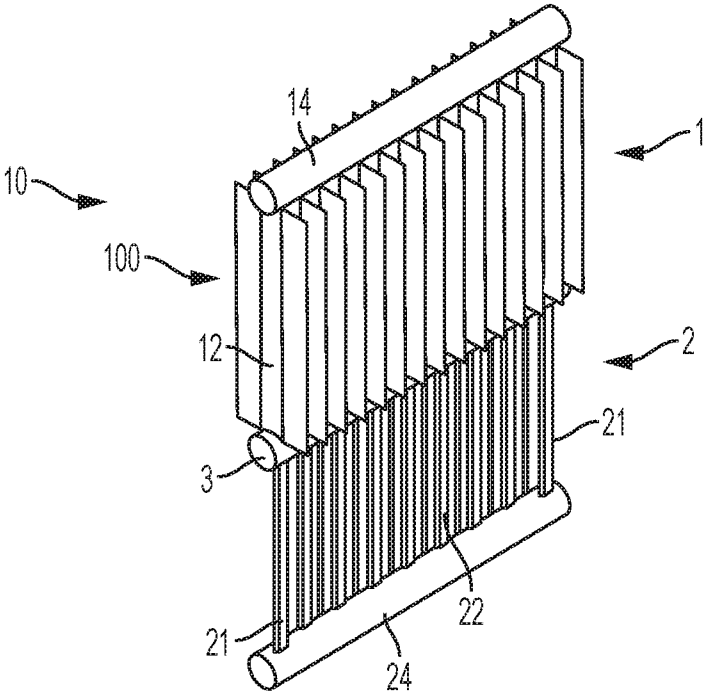


FIG. 36

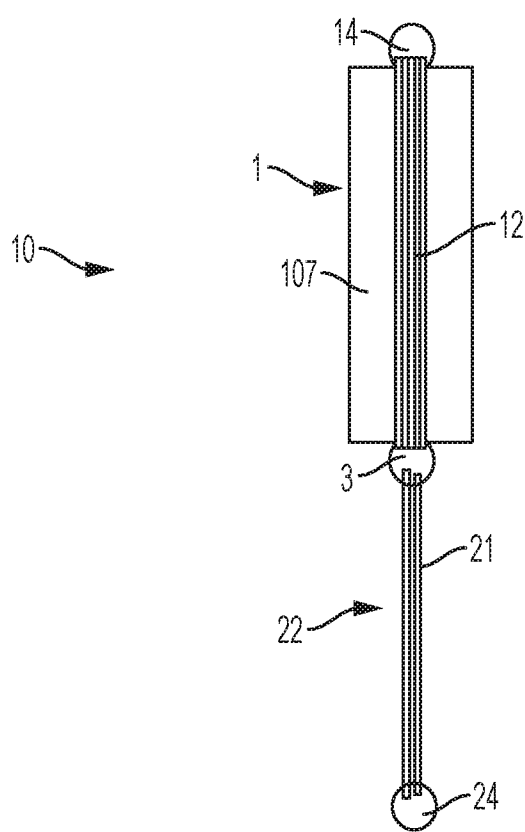


FIG. 37

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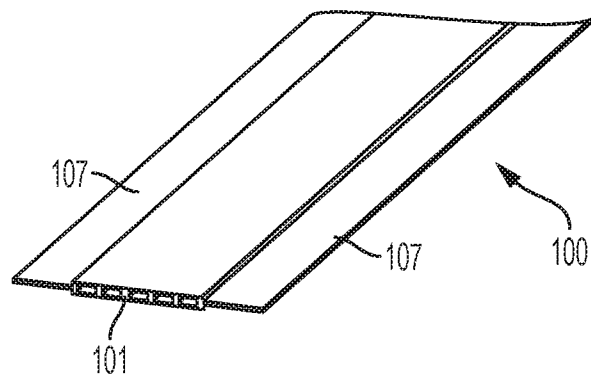


FIG. 38

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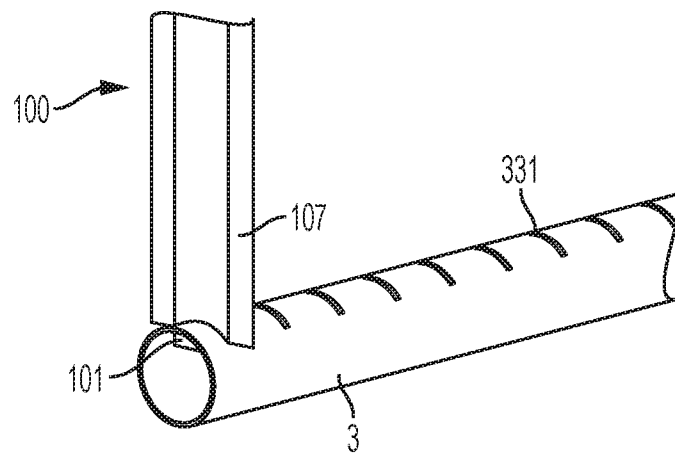


FIG. 39

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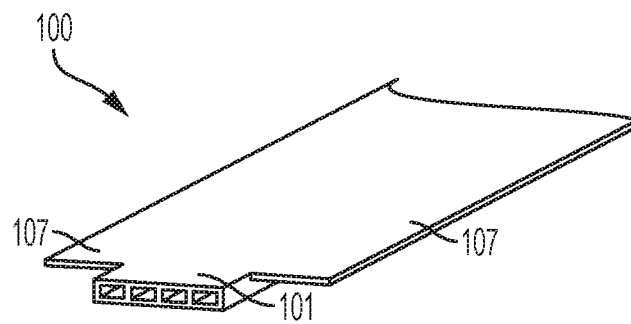


FIG. 40

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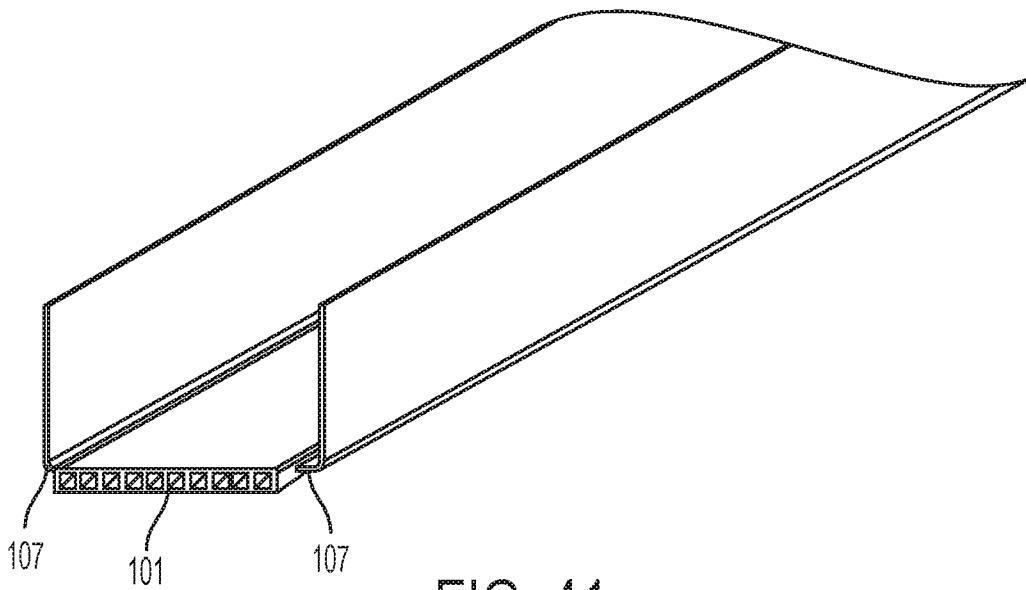


FIG. 41

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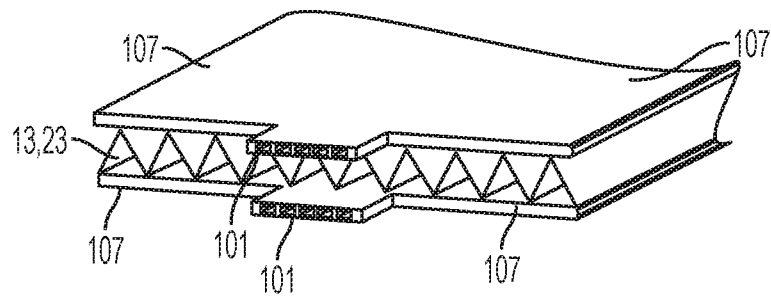


FIG. 42

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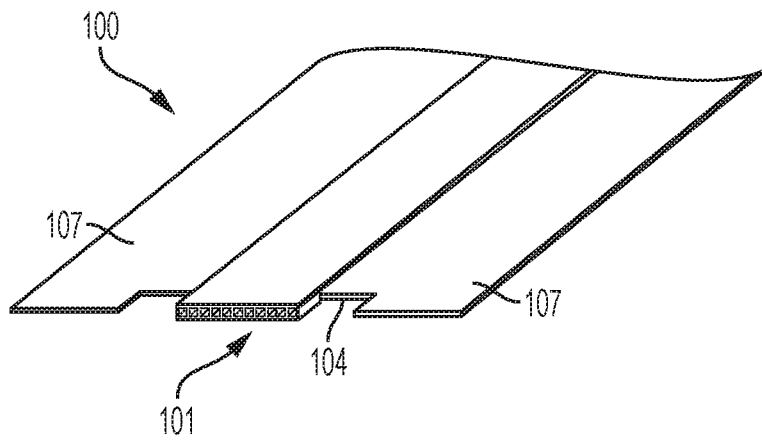


FIG. 43

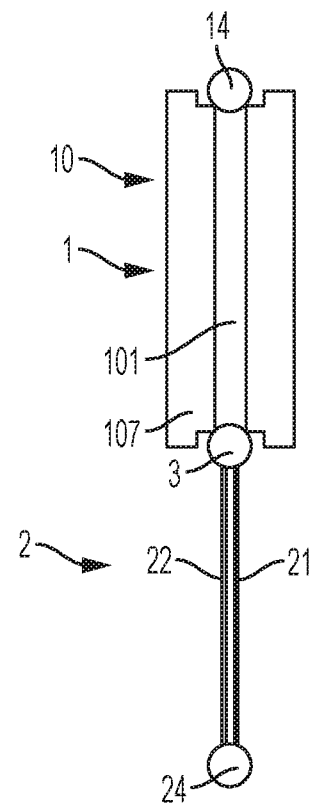


FIG. 44



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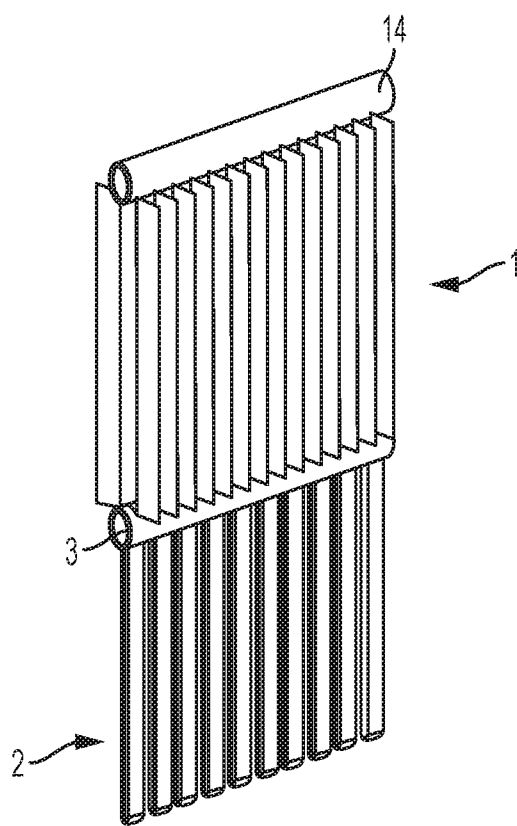


FIG. 45

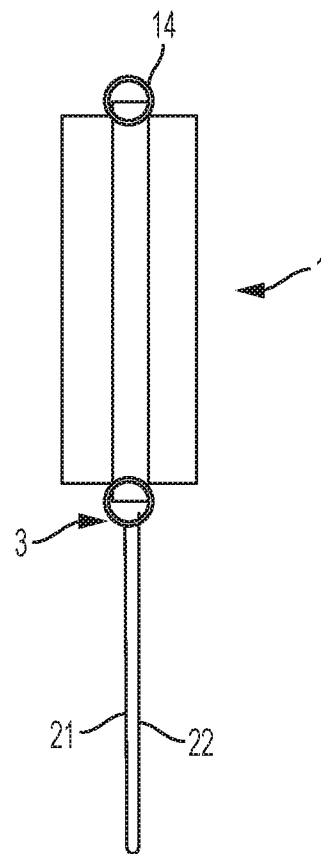


FIG. 46

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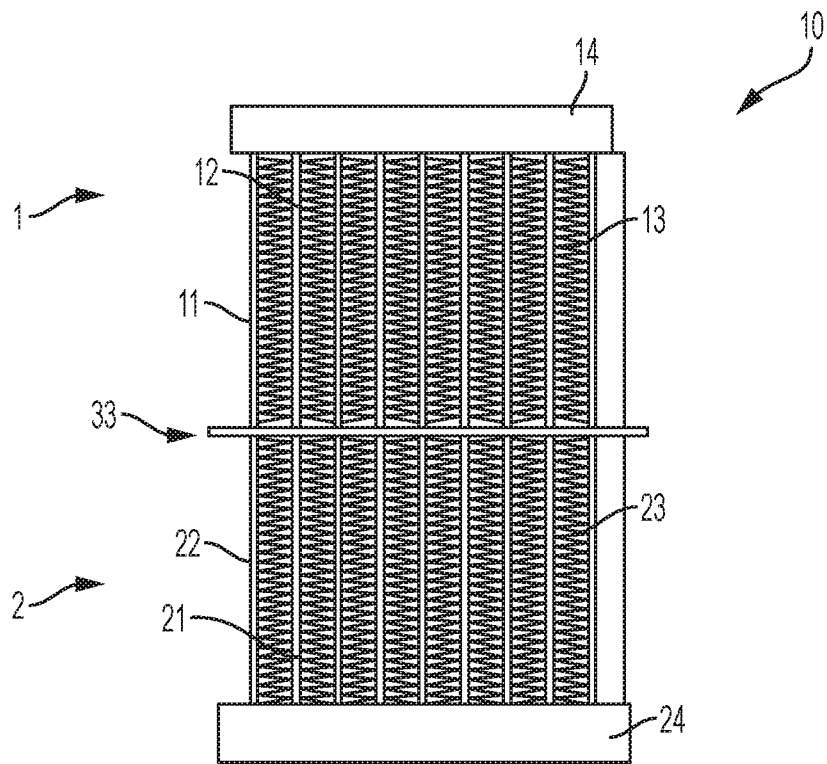


FIG. 47

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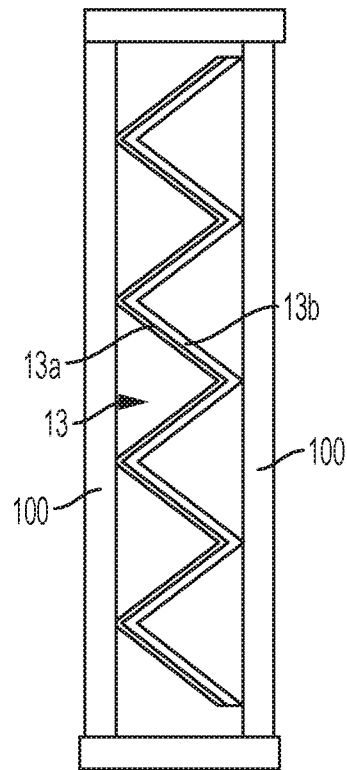


FIG. 48

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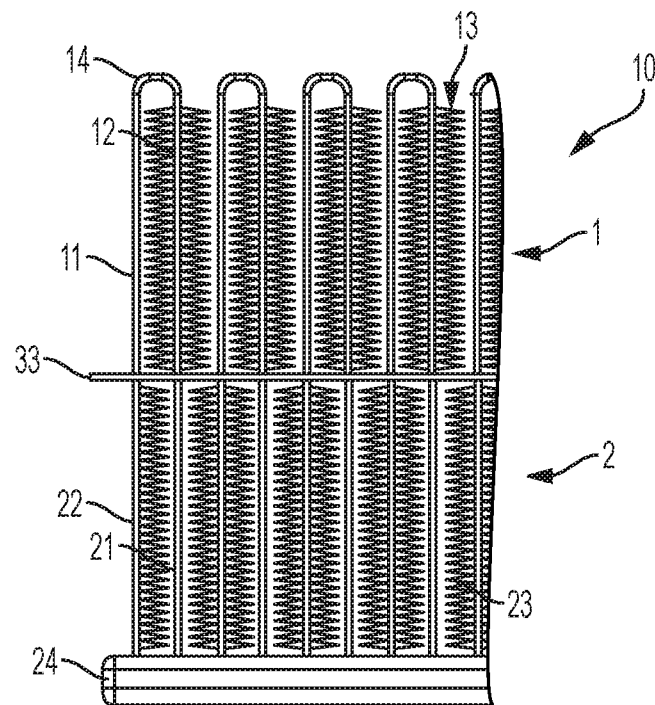


FIG. 49

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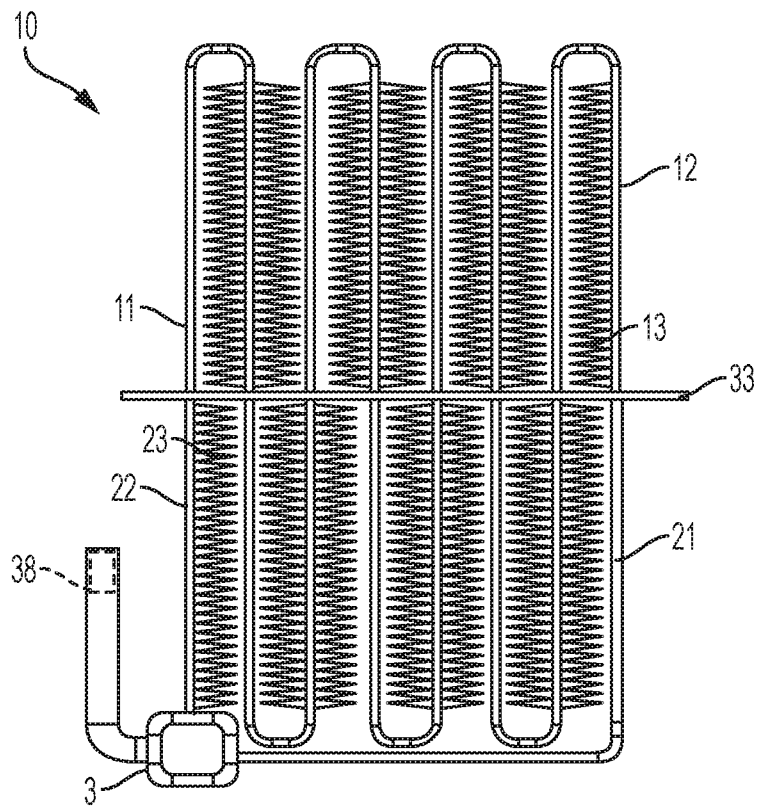


FIG. 50

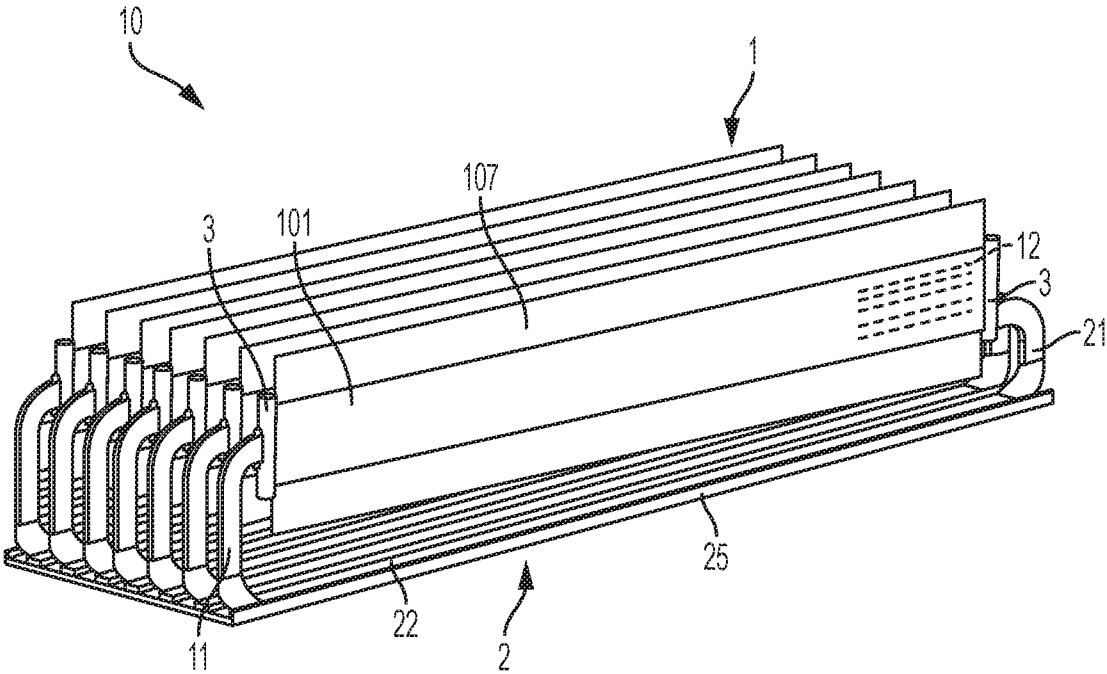


FIG. 51

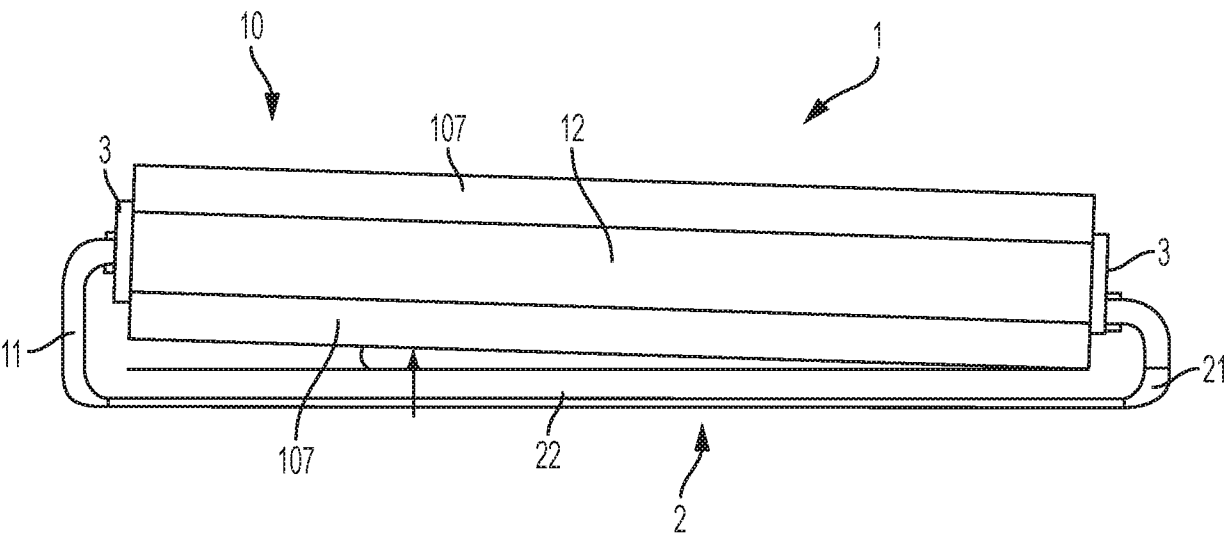


FIG. 52

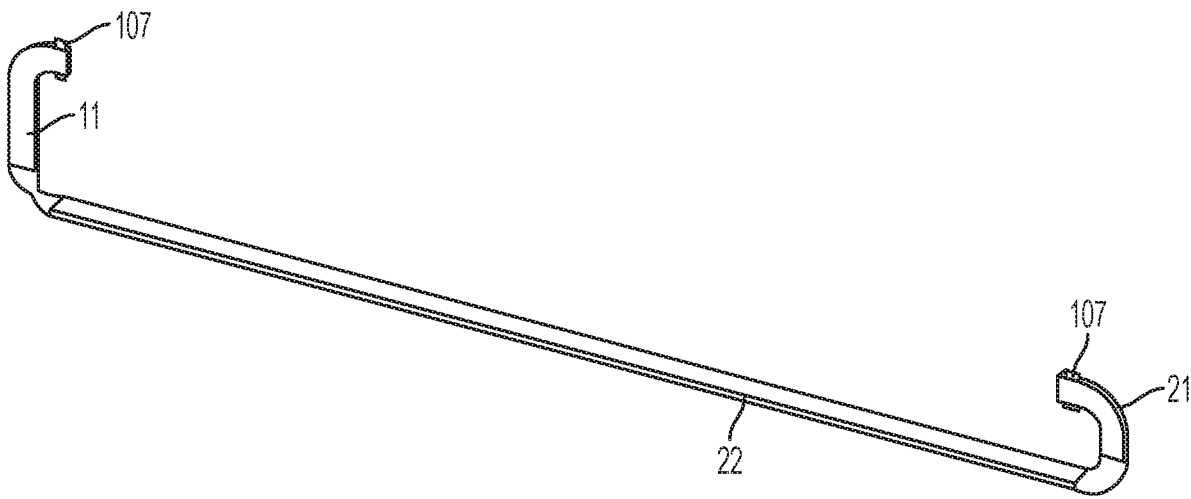


FIG. 53



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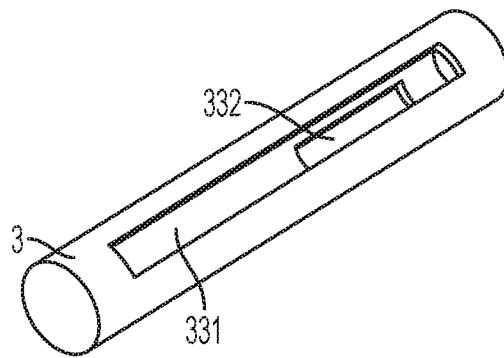


FIG. 54

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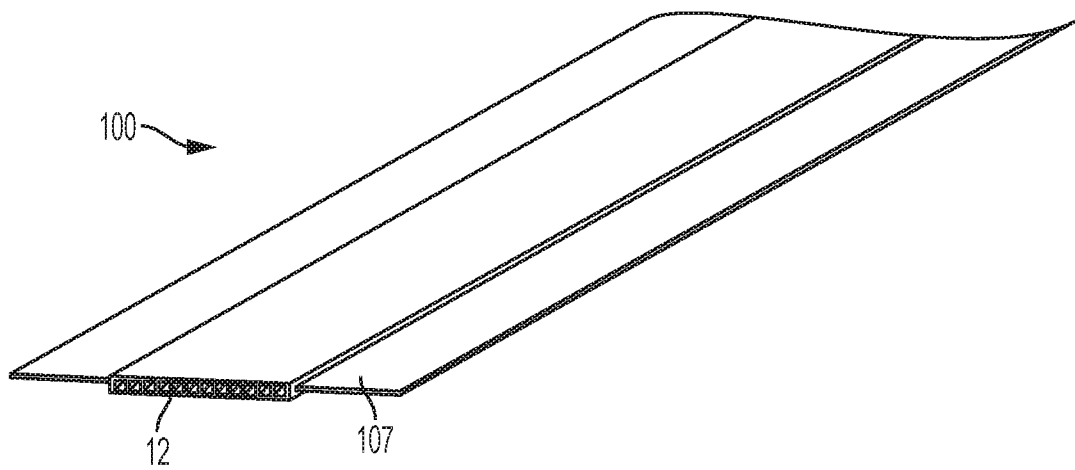


FIG. 55

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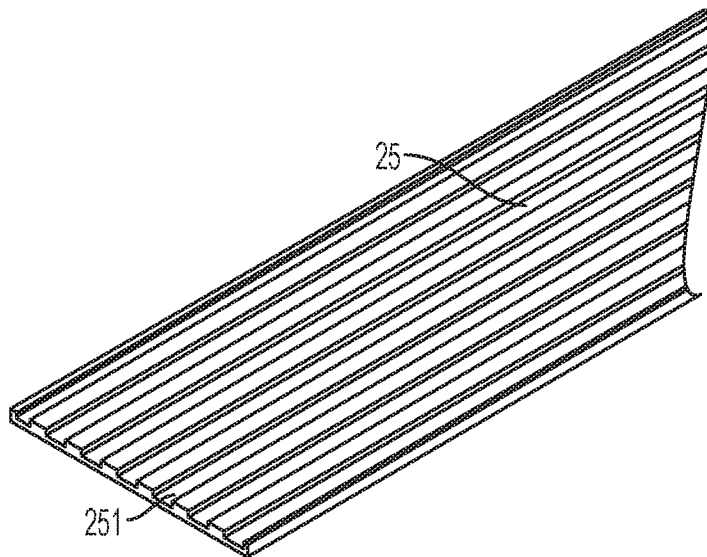


FIG. 56

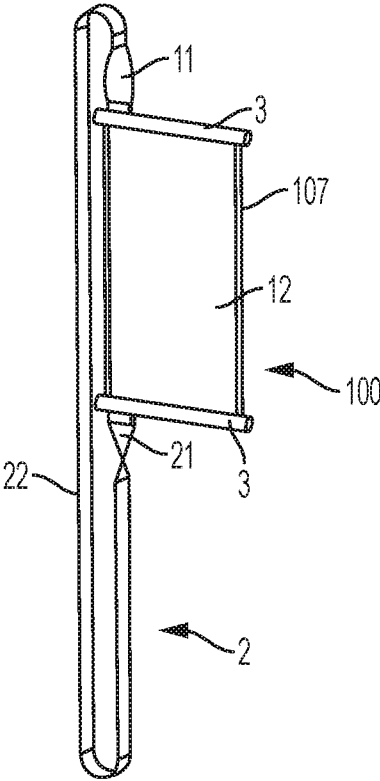


FIG. 57

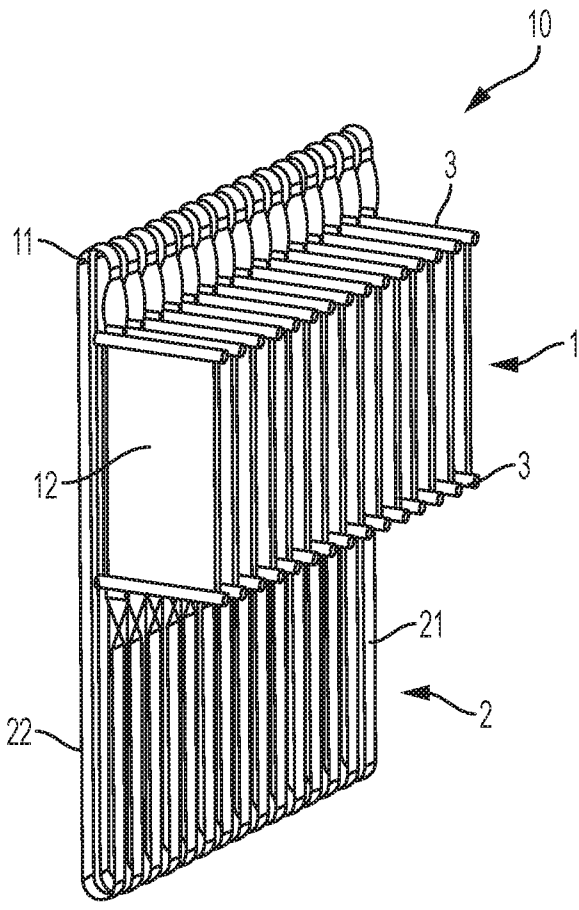


FIG. 58

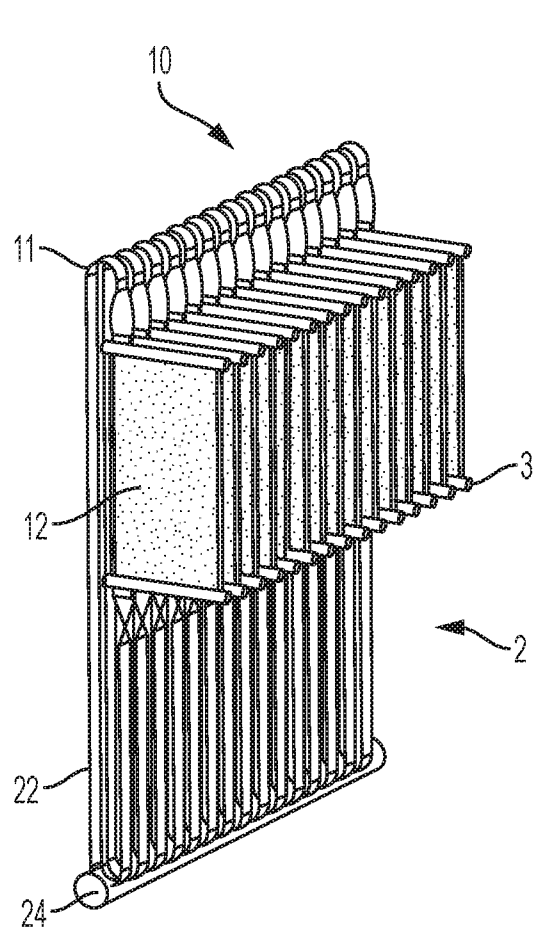


FIG. 59

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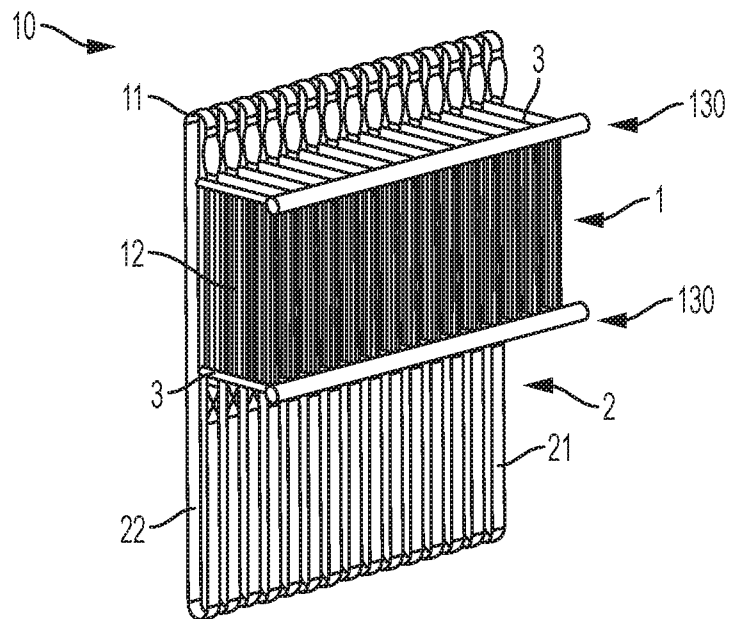


FIG. 59A

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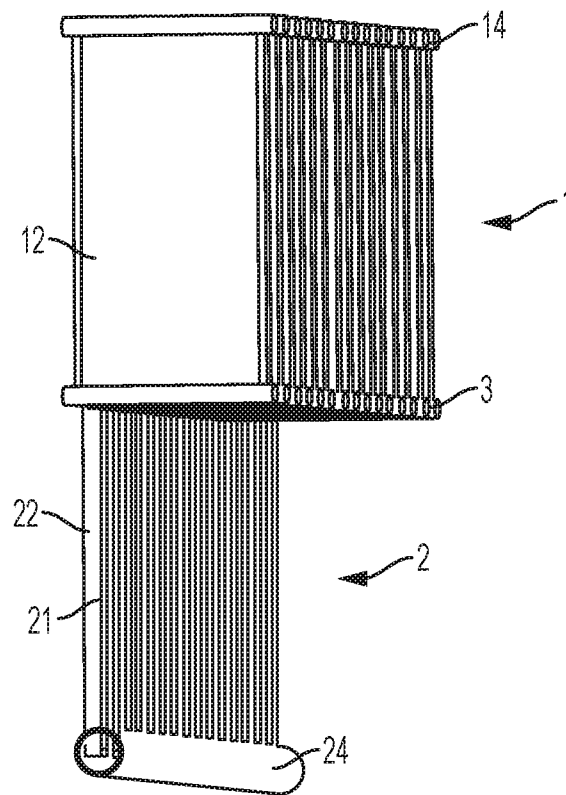


FIG. 60

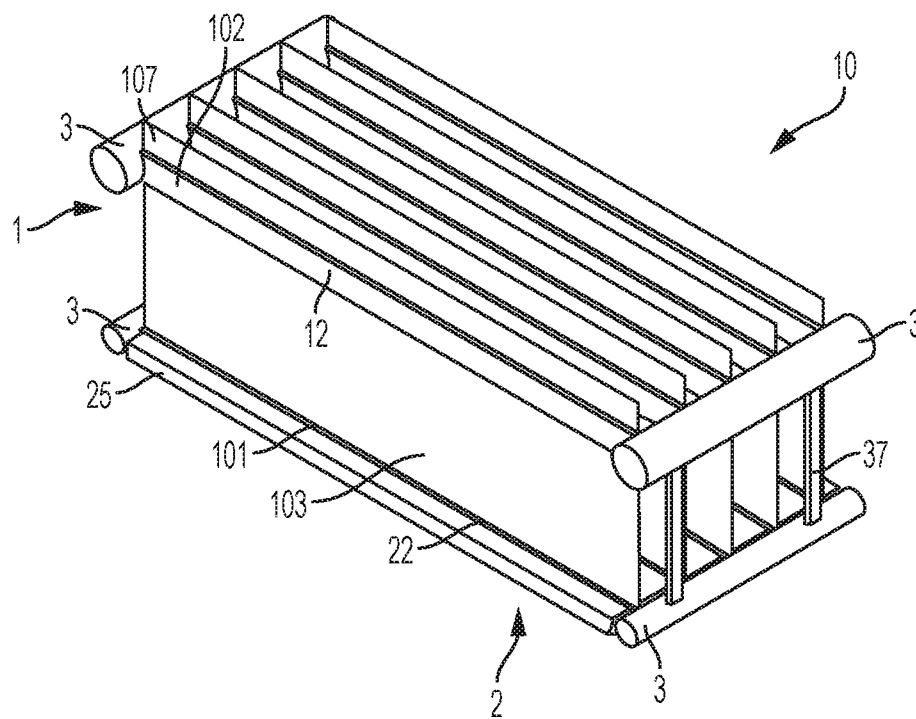


FIG. 61



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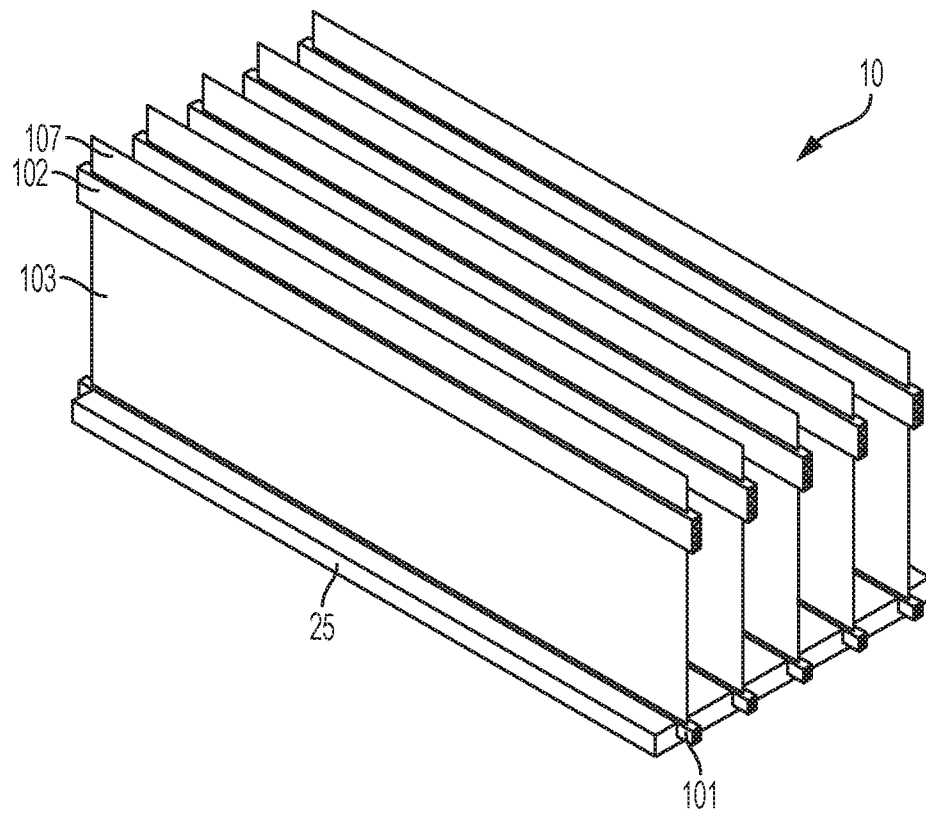


FIG. 62

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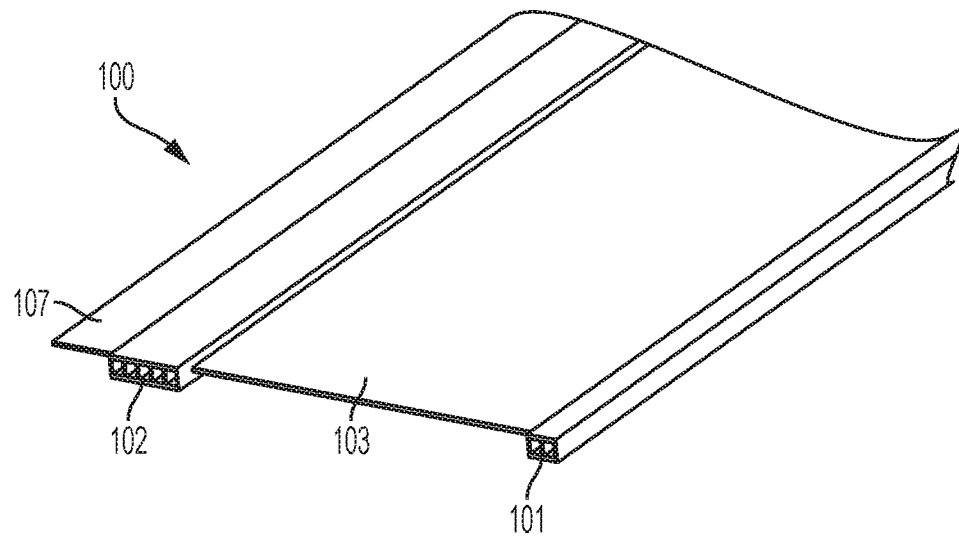


FIG. 63

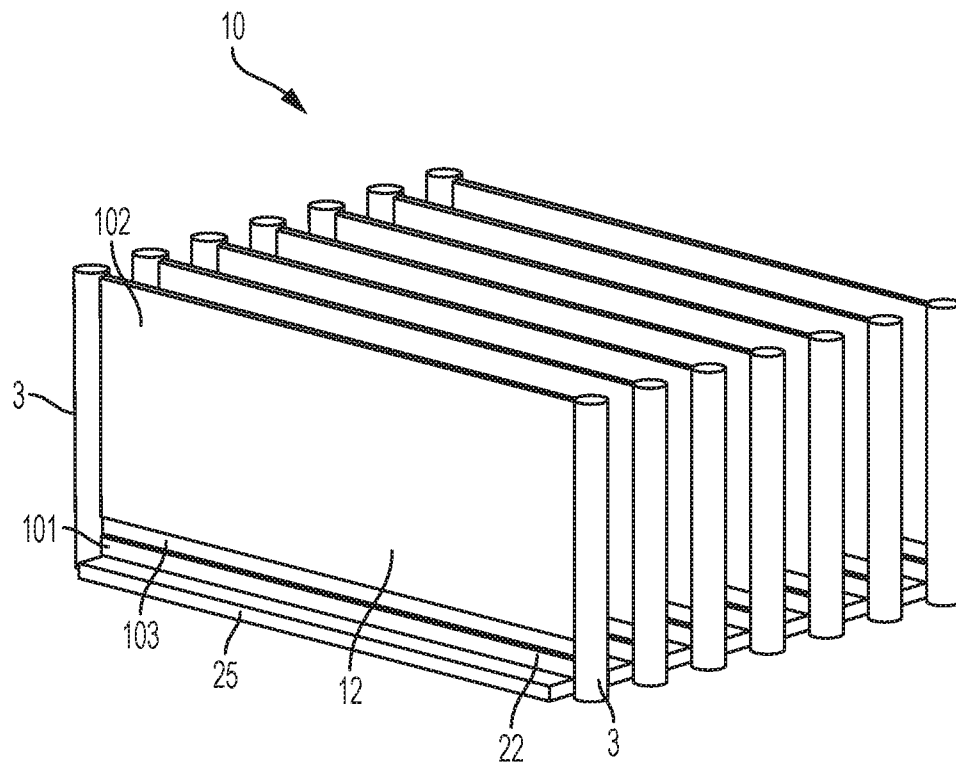


FIG. 64

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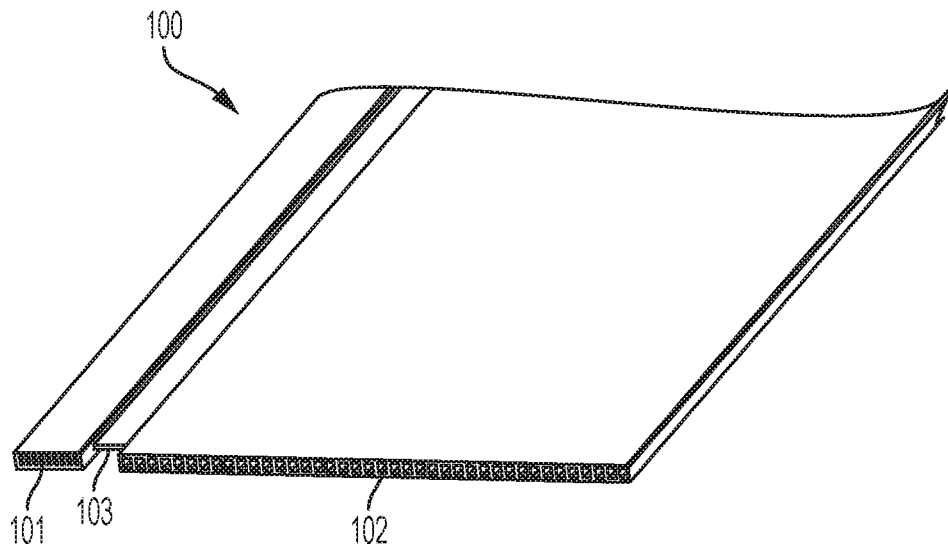


FIG. 65

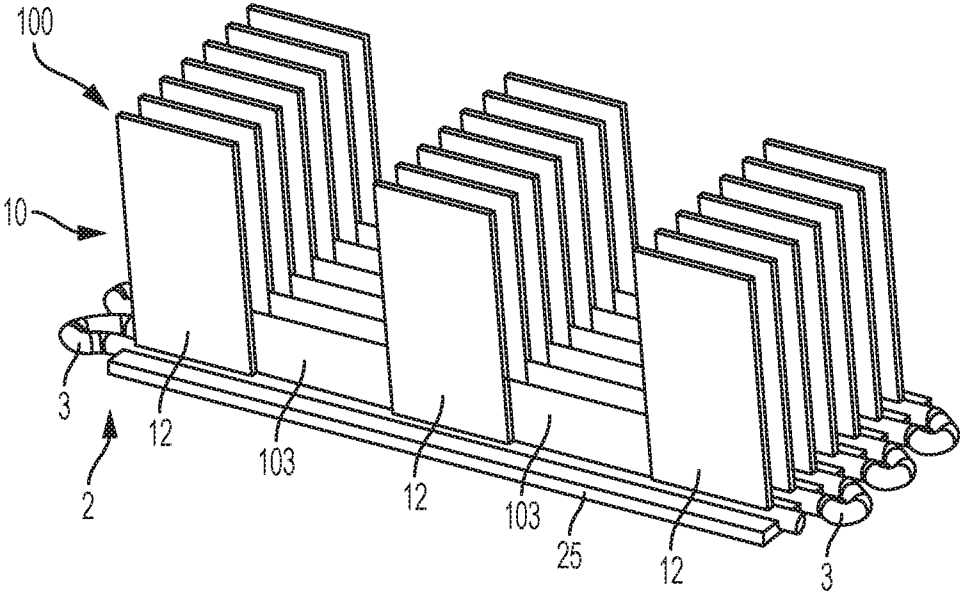


FIG. 66

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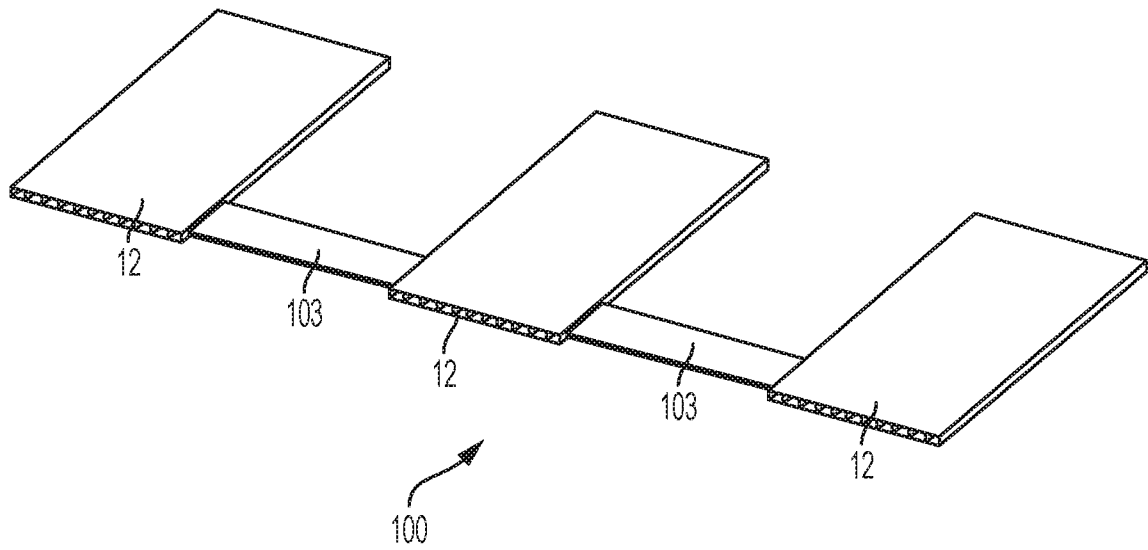


FIG. 67

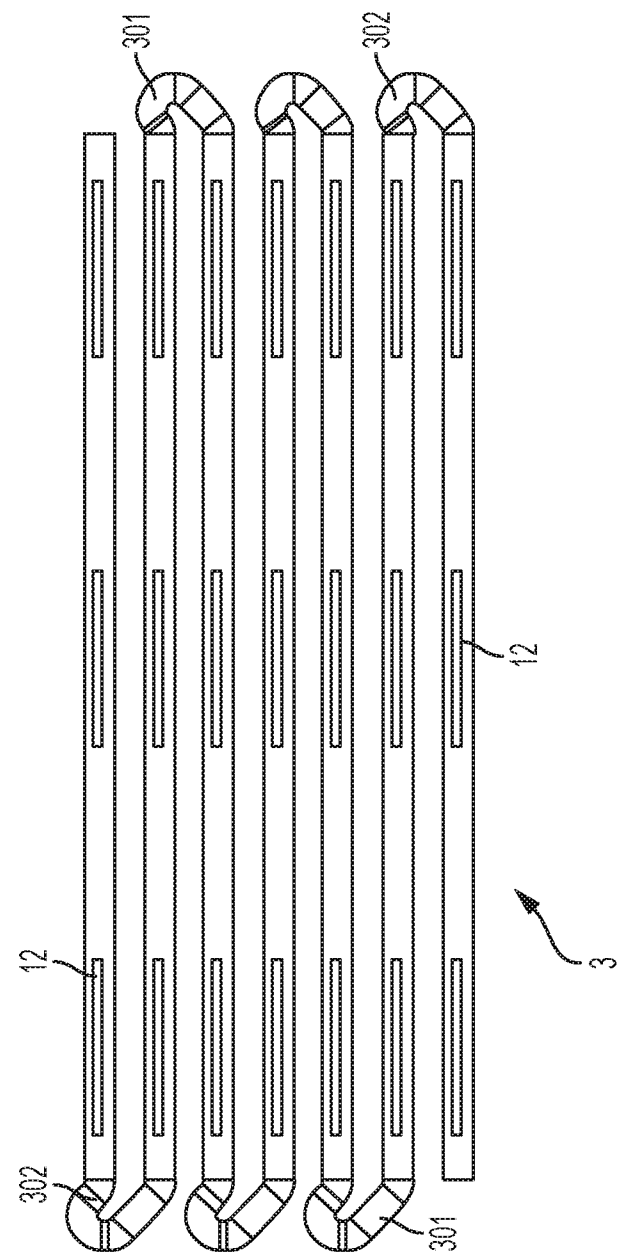


FIG. 68

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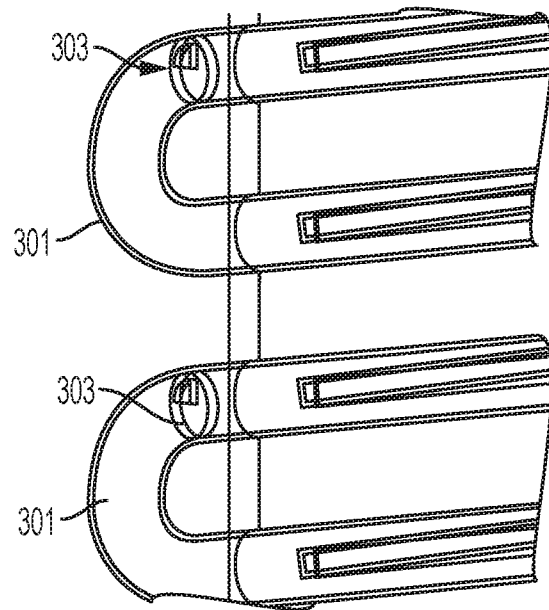


FIG. 69



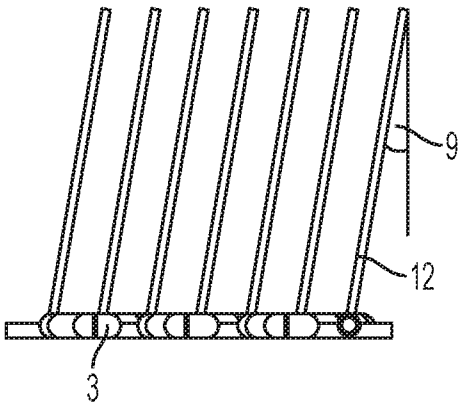


FIG. 70

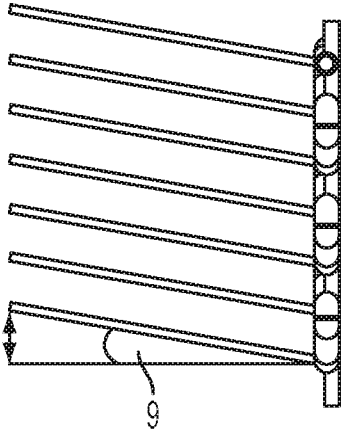


FIG. 71

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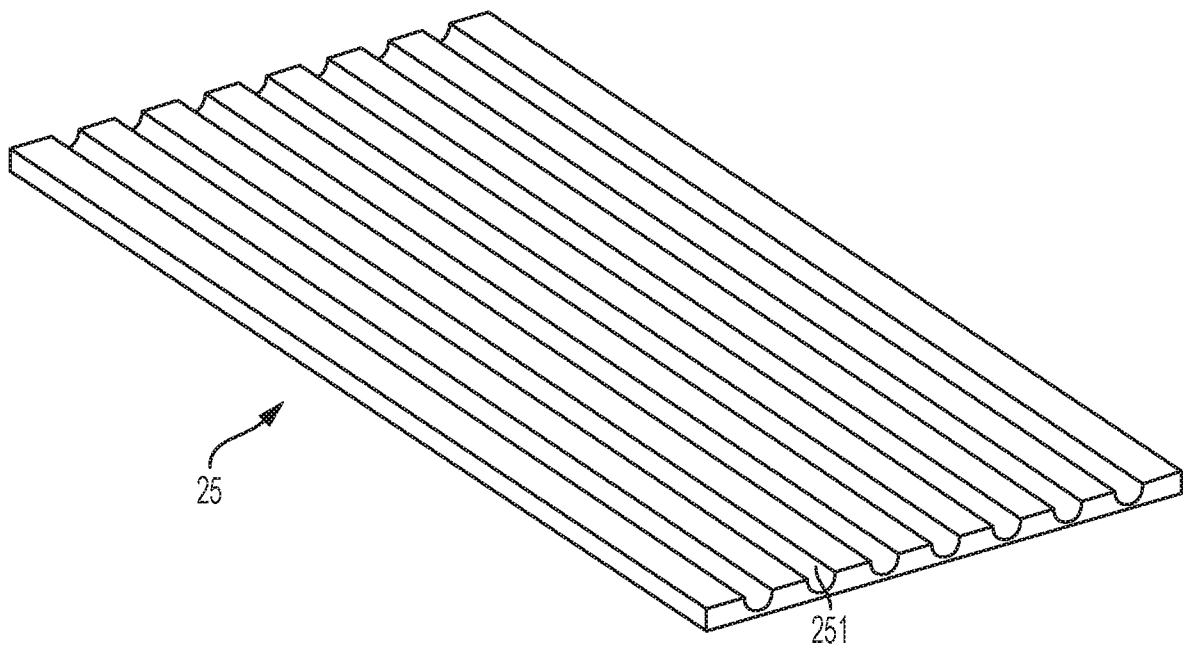


FIG. 72

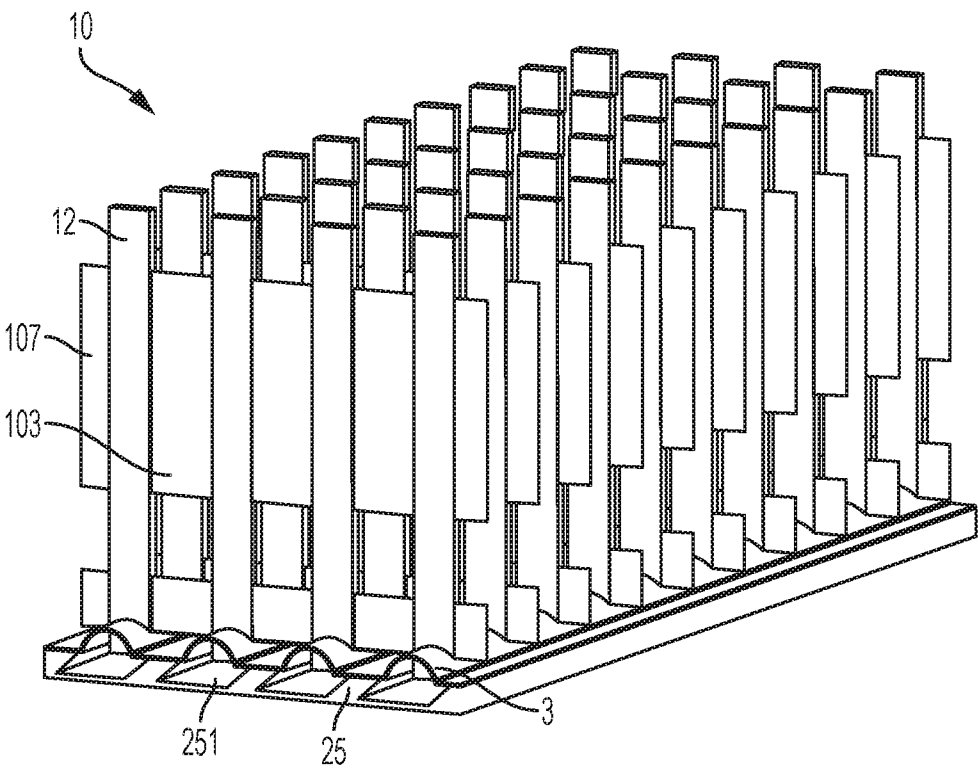


FIG. 73

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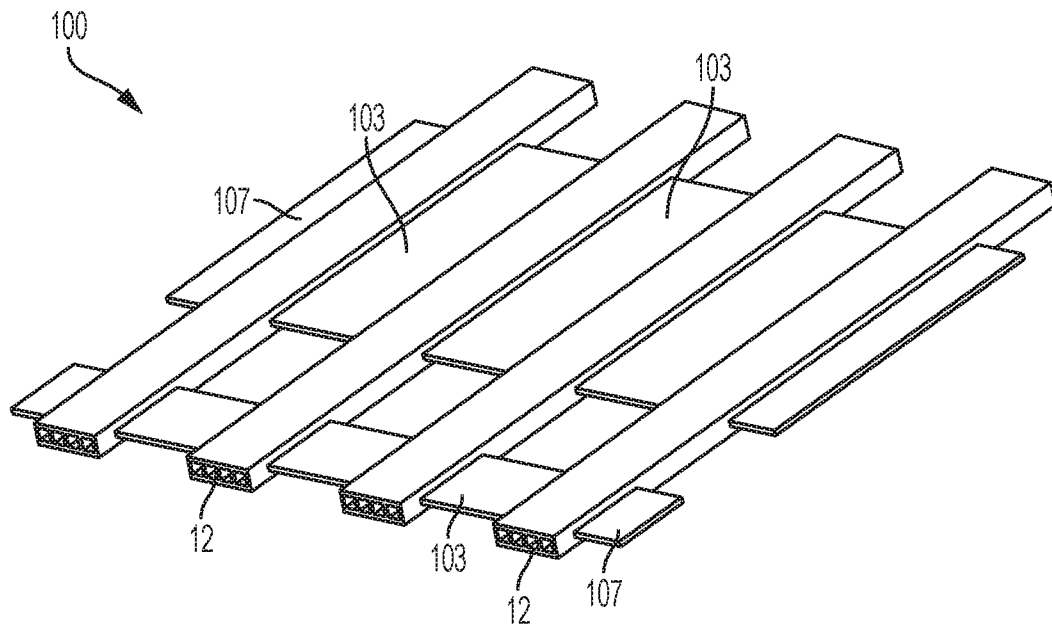


FIG. 74

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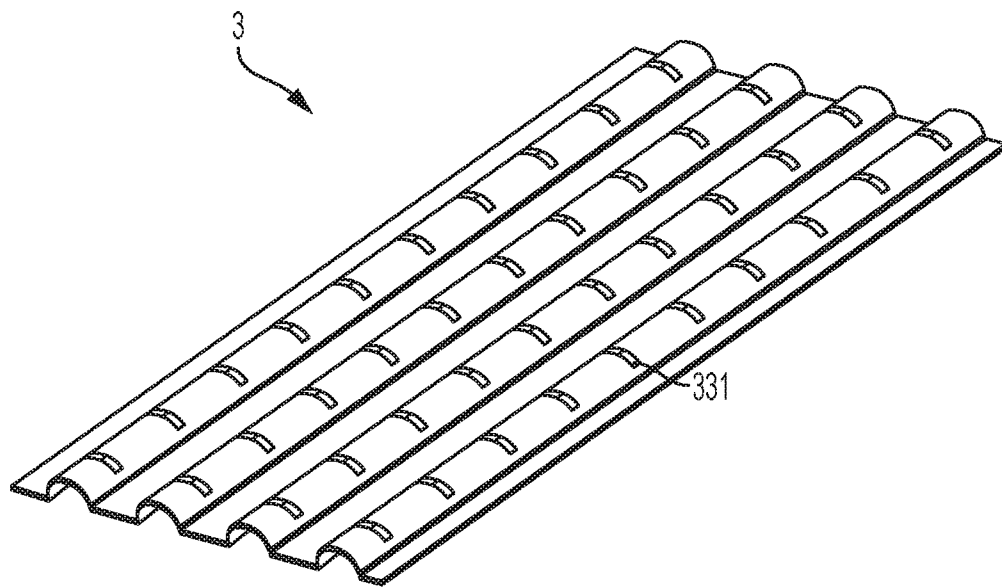


FIG. 75

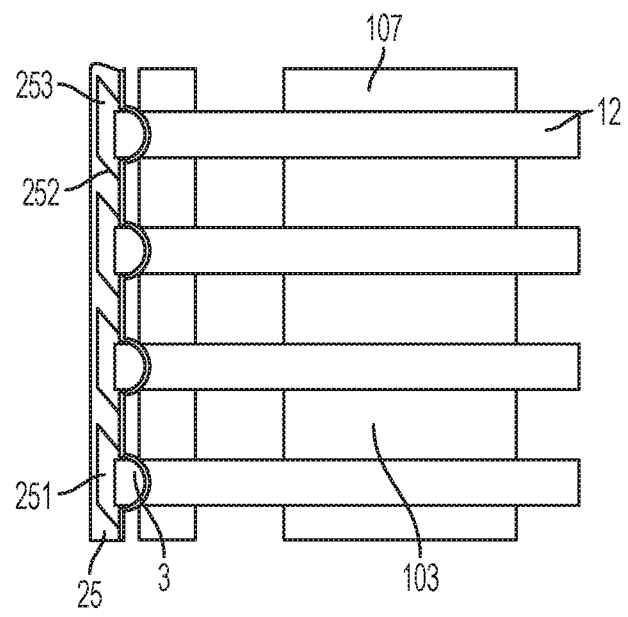


FIG. 76

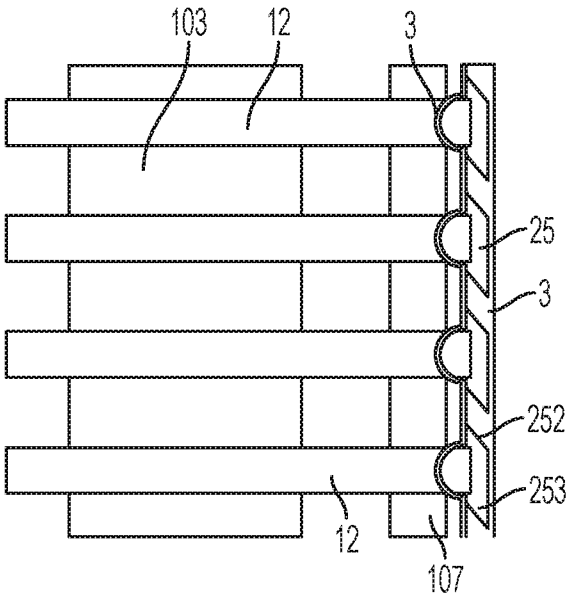


FIG. 77

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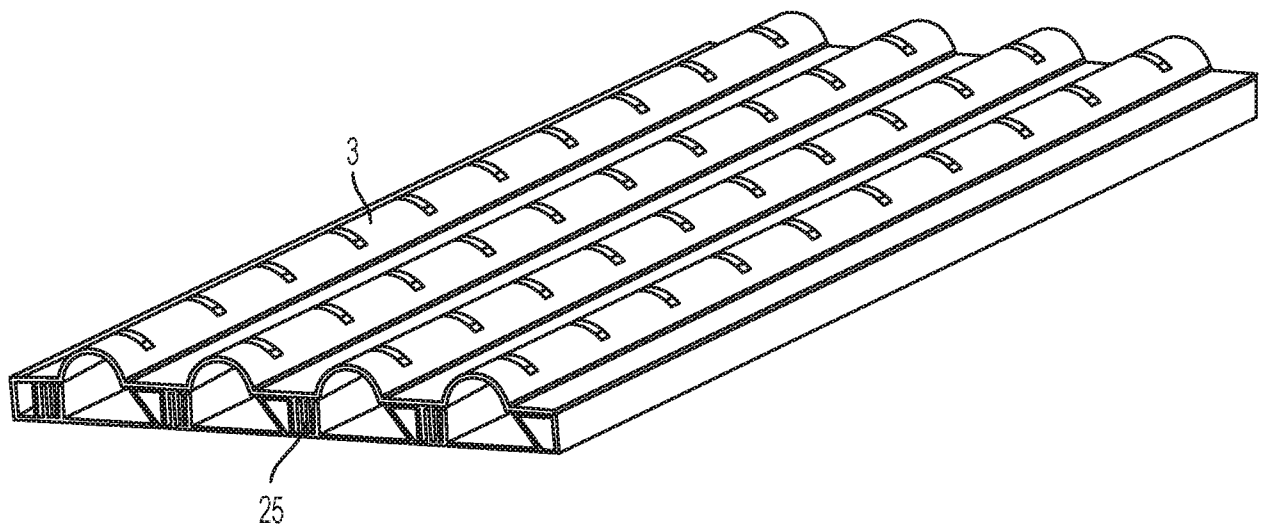


FIG. 78

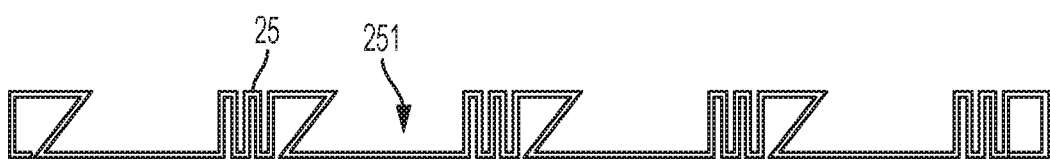


FIG. 79



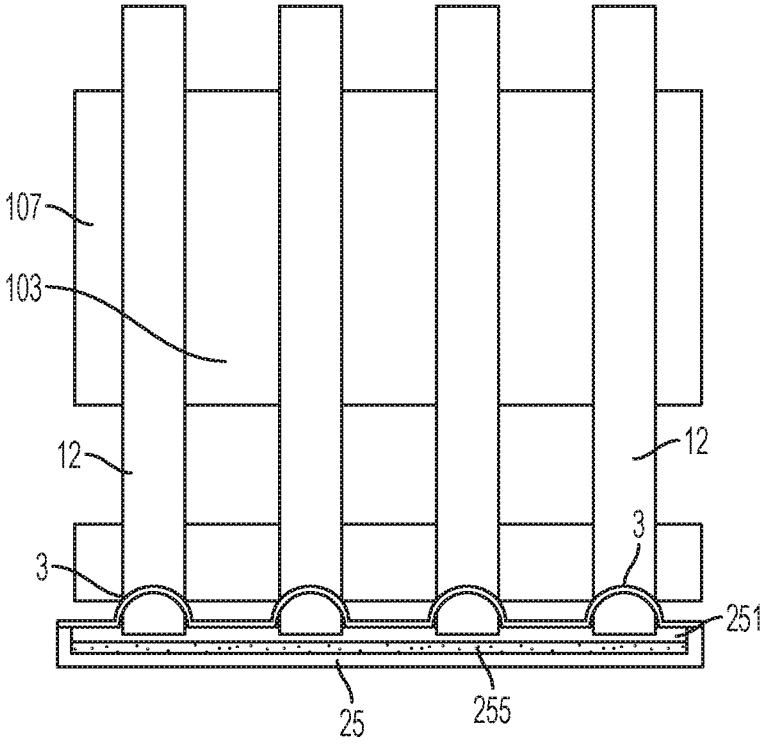


FIG. 80

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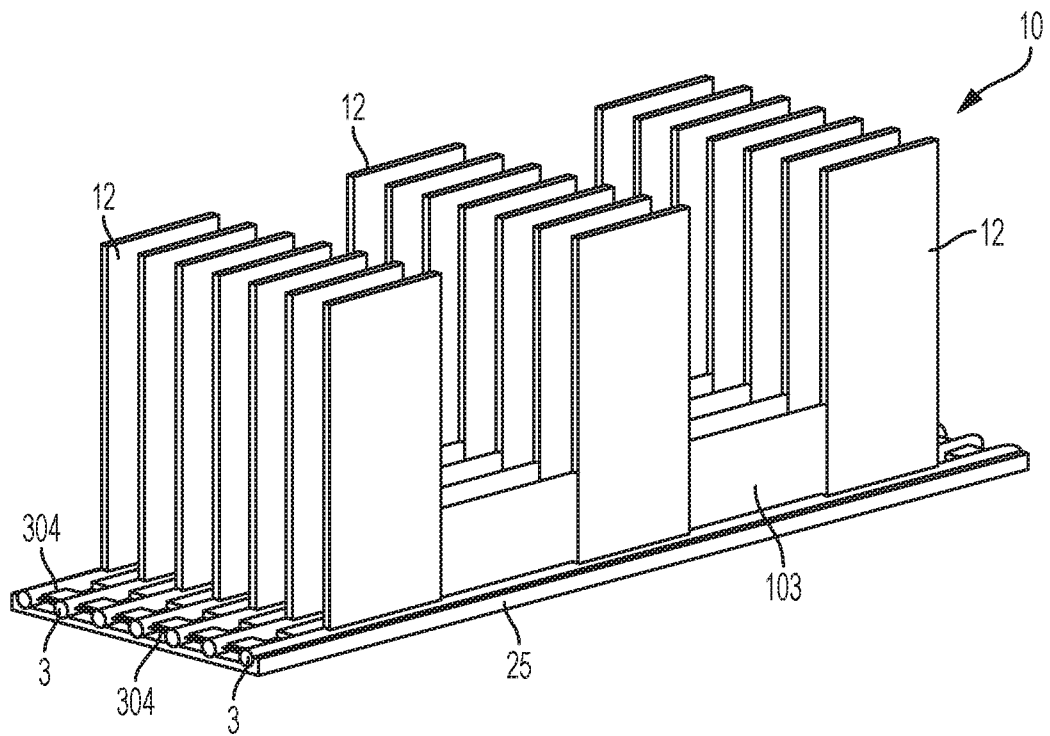


FIG. 81

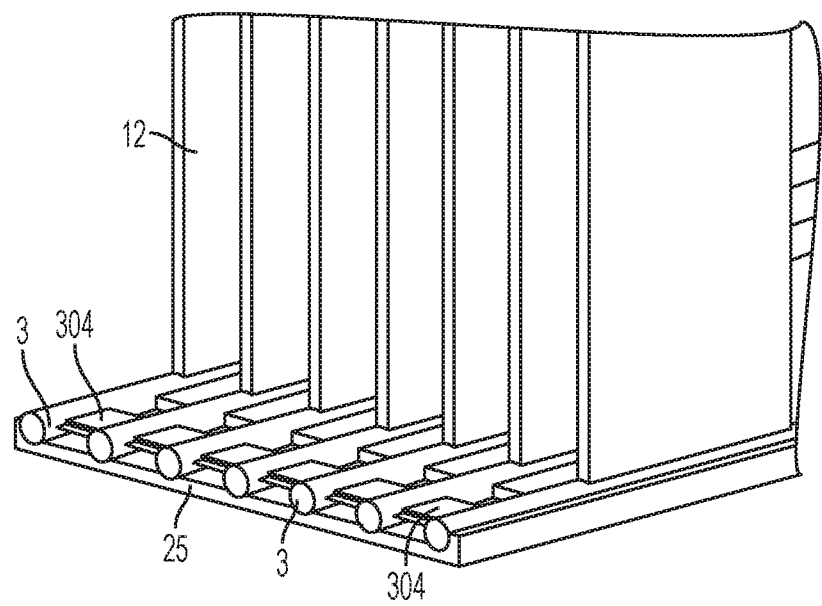


FIG. 82

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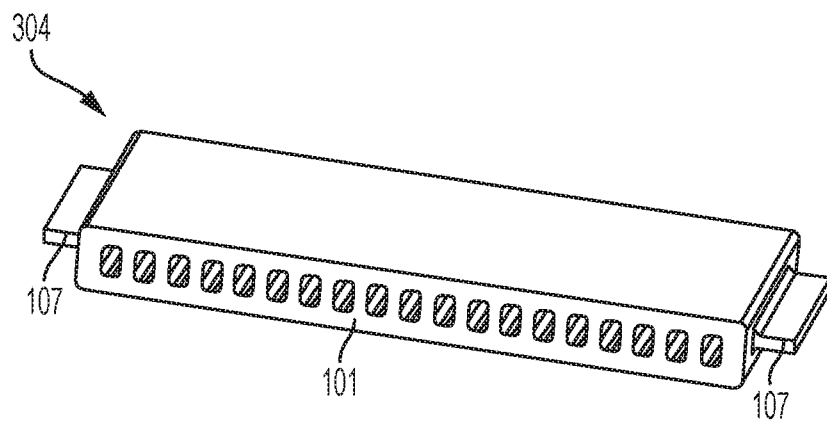


FIG. 83

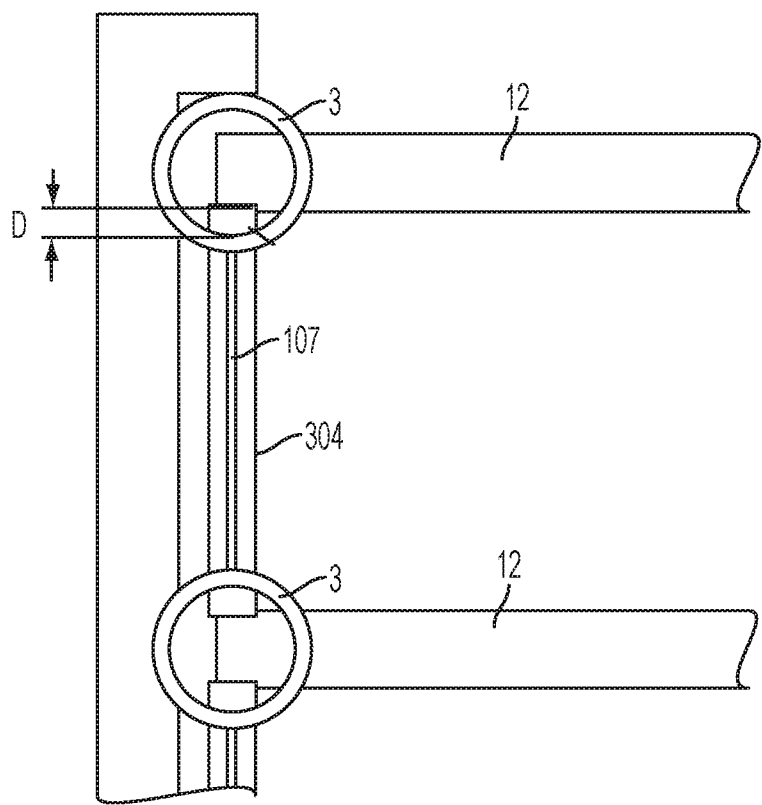


FIG. 84

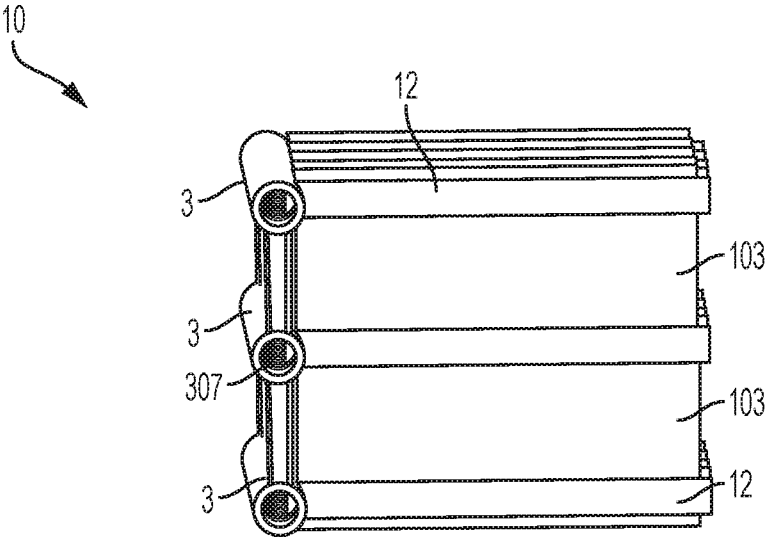


FIG. 85

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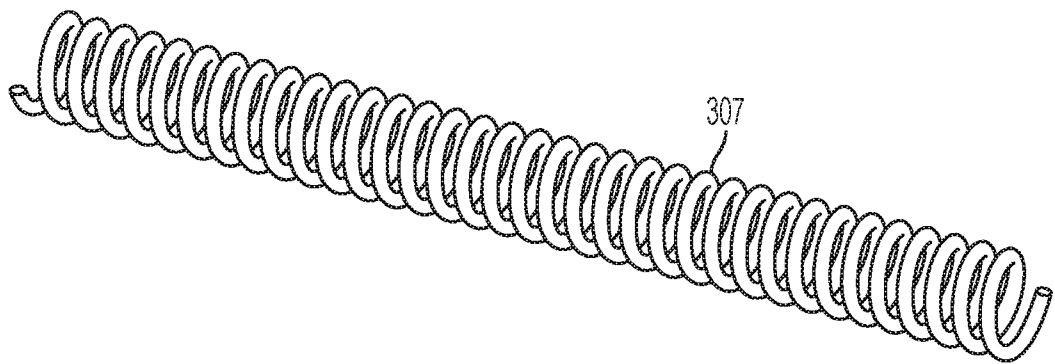


FIG. 86

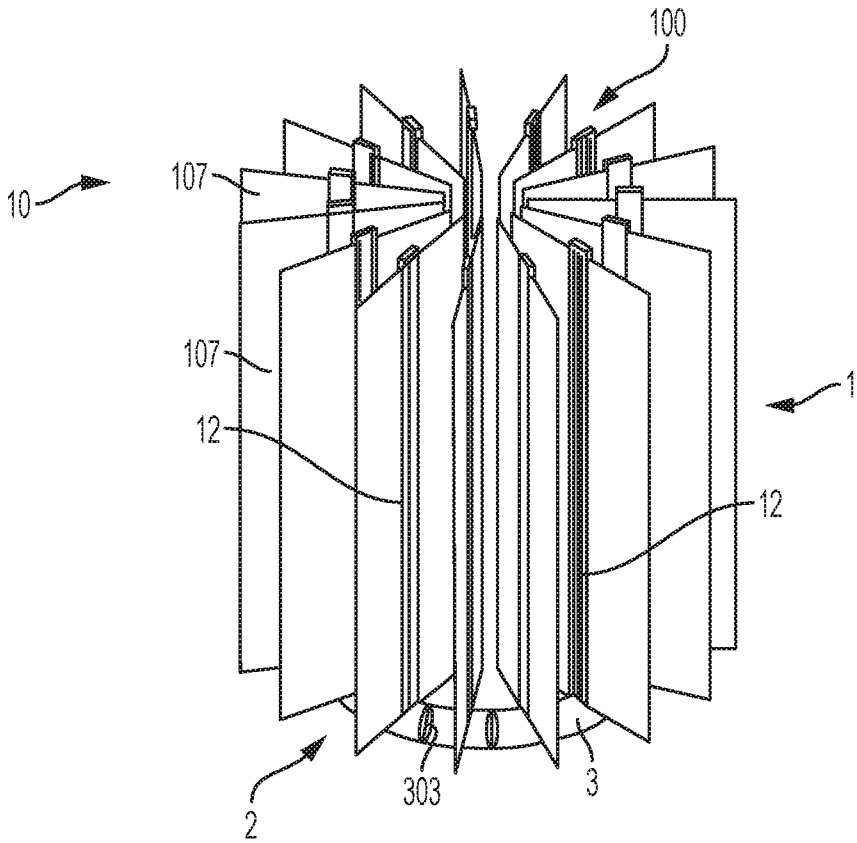


FIG. 87



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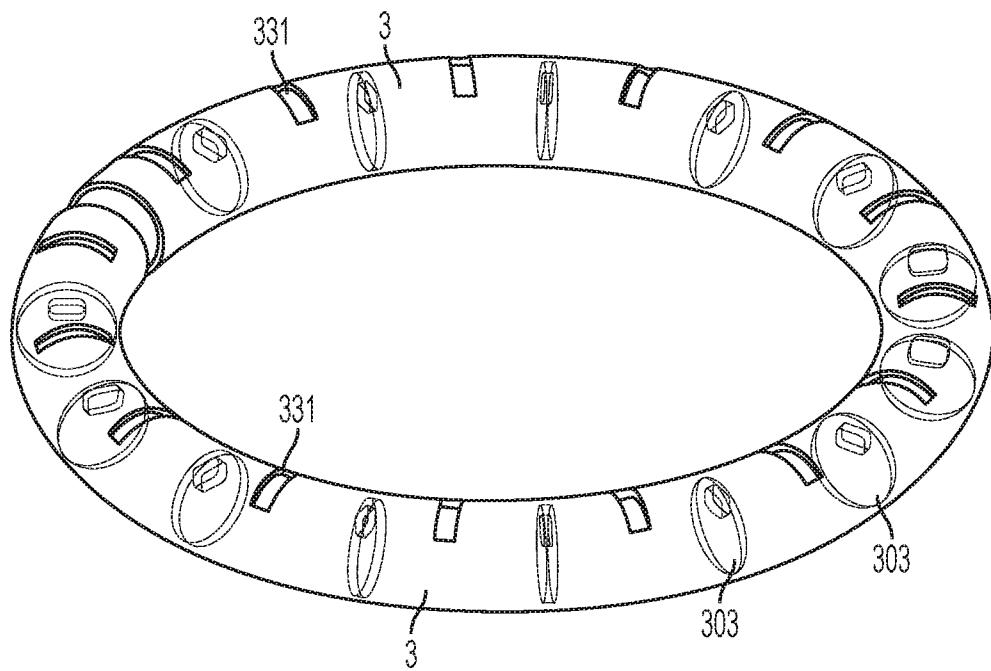


FIG. 88

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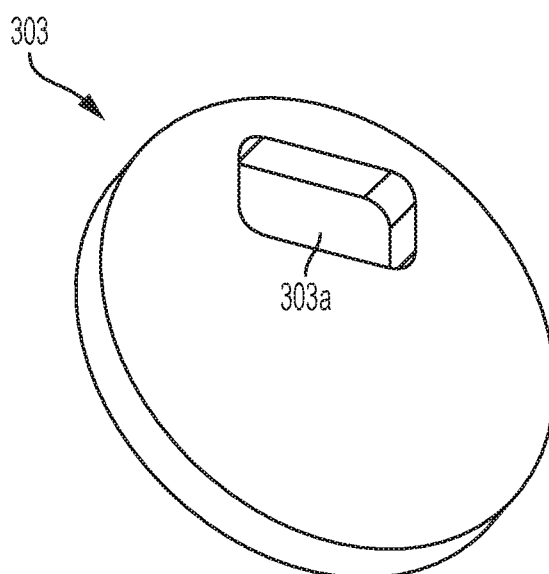


FIG. 89

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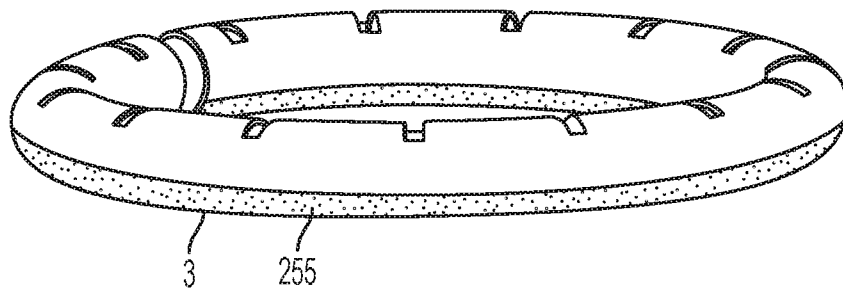


FIG. 90

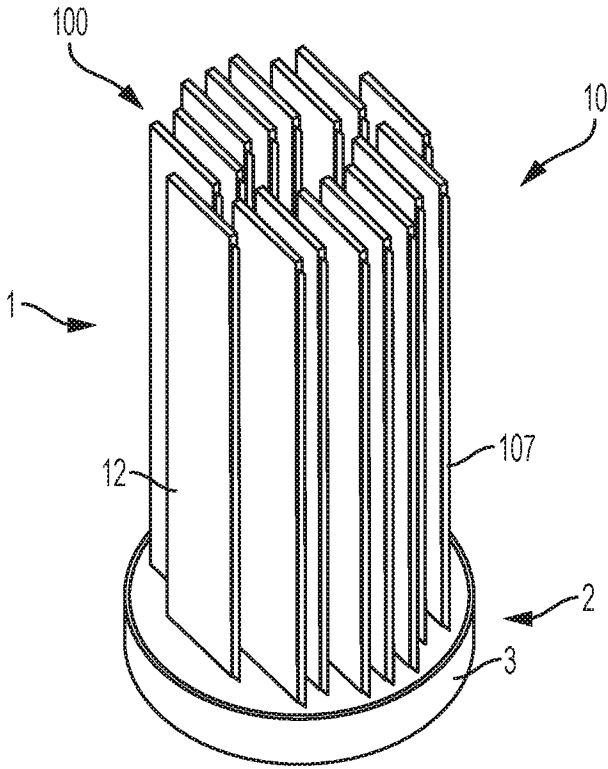


FIG. 91

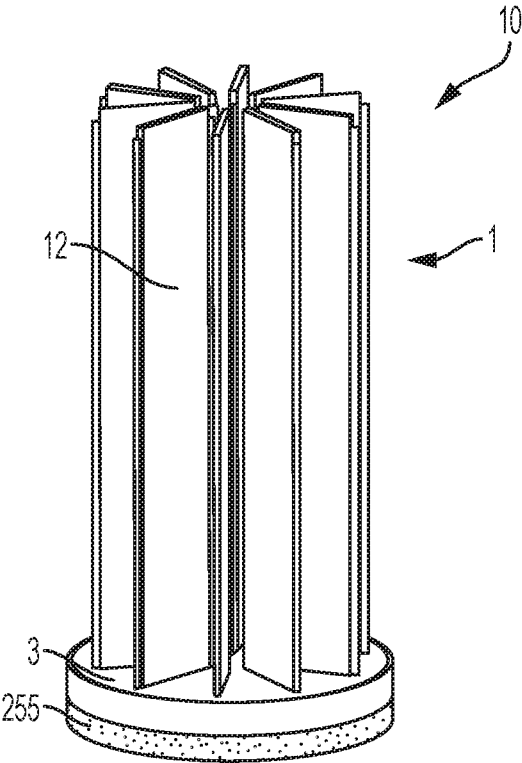


FIG. 92

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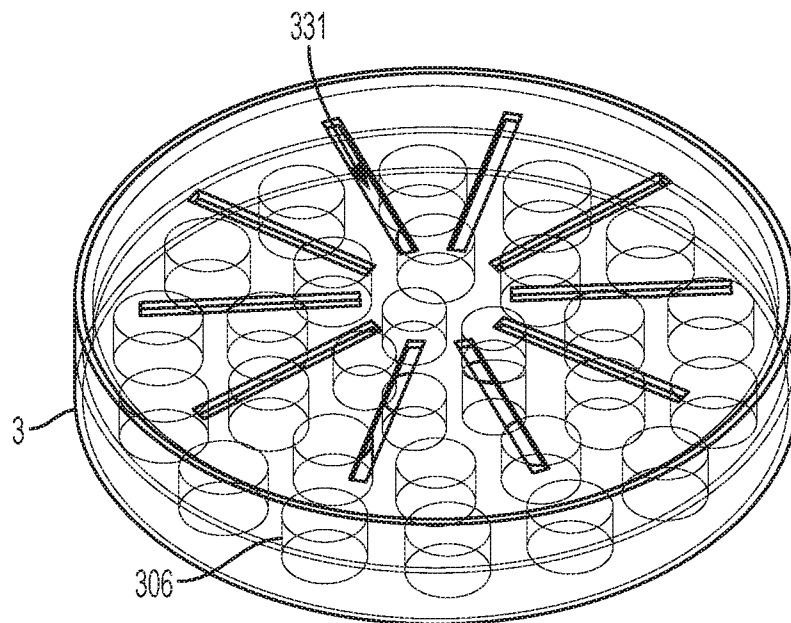


FIG. 93

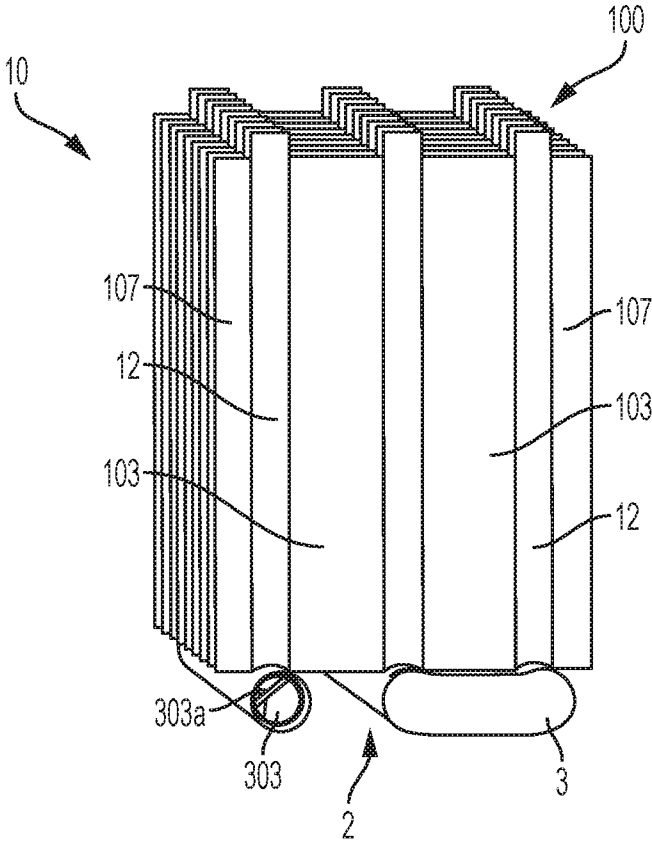


FIG. 94

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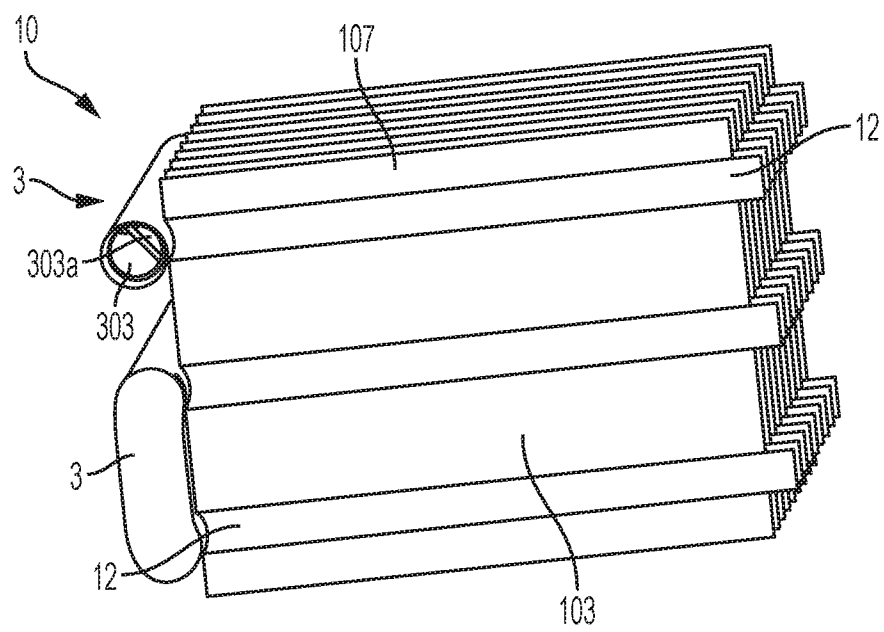


FIG. 95



## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2016/028342

A. CLASSIFICATION OF SUBJECT MATTER  
INV. F28D15/02 F28D1/053  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/104592 A1 (COTTET DIDIER [CH] ET AL) 2 May 2013 (2013-05-02) cited in the application the whole document -----	1-63
A	US 2014/090814 A1 (KONDOU YOSHIHIRO [JP] ET AL) 3 April 2014 (2014-04-03) the whole document -----	1-63
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Further documents are listed in the continuation of Box C.



See patent family annex.

## \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

7 July 2016

Date of mailing of the international search report

20/09/2016

Name and mailing address of the ISA/

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Axters, Michael

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2016/028342

### Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-63

#### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-63

A thermosiphon device comprising at least one flat multiport tube structure defining one or more flow channels, and a web that extends from the flow channels in a plane of the multiport tube structure.

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2. claims: 64-70

A thermosiphon cooling device including a manifold fluidly connecting the evaporator section and the condenser section, wherein the manifold includes first and second liquid chambers that are fluidly coupled to the first and second sets of condensing channels, respectively, and a vapor chamber fluidly coupled to the vapor supply path, and wherein the manifold includes an end cap that fluidly couples the first and second liquid chambers.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/028342

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