Technology Review:

Integrating Heat Pipes into Heat Sinks, 2012 to 2013

Qpedia continues its review of technologies developed for electronics cooling applications. We are presenting selected patents that were awarded to developers around the world to address cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications.

We are specifically focusing on patented technologies to show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application.

In this issue our spotlight is on integrating heat pipes into heat sinks. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors.

HEAT PIPES AND THERMOELECTRIC COOLING DEVICES

US 2012/0192574 A1, Ghoshal, U., et al.

Before describing the embodiments in detail, in accordance with the present invention, it should be observed that these embodiments reside primarily in thermoelectric cooling systems with heat pipes. Accordingly, the system components have been represented to show only those specific details that are pertinent for an understanding of the embodiments of the present invention, and not the details that will be apparent to those with ordinary skill in the art.

Heat pipe 100 comprises three sections—an evaporation section 102, an adiabatic section 104, and a condenser section 106. Evaporation section 102 includes a chamber 108 and a fluid reservoir 110 that contains a working fluid 112. In an embodiment of the present invention, evaporation section 102 is a sintered surface, a grooved surface, or a meshed surface that enhances evaporation. Working fluid 112 is selected on the basis of the desired heat flow through heat pipe 100. If the heat flow through heat pipe 100 is high, water

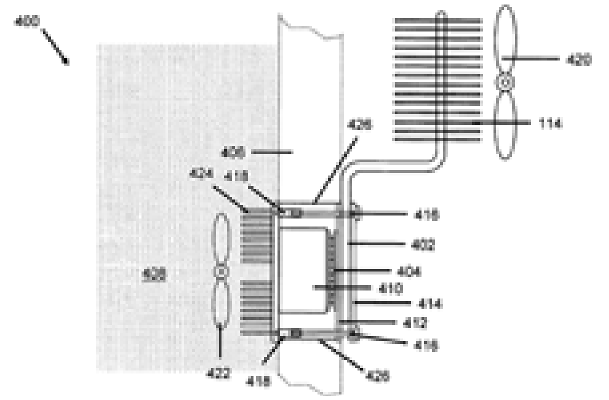
PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
US 2012/0192574 A1	HEAT PIPES AND THERMOELECTRIC COOLING DEVICES	Ghoshal, U., et al.	Aug 2, 2012
US 2013/0025830 A1	HEAT SINK ASSEMBLY OF FIN MODULE AND HEAT PIPES	Lin, C., et al.	Jan 31, 2013
US2013/0098582 A1	METHOD USING HEAT PIPES WITH MULTIPLE EVAPORATOR/ CONDENSER ZONES AND HEAT EXCHANGERS USING SAME	Stark, W.	Apr 25, 2013

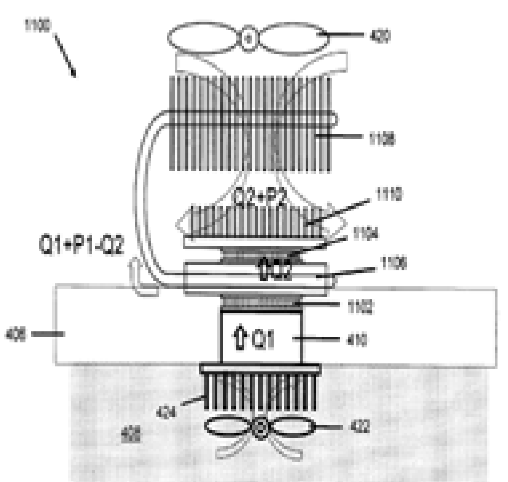
is chosen as working fluid 112. If the heat flow through heat pipe 100 is low, any other fluid with lower heat of vaporization than water is chosen as working fluid 112. Examples of fluids with low heat of vaporization include, but are not limited to, ammonia, ethanol, acetone, fluorocarbons such as Freon, mixtures of water and ethyl alcohol, and mixtures of water and ammonia.

Adiabatic section 104 of heat pipe 100 is thermally insulating. In an embodiment of the present invention, adiabatic section 104 is made of a material chosen from, but not limited to, nickel, titanium, stainless steel, macor, glass, or other ceramics to decrease the conductivity of adiabatic section 104.

Condenser section 106 is connected to a heat sink 114. Heat sink 114 has fins that facilitate transfer of heat to the ambient. Heat pipe 100 acts like a space transformer that extracts heat from a small area, which is essentially the footprint of a thermoelectric device and rejects the heat over a large area comprising heat sink 114.

Heat pipe 100 has a directional dependency of heat flow and it acts as a thermal diode. It allows heat flow from evaporation section 102 to condenser section 106 and prevents heat flow from condenser



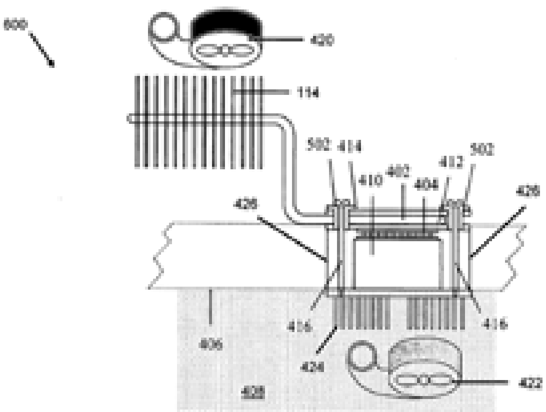


section 106 to evaporation section 102. Evaporation section 102 is connected to a surface from which heat has to be extracted. In an embodiment of the present invention, evaporation section 102 is connected to the thermoelectric device.

When the thermoelectric device is switched on, the heat rejected by the thermoelectric device is transferred to working fluid 112. Working fluid 112 evaporates by absorbing heat and forms vapor in chamber 108. The vapor reaches condenser section 106 through adiabatic section 104 and loses heat to condenser section 106 to form droplets. Thereafter, condenser section 106 transfers the heat to the ambient through heat sink 114. The droplets then return to evaporation section 102 and replenish fluid reservoir 110.

When the thermoelectric device is switched off, a cold side of the thermoelectric device reduces the temperature of a hot side to a temperature lower than the ambient temperature. Since no heat is rejected from the thermoelectric device, working fluid 112 remains in a liquid state in evaporation section 102. Further, adiabatic section 104 prevents heat flow from the ambient to evaporation section 102. Hence, heat transfer from the ambient to the thermoelectric device is minimized.

Heat pipe 200 is different from heat pipe 100 with respect to the material of adiabatic section 104 and condenser section 106. In an embodiment of the present invention adiabatic section 104 and condenser section 106 of heat pipe 200 comprise a



single tube made of nickel, aluminum, or stainless steel. In heat pipe 200, the single tube that forms adiabatic section 104 and condenser section 106 is attached to evaporation section 102 at a single brazed solder joint. This makes heat pipe 200 easier to manufacture as compared to heat pipe 100, where adiabatic section 104 is joined both to condenser section 106 and evaporation section 102. Heat pipe 300 contains the elements mentioned in conjunction with FIG. 1. Heat pipe 300 is different from heat pipe 100 with respect to the material of adiabatic section 104. Adiabatic section 104 of heat pipe 300 is made by externally etching a copper wall (as illustrated by the arrows). The thickness of the copper wall is reduced to decrease the thermal conduction of adiabatic section 104. Since a thin copper wall is mechanically weak, the copper wall is reinforced with an insulating epoxy material or any other material that is insulating as well as mechanically strong.

In this embodiment of the present invention, a single tube forms evaporation section 102, adiabatic section 104, and condenser section 106 of heat pipe 300, and adiabatic section 104 is created by reducing the wall thickness. Therefore, the simple design makes heat pipe 300 easy to manufacture. Thermoelectric cooling device 400 contains a heat pipe 402 connected to a hot side of a thermoelectric device 404. Heat pipe 402 is connected to thermoelectric device 404 through a Thermal Interface Material (TIM).

In another embodiment of the invention, heat pipe 402 is connected to thermoelectric device 404 through low temperature solder or thermally conducting epoxy.

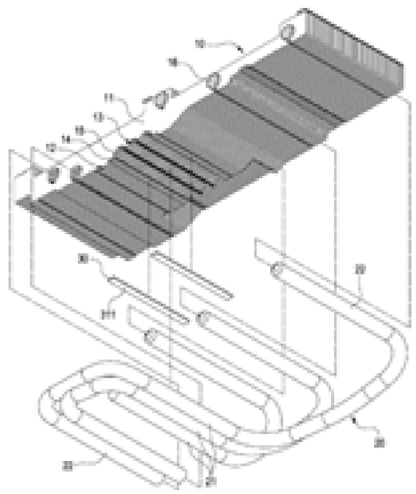
Thermoelectric device 404 is connected to a chamber 406. Chamber 406 contains a fluid 408 that needs to be cooled. In an embodiment of the present invention, chamber 406 is the cooling chamber of a refrigerator. A metal standoff 410 connects a cold side of thermoelectric device 404 to chamber 406. In an embodiment of the present invention metal standoff 410 is made of aluminum. A first plate 412, a second plate 414, and screws 416 hold heat pipe 402 to the hot side of thermoelectric device 404 and chamber 406. Heat pipe 402 is soldered to first plate 412, which is made of copper or copper alloy. Since first plate 412 is prone to buckling under compressive forces, second plate 414 is used to press heat pipe 402 to the hot side of thermoelectric device 404. Second plate 414 is made of a hard material that provides strength to second plate 414. Screws 416 are made of a metal and have an insulating standoff 418 that prevents the heat flow from the hot side of thermoelectric device 404 to fluid 408. Insulating standoff 418 can be made of materials such as plastics, ceramics, or other thermally insulating materials.

HEAT SINK ASSEMBLY OF FIN MODULE AND HEAT PIPES

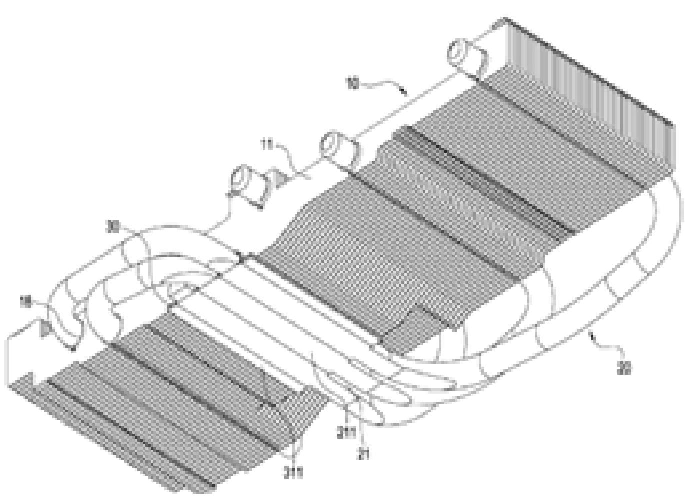
US 2013/0025830 A1, Lin, C., et al.

The detailed description and technical contents of the present invention will become apparent with the following detailed description accompanied with related drawings. It is noteworthy to point out that the drawings is provided for the illustration purpose only, but not intended for limiting the scope of the present invention.

The present invention provides a heat sink assembly including a fin module 10, a plurality of heat pipes 20 and a pair of side plates 30.

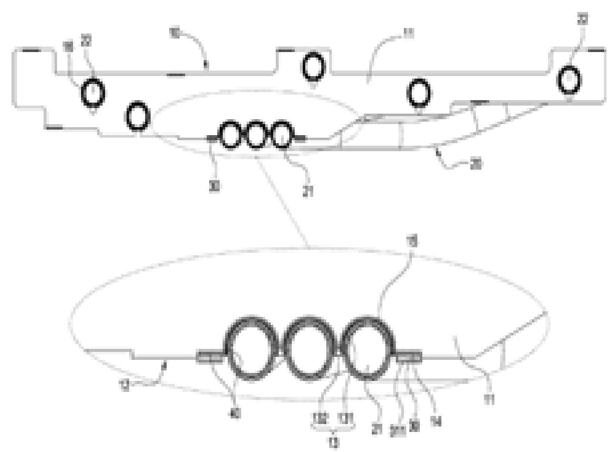


The fin module 10 is made by stacking a plurality of fins 11. Such fins 11 may be made of aluminum, copper or the alloys thereof. The fin module 10 is formed with a flat side 12. The flat side 12 is further formed with a trough 13 having three sub-troughs 131. The number of the sub-troughs 131 is not limited to three; any quantity except one is available. A separation section 132 is provided between any two adjacent sub-troughs 131. The separation sections 132 are lower than the flat side 12 in level so that a height difference is formed there between. Two lateral sides of the trough 13 are separately formed with a recess 14. The sub-troughs 131 and recesses 14 of the fins 11 are formed with bent flanges 15. Through holes 16 are provided in the fins 11.



There is a wick structure and working fluid in the heat pipes 20. Heat can be transferred from one end to the other end of the heat pipe 20 by means of phase change of the working fluid. In the shown embodiment, there are three heat pipes 20. Each heat pipe 20 has an evaporation section 21 and one or two condensation sections 22. The evaporation sections 21 are parallely accommodated in the sub-troughs 131 of the trough 13.

The side plates 30 are also made of aluminum, copper or the alloys thereof. The coefficient of thermal conductivity of the side plates 30 is higher than or equal to that of the fins 11. In the shown embodiment, the side plates 30 are separately accommodated in the recesses 14. A part of each of the side plates 30 protrudes from the flat side 12 and the exposed part thereof has an outer surface 311.



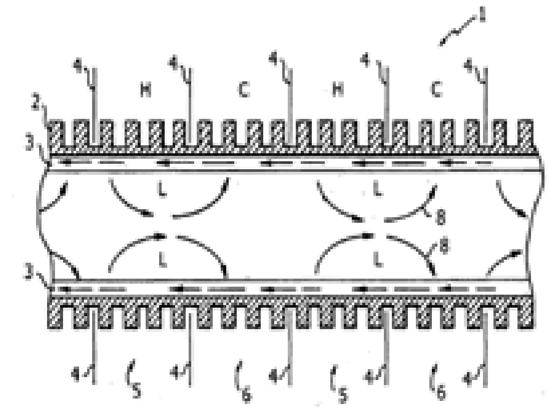
Solder 40 is soldered on the bent flanges 15 of the trough 13 and recesses 14 as shown in FIG. 3. The evaporation sections 21 of the heat pipes 20 are placed in the trough 13 and the side plates 30 are placed in the recesses 14 and beside the heat pipes 20. The heat pipes 20 and side plates 30 are soldered on the fins 11 of the fin module 10. Then the heat pipes 20 are pressed by a tool (not shown) to form a flat surface 211 coplanar with the outer surface 311 of the side plates 30. The flat surface 211 is continuous and coplanar. In other words, the deformed heat pipes 20 are in contact with each other.

The heat sink assembly of the present invention may be applied to a heat source 8 on a circuit board 7. The heat source 8 is in thermal contact with the outer surface 311 of the side plates 30 and the flat surface 211 of the heat pipes 20. The heat from the heat source 8 is absorbed by the evaporation sections 21 and the side plates 30. After the side plates 30 and the evaporation sections 21 absorb the heat, the working fluid in the heat pipes 20 evaporates to become vapor. The vapor carries away the heat and flows toward a low-temperature region of the heat pipe 20. When the vapor reaches the condensation section 22, the vapor condenses in the condensation section 22 by means of the heat exchange of the fins 11 of the fin module 10 with external air. The condensed working liquid reflows to the evaporation section 21 by means of the capillary force in the wick structure.

METHOD USING HEAT PIPES WITH MULTIPLE EVAPORATOR/CONDENSER ZONES AND HEAT EXCHANGERS USING SAME

US2013/0098582 A1, Stark, W.

The method of this invention utilizes smaller-tube heat pipes with an airflow arrangement that allows for short distances between evaporating and condensing sections of the heat pipe. Therefore, the overall tube length can be increased indefinitely, without traditional degradation of performance. Length of each tube is infinitely variable. While tube diameters of each heat pipe may vary, typical tube diameters may be ⅛ inch to 2 inches in diameter, although they can be smaller than ⅛ inch in diameter or more than 2 inches in diameter. Traditional heat pipes have one evaporator end where input heat is added and one condenser end where heat is extracted. In contrast, in the heat pipe method of this invention, a heat pipe is exposed to multiple alternate hot and cold zones adjacent to each other by external means. So, although the heat pipe itself is of traditional construction, it no longer has a single evaporator end and a single condenser end. The operation is similar to that of a string of short heat pipes laid end to end, but the single long small diameter



heat pipe is more practical and of much lower cost to manufacture. In operation, each evaporator zone accepts input heat to cause evaporation of the working fluid in the wick of the immediate vicinity. The vapor produced moves to either side by local pressure differences to condense in the two adjacent condenser zones where it is absorbed by the wick as a liquid and flows in the wick back to adjacent evaporator zones at each side. Thus each evaporator zone creates two fluid loops, whereby evaporated working fluid splits up left and right, condenses in the adjacent condenser zones and flows back to the evaporator zone as a liquid within the wick.

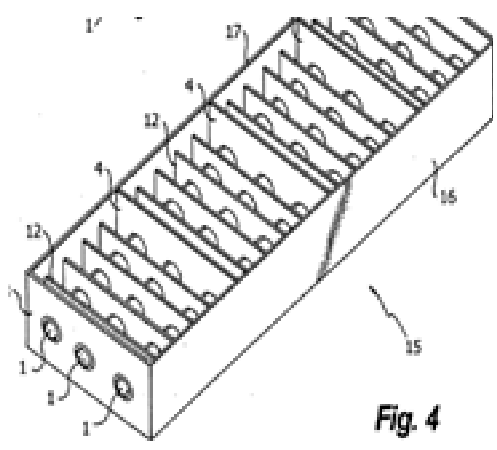
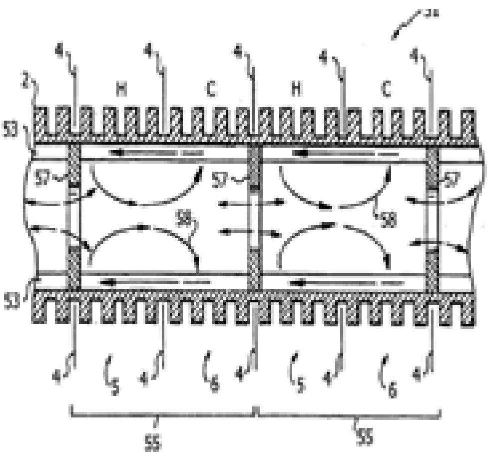


Fig. 4

In an alternate embodiment of the heat pipe of this invention, additional torus shaped (like a donut or washer) plugs are added internally to partition each pair or grouping of pairs of heat/cool zones from the adjacent one. The central openings in the plugs allow gas pressures to equalize As the plugs may be rigid and extended to the inside of the heat pipe housing, they would partition the wick layer by actually cutting it or squeezing it against the housing. The plugs may also be resilient such as an elastomer/rubber in which case the wicking internal layer would also be squeezed so as to limit liquid flow within the heat/cool zone. The solid walls of the plugs act as a dam to hold liquid between hot/cold sections of pipe. The purpose of these added plugs is also to counteract any gravitational effects due to sagging or bowing of a long heat pipe or not being horizontally level thereby inducing the puddling of liquid which can result in the wick. Note that the vapor flow would be mainly confined to flow from hot to cold region within the partitioned sections, but the central hole will permit some vapor flow to adjacent regions to equalize any positional or temporal imbalances along the heat pipe.



A heat pipe used by the method of this invention by creating alternate adjacent evaporator/condenser pairs along its length can be applied to a variety of applications such as removing heat from electronics or in medical equipment or chemical manufacture. Liquid-to-liquid, liquid-to-air, contact surface-to-contact surface, or air-to-air heat transfer can be accommodated. In this invention, air-to-air heat exchangers for HVAC application will be discussed.

Although other configurations are possible, the heat exchangers of this invention are configured in a geometry not unlike that of fin tube heat exchangers commonly used in cooling coils, steam heating, and similar applications. The long small diameter heat pipes run parallel to each other preferable through common fins; they are passive independent entities and therefore not interconnected fluidically. They are placed in the same positions of the long parallel runs in a similar fin tube unit. One or more heat pipes can be used forming a flat rectangular array.

Multiple rows of heat pipes can also be configured, preferably staggering the heat pipes in each row. A four sided housing around the sides of the heat pipe/fin unit leaves the fins exposed on top and bottom completing the heat pipe heat exchanger (HPHE).