United States Patent

[11] 3,598,178

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[21] Appl. No. **827,566**
[22] Filed **May 26, 1969**
[45] Patented **Aug. 10, 1971**
[73] Assignee **General Electric Company**

[54] **HEAT PIPE**
6 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **165/105,**
62/514, 313/12, 317/234
[51] **Int. Cl.** **F28d 15/00**
[50] **Field of Search** 165/105;
62/514; 317/234; 313/12

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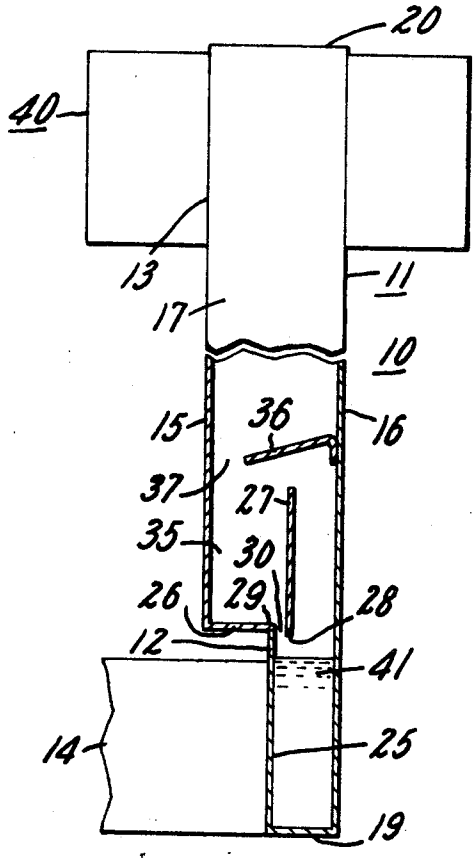
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ABSTRACT: A heat pipe including a sealed container having a pair of opposed sidewalls and a pair of ends, one of the ends being located below the other of the ends. A portion of one sidewall of the container is recessed from the remainder thereof adjacent the aforementioned one end, and is thermally conductive to provide a heat transfer surface inside of the container. A baffle located in the container has an edge spaced from the upper edge of the heat transfer surface to form an elongated aperture therewith. The baffle extends in the direction of the other end of the container and forms a reservoir with the sidewalls of the container.



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Fig. 2.

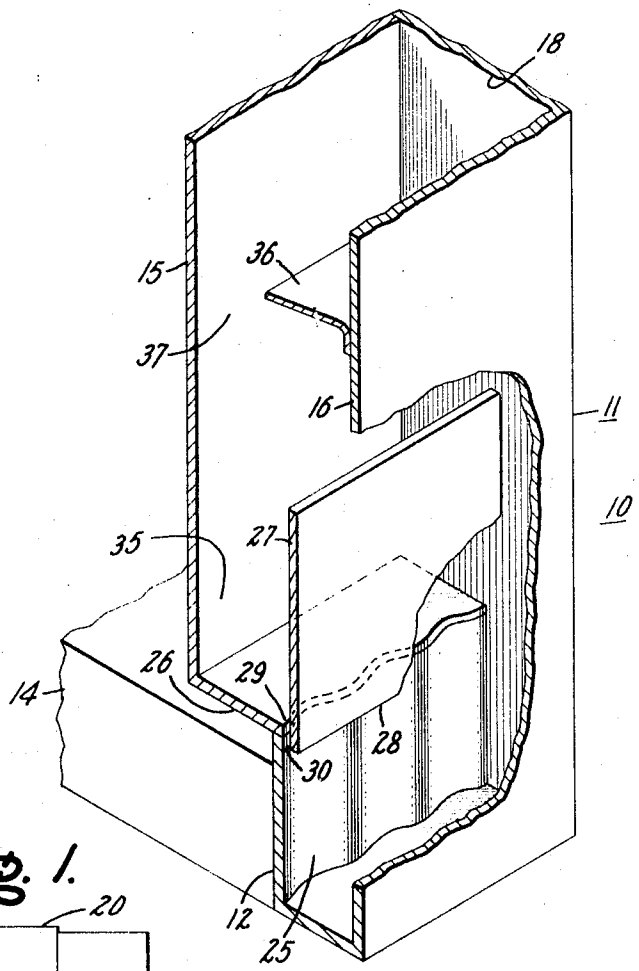
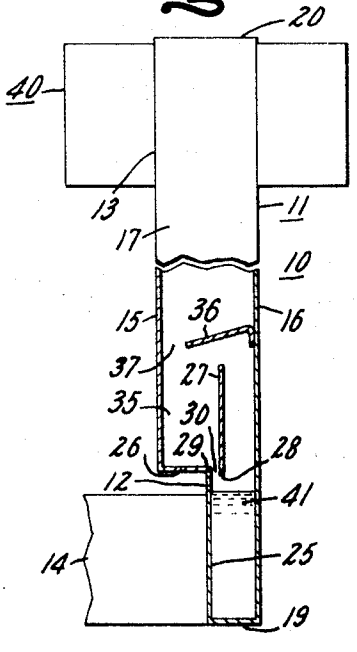


Fig. 1.



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Fig. 3.

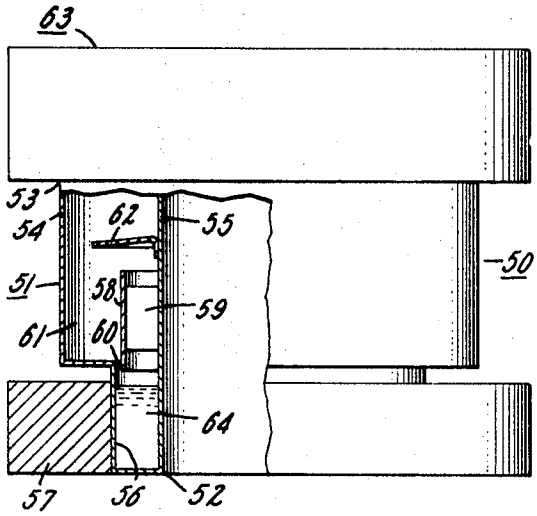


Fig. 5.

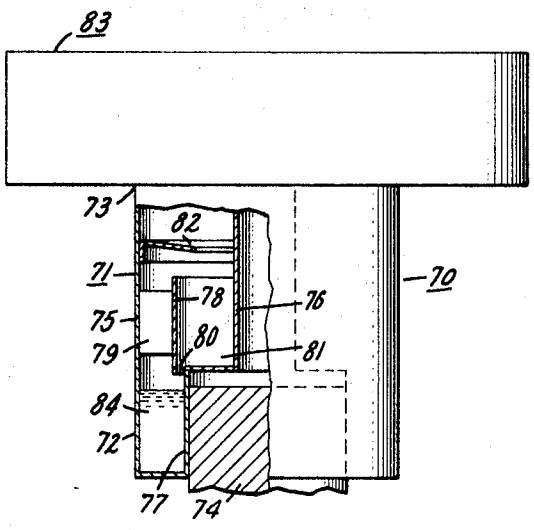


Fig. 4.

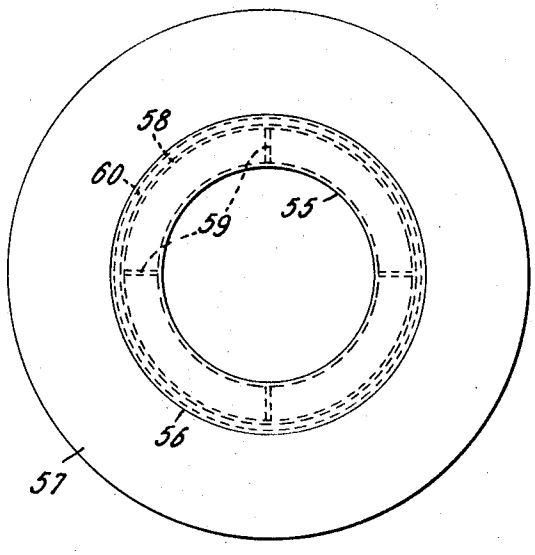
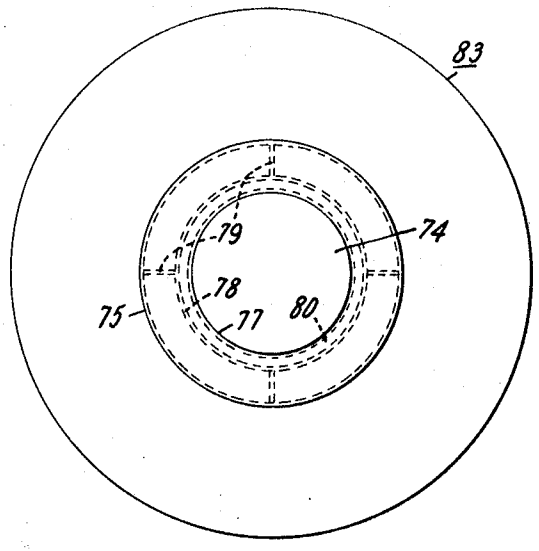


Fig. 6.



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HEAT PIPE

The present invention relates in general to heat pipes and in particular to a combination of passive elements thereof which provide effective coupling of heat from a source to a heat sink.

A heat pipe is a device for transferring heat from a hot to a cold region with minimum temperature drop, that is, less than the drop which can be obtained with even the highest thermal conductivity materials. The device consists essentially of a closed container containing some liquid and its vapor. The addition of heat at the hot end of the container evaporates the liquid. The vapor travels to the cold end of the container, condenses and returns to the hot end by force of gravity or by capillary means such as wicking.

Such devices are currently being applied for cooling of various electronic and optical devices as well as large electrical apparatus. In many potential heat pipe applications, such as in conjunction with a cooling of semiconductor devices, the heat flux which must be removed at the evaporator surface is near or greater than the critical heat flux limit of the coolant, usually water, in restricted pool boiling. This is especially the case if high heat flux transients are involved. A conventional flat surface immersed in a pool of water will thus not overcome such thermal operating limit, a limit which tends to become more serious as realistically small geometries are required.

An object of the present invention is to provide a heat pipe of passive elements yet which is able to transfer heat from a source to a sink at high rates.

Another object of the present invention is to provide passive means in a heat pipe for providing effective and efficient coupling of heat thereto.

The features of my invention which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings wherein:

FIG. 1 is a side view in partial cross section of a heat pipe embodying the present invention.

FIG. 2 is a perspective view of the portion of the heat pipe of FIG. 1 shown in section for the purpose of showing the parts and arrangement thereof in accordance with the present invention.

FIG. 3 is a side view in partial cross section of a heat pipe in accordance with another embodiment of the present invention.

FIG. 4 is a bottom view of the device of FIG. 3.

FIG. 5 is a side view in partial cross section of a heat pipe in accordance with a further embodiment of the present invention.

FIG. 6 is a bottom view of the device of FIG. 5.

Referring now to FIGS. 1 and 2, there is shown a heat pipe 10 including a vertically oriented container 11 having a heat input end 12 and a heat output end 13 above the heat input end. Part of a device 14 in which heat is generated is shown coupled to the heat input end of the heat pipe. The container 11 is rectangular in cross section and has four sides 15, 16, 17 and 18 or walls of thermally conductive material, for example, copper. Sides 15 and 16 are opposite one another. Similarly, sides 17 and 18 are opposite one another. End wall 19 is provided adjacent the heat input end 12 and end wall 20 is provided adjacent the heat output end. Side 15 has a portion 25, shown corrugated, at the heat input end of the container and which is recessed from the main wall 15 to form a heat transfer surface to which the device 14 generating heat is coupled. The device 14 is spaced from the undersurface 26 joining side 15 with the recessed portion 25 to avoid coupling of heat thereto for reasons which will be apparent below.

A baffle or barrier 27 is provided having an edge 28 spaced from the upper edge 29 of the heat transfer surface 25 so as to form an elongated aperture 30 therewith. The baffle 27 extends in the direction of the heat output end of the container for a distance and is joined to opposed sides 17 and 18. The baffle 27, the undersurface portion 26 of side 15 and parts of the three sides 15, 17 and 18 of the container form a reservoir 35 for the operating fluid of the heat pipe. Another baffle 36 is provided intermediate the heat input and heat output end of the container and connected to the side 16 of the container spaced opposite from the side 15 having the recessed wall and the heat transfer surface 25. The baffle 36 is connected to the opposed sides 17 and 18 and extends into the space between the sides 15 and 16 for a distance which overhangs the baffle 27. The remote end of the baffle 36 is spaced from the wall 15 so as to provide an opening 37 through which vaporized fluid may pass to the heat output end of the container. At the heat output end, suitable condensing means 40 is provided, for example, the means generally designated in block form may be fins which are either convection or forced air cooled. The heat input end of the container in the vicinity of the heat transfer surface contains a vaporizable liquid 41 such as water, a refrigerant or other suitable fluid determined by the use to which the heat pipe is to be put.

Upon the application of heat to the heat transfer surface 25 from the heat generating device 14, the pool of liquid 41 is vaporized and rises. The vapor is deflected by the baffle 36 and passes upward through the opening 37 to the heat output end 13 where the condenser means 40 condenses the vapor into a liquid. The liquid flows into the reservoir 35. Concurrently with the filling of the reservoir, the liquid flows by gravity through the elongated aperture 30 over the heat transfer surface 25 thereby becoming evaporated over again and reexecuting the cycle just described. In the case where there is a large transient heat input to the heat transfer surface 25, the liquid 41 is not only vaporized but ejected at the heat input end. Such ejected fluid is deflected by the baffle 36 and falls into the reservoir 35. In the steady state condition of operation the reservoir is provided with sufficient fluid to supply the heat transfer surface with a film to enable effective coupling of heat into the heat pipe.

While the apparatus has been described in terms of a vertical positioning thereof with the heat output end located above the heat input end, it will be appreciated that the heat pipe may be tilted considerably as long as a small vertical component, that is, a gravitational component, exists which permits liquid from the reservoir 35 to flow through the opening 30 over the heat transfer surface 25. In cases where the alignment of the heat pipe is fairly close to the horizontal direction, i.e., perpendicular to the direction of the force of gravity, the fluid which is condensed by the condenser portion of the heat pipe may be returned to the reservoir through such means as wicking (not shown), if needed. For a near horizontal orientation of the heat pipe, the proper feeding of condensate to the heat transfer surface 25 would depend on the capacity of the selected wicking material.

The heat-generating device 14 is spaced from the bottom 26 of the reservoir 35, to isolate the liquid thereof from significant heat-coupling relationship therewith. In FIG. 2 heat transfer surface 25 is shown as a corrugated surface to enhance the heat transfer effectiveness of such surface. It will be appreciated that such surface could be made flat and conversely the baffle 27 could be made corrugated to provide elongated opening 30 of desired dimensions and form. The barrier 27 is arranged so that the liquid is properly manifolded to run as a film over the corrugated evaporative surface 25. The falling film evaporator surface which results allows the critical heat flux to be greater than that which would exist in small cavity pool boiling. The thermal syphon and deflector system described above insures this mode of operation through the initial ejection of liquid at the beginning of the operation and by allowing condensate to feed back only behind the deflection barrier 27.

Referring now to FIGS. 3 and 4, there is shown another embodiment of the present invention including a vertically

oriented sealed container 51 having a heat input end 52 and a heat output end 53 above the heat input end. The heat pipe 50 shown therein is of cylindrical configuration and includes a pair of opposed cylindrical walls 54 and 55 corresponding to walls 15 and 16, respectively of FIGS. 1 and 2. The cylindrical walls 54 and 55 are concentric. The diameter of wall 54 is larger than the diameter of wall 55. A heat transfer surface 56, situated at the heat input end of the heat pipe and also cylindrical in shape, is coupled to a heat generating device 57 connected thereto. A cylindrical barrier or baffle 58 is provided within the container corresponding to element 27 of FIG. 2 and is supported from wall 55 by suitable supports 59. The lower edge of the barrier 58 is in spaced relationship to the upper edge of the heat transfer surface 56 to provide an annular opening 60 therewith to enable liquid in the reservoir 61 formed by the side 54 and the barrier 55 to flow in a thin film over the heat transfer surface 56. An annular baffle 62 is connected to the inner wall 55 of the container and extends over the barrier 58 into spaced relationship with the opposed wall 54. The baffle 62 corresponds to baffle 36 of FIGS. 1 and 2. Suitable condenser means 63 is connected to the heat output end to remove the heat from the vapor flowing to that end. The heat input end of the container in the vicinity of the heat transfer surface contains a vaporizable liquid 64. The operation of the apparatus of FIGS. 3 and 4 is similar to the operation of apparatus of FIGS. 1 and 2. The configuration has the particular advantage in that it enables heat transfer from a cylindrical surface to be efficiently removed therefrom.

Referring now to FIGS. 5 and 6 there is shown a further embodiment of a heat pipe 70 in accordance with the present invention including a vertically oriented sealed container 71 having a heat input 72 and heat output 73 end above the heat input end. Part of a cylindrical device 74 is shown in which heat is generated and coupled to the heat input end of the heat pipe. The cylindrical container 71 has a pair of opposed sides 75 and 76. Side 75 is larger in diameter than side 76. The side 76 includes a recessed portion 77 which forms a heat transfer surface to which the device 74 generating heat is coupled. The device 74 is spaced from the under surface joining the side 76 with recessed portion 77 to avoid coupling of heat thereto for reasons indicated above. A cylindrical barrier 78 or baffle supported from wall 75 by supports 79 has a lower edge spaced from the upper edge of the heat transfer surface 77 so as to form an annular aperture 80 therewith. The baffle 78, the underportion of the wall 76 and the wall 76 form a reservoir 81 for operating fluid for the heat pipe. A second baffle 82 is provided intermediate the heat input and heat output end of the container and connected to the side 75 of the container spaced opposite from the side 76 having the recessed wall and heat transfer surface. The baffle 82 extends into the space between the walls 75 and 76 for a distance which overhangs the baffle 78. The baffle 82 is spaced from the 76 so as to provide an opening through which vaporized fluid may pass into the heat output end of the container. At the heat output end suitable condensing means 83 is provided. The heat input end of the container in the vicinity of the heat transfer surface contains a vaporizable liquid 84. The operation of the heat pipe of FIGS. 5 and 6 is similar to the operation of the pipe of FIGS. 1 and 2. The structure of FIGS. 5 and 6 enable heat to be rapidly removed from heat-generating devices which have cylindrical configurations.

Accordingly, it is seen that an evaporator system is provided for a heat pipe which does not depend upon external forced circulation to provide fluid over the heat transfer surface. In effect, a thermal syphon, without the need for external pumps, is provided for transporting the vaporizable liquid from a heat transfer surface to a reservoir. A particular advantage of the structure is that a pool of liquid is used in the initial operation of the heat pipe and provides large heat transient storage capability. Such storage capability accommodates large transient heat pulses.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A heat transfer device comprising
a sealed container having a pair of opposed sidewalls and a pair of ends, one of said ends located below the other of said ends,
a portion of a sidewall of said container being recessed from the remainder thereof adjacent said one end, said portion being thermally conductive and providing a heat transfer surface inside of said container,
a baffle located in said container and having an edge spaced from the upper edge of said heat transfer surface to form an elongated aperture therewith, said baffle extending in the direction of said other end of said container, said baffle and another portion of said one sidewall of said container forming a reservoir,
a vaporizable liquid being disposed in said container at said one end,
means adjacent said other end for condensing vapors of said liquid,
whereby as heat is conducted to said heat transfer surface said liquid is converted into vapor and rises to said other end of said container where said vapor is condensed and returned to said reservoir, the liquid in said reservoir flowing downward through said elongated aperture along said heat transfer surface in a film where it is again vaporized.

2. The combination of claim 1 in which another baffle is provided extending from said other sidewall toward said one wall, said other baffle extending above and over said one baffle to provide a deflection of unvaporized fluid from said one end and said other end to said reservoir,
whereby as heat is applied to said heat transfer surface said liquid is converted into vapor which moves under the pressure created thereby along and around said other baffle to said other end of said container where said vapor is condensed on the surface of said other baffle adjacent said other end and is deflected into said reservoir.

3. The combination of claim 1 in which each of said opposed sidewalls, and said one portion of said one sidewall are cylinders.

4. The combination of claim 3 in which the diameter of said one sidewall is greater than the diameter of said other sidewall.

5. The combination of claim 3 in which the diameter of said other sidewall is greater than the diameter of said one sidewall.

6. The combination of claim 1 in which said container is generally rectangular in cross section.