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[54] **HEAT TRANSFER DEVICE**

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[52] **U.S. Cl.** **165/105**, 165/133

[51] **Int. Cl.** **F28d 15/00**

[58] **Field of Search** 165/133, 105

[56] **References Cited**

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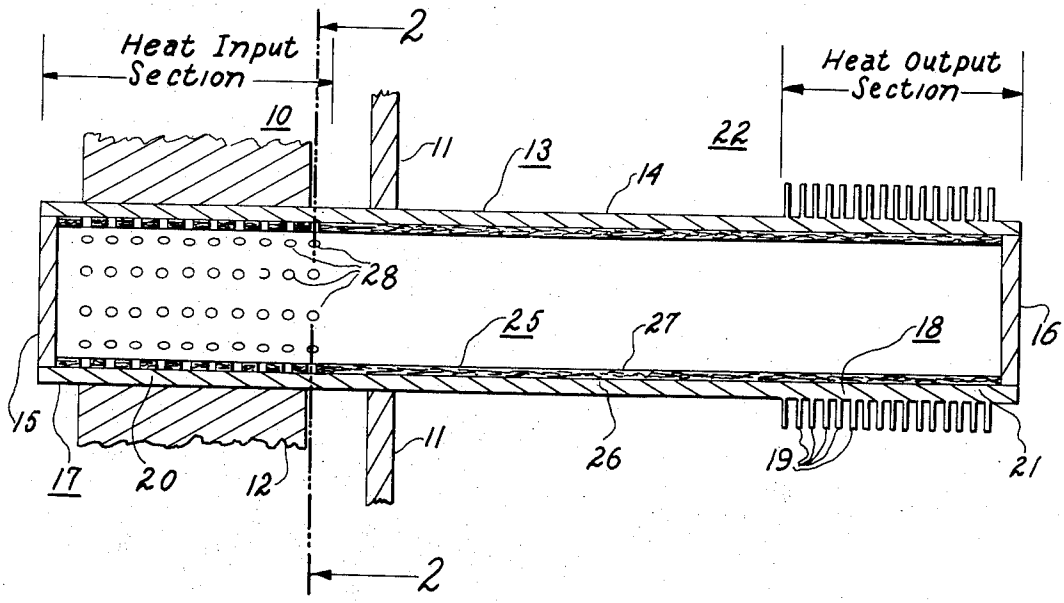
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[57] **ABSTRACT**

In a heat pipe, the portion of the wicking which supplies the evaporator section of the heat pipe with liquid is provided with a plurality of openings of relatively low impedance to vapor flow therethrough and extending orthogonally from the surface in contact with the heat input surface of the evaporator section to the opposing surface thereof to minimize vapor accumulation which blocks the flow of the liquid to the evaporator surface.

4 Claims, 3 Drawing Figures



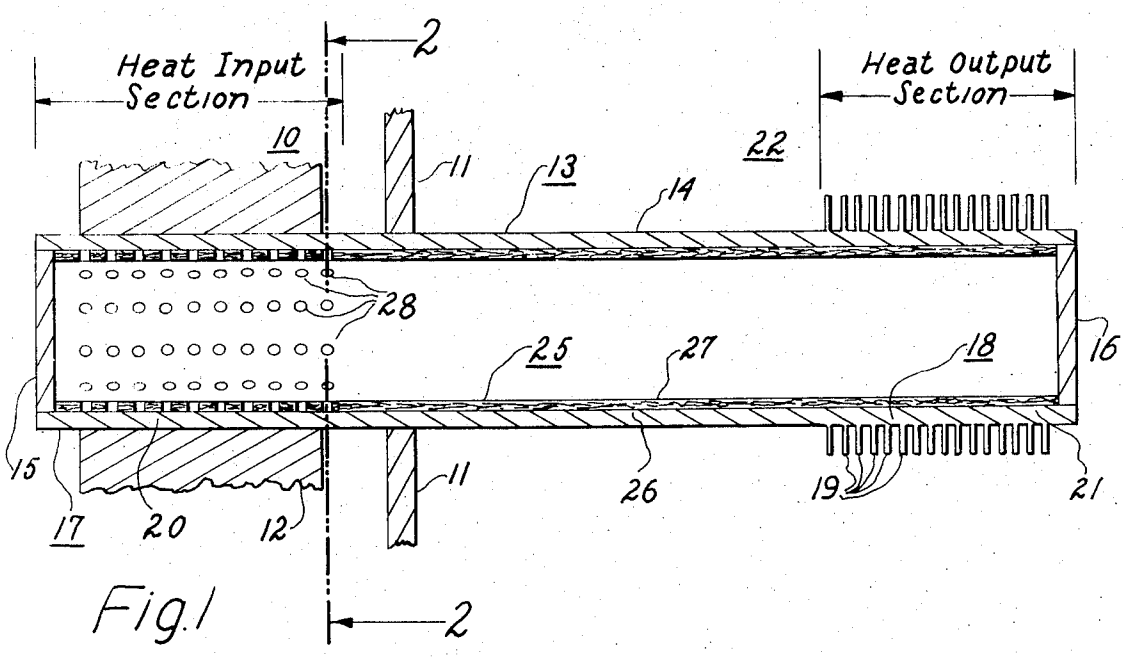


Fig. 1

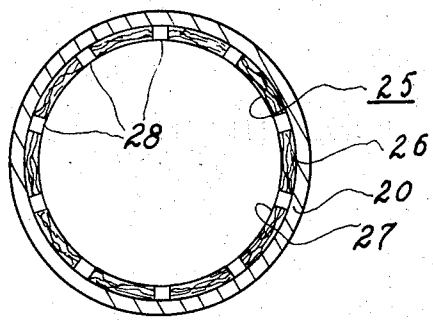


Fig. 2

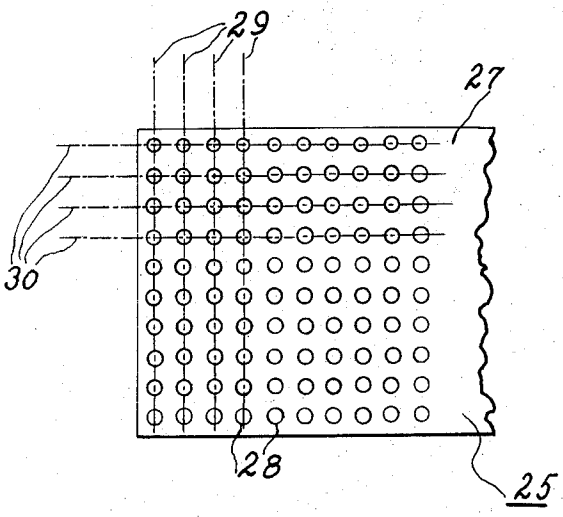


Fig. 3

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HEAT TRANSFER DEVICE

The present invention relates, in general, to a heat transfer device involving the evaporation of a liquid supplied to a heat transfer surface of the device by a wicking means and in particular to heat pipes utilizing such devices.

A heat pipe is a device utilizing an evaporation and condensation cycle for transferring heat from a hot or heat input region to a cold or heat output region thereof with minimum temperature drop. One type of heat pipe comprises a closed container within which is included a wicking material saturated with a vaporizable liquid and extending from the heat input region to the heat output region thereof. The addition of heat at the heat input region of the container evaporates the liquid being supplied thereto. The vapor moves to the heat output region of the container where it is condensed. The condensed liquid is returned to the heat input region by capillary action in the wicking material. Such devices are currently being utilized to cool electrical, optical and other devices in which heat is generated.

It is desirable to use wicking material which has a small mean pore size in order to provide good capillary pressure rise in the wicking material to perform the function of returning liquid from the condenser region to the evaporator region of the heat pipe. Capillary pores or passages of small size present high impedance to the flow of vapor which is generated at the evaporator region and must pass through the wicking material to perform its function of transferring heat to the condenser region. At large values of applied heat flux, vapor builds up in the vicinity of the heat transfer surface, blocks the flow of liquid through the capillary passages or tubes of the wicking material and limits the heat which can be carried away by the heat pipe.

Accordingly, an object of the present invention is to increase the heat transfer coefficient and the maximum allowable evaporator heat flux of heat transfer devices of the kind described.

Another object of the present invention is to provide minimum impedance to heat transfer, liquid flow and vapor flow in the vicinity of the evaporator heat transfer surface in a heat transfer device utilizing a wicking material for providing liquid to the evaporator surface.

In carrying out the invention in one embodiment as applied to a heat pipe having an evaporator wall, there is provided a layer of wicking material having a pair of opposed surface portions, one of which is in contact with the internal surface of the evaporator wall. The layer of wicking material includes a multiplicity of capillary passages, each of small cross-sectional area, extending in various directions and to various extends, and interconnected to move liquid therethrough from one surface region to another. The wicking material also includes a plurality of openings each of large cross-sectional area in relation to the cross-sectional area of a capillary passage, and each extending from one surface portion to the opposed surface portion thereof to provide a relatively low impedance path to the passage of vapor therethrough.

The features of our invention which we desire to protect 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 drawing wherein:

FIG. 1 is a cross-sectional view of the heat pipe embodying the present invention.

FIG. 2 is a view of the portion of the heat pipe of FIG. 1 taken along section lines 2—2 of FIG. 1.

FIG. 3 is a developed view of the inside surface of the wicking material of the heat pipe of FIGS. 1 and 2 located in the evaporator or heat input section thereof.

Referring now to FIGS. 1, 2 and 3, there is shown a chamber 10 formed by an enclosure 11, only part of which is shown, in which is included a device 12, also only part of which is shown. The device 12 generates heat which must be removed therefrom. For such purpose a heat pipe 13 is provided. The heat pipe 13 is in the form of a tubular or cylindrical container 14 of metallic material sealed at its ends by end walls 15 and 16 and having a heat input section 17 at one end thereof and a heat output section 18 at the other end thereof. The heat pipe is mounted in an opening in the enclosure 11 with input section 17 thereof conductively connected to the heat generating device 12 and with the heat output section 18 extending into an outer region which may be the atmosphere 22 to which heat is rejected or transferred. The heat output section 18 of the container is provided with fins 19 to facilitate the dissipation of heat from the output section. The heat input section 17 includes an end region of the metallic container 14 in the form of a cylindrical wall 20 and the heat output end includes the other end region of the container 14 in the form of a cylindrical wall 21.

A tubular or cylindrical layer 25 of wicking material having a pair of opposed cylindrical surfaces 26 and 27 is included within the container. A portion of surface 26 of the wicking material is in contact with the inside surface of the wall 20 and another portion of the same surface is adjacent to the inside surface of the other wall 21. The wicking material may be made of any of a variety of materials such as felt material of sintered metal fibers and includes a multiplicity of capillary passages or pores of small mean cross-sectional area extending in various directions and to various extents, and interconnected to move liquid therethrough from one surface region thereof to another. A portion of the wicking material in contact with the wall 20 is provided with a plurality of openings in the form of cylindrical holes 28 of circular cross section extending orthogonally from one surface of the layer in contact with the wall to the opposite surface thereof. The holes 28 are of uniform diameter and are uniformly spaced with respect to one another as shown in FIG. 3. The holes are centered on the corners of the squares formed by the intersections of one set of equally spaced parallel lines 29 with another set of equally spaced parallel lines 30 orthogonal to the first set. The lines 29 correspond to straight line elements of the surface 27 parallel to the longitudinal axis of layer 25 of wicking material and lines 30 correspond to circular line elements, the planes of which are perpendicular to the longitudinal axis of layer 25. The spacing of the adjacent lines in each set are the same; accordingly, the basic figure of the pattern of lines is a square. The cross-sectional area of an opening 28 is shown as relatively large in relation to the mean cross-sectional area of a capillary passage or pore to provide a low impedance path to the passage

of vapor therethrough. However, it will be understood that openings of mean cross-sectional area comparable to the mean cross-sectional area of the capillary passages will provide satisfactory operation. The openings **28** are orthogonal to the surface to provide the shortest path from the heat input surface of the wall **20** to the space above the wicking. The layer of wicking material is saturated with a vaporizable liquid suitable for the use to which the heat pipe is to be part and may include such fluids as water, alcohol or fluorocarbon refrigerants. Accordingly, heat supplied to the input section **17** causes liquid in contact therewith to change to a vapor which readily passes through the openings **28** and the space above the layer **25.** In response to the pressure created by the evaporation process the vapor moves to the region adjacent to the wall **21,** which is connected to a heat sink in the form of atmosphere of lower temperature than the source of heat through the fins **19,** where the vapor is condensed into a liquid. The liquid is absorbed in the layer wicking material and is returned by the capillary action to the input wall **20.**

In an embodiment of the invention in which sintered, felted nickel fibers were used as the wicking material, holes were provided of circular cross section of 1/64 inch centered on the corners of the squares formed by the intersections of one set of equally spaced parallel lines with another set of equally spaced parallel lines orthogonal to the first set. The spacing of adjacent lines in each set was 1/8 inch. The mean pore diameter was estimated to be .004 inch. The wicking material was saturated with water. In the operation of the heat transfer device with the holes as described, the maximum heat transfer was increased by a factor of two over the structure described without the holes.

It will be understood that the hole cross-sectional size could be reduced and a larger number of holes utilized or that the hole cross section size could be increased and a smaller number of holes utilized without affecting aggregate cross-sectional area of the openings in relation to the surface of the layer in the heat input or evaporator section with equally beneficial results. Also, the aggregate cross-sectional area of the openings could be increased by providing a greater density of holes to assure adequate venting of vapor. The aggregate cross-sectional area should not be so great as to appreciably reduce the aggregate liquid transport capacity of the wicking material. In most applications aggregate cross-sectional area would be a small fraction of the total surface area of the wicking. Accordingly, liquid transport would not be appreciably affected. When thicker layers of wicking material are utilized, holes of larger cross section would be preferable to keep impedance to vapor flow at a minimum. In some applications, it will be understood that holes arranged in different surface patterns, regular and irregular, and holes of different shape would be desirable. The portion of the layer of wicking material in contact with the heat output section **18** or wall **21** may be provided with structure such as described and claimed in a copending application filed concurrently herewith, Ser. No. 124,805, filed Mar. 16, 1971, and assigned to the assignee of the present invention, in place of the structure shown in FIG. **1.**

While the invention has been described in a specific embodiment, it will be appreciated that modifications may be made by those skilled in the art and we intend by the appended claims to cover all such modifications and changes as fall within the true spirit and scope of the invention.

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

1. A heat transfer device comprising

a closed container including a wall of high thermal conductivity material located in one portion of said container and including another wall of high thermal conductivity material located in another portion of said container,

a layer of wicking material within said enclosure having a pair of opposed parallel surfaces, a portion of one of said surfaces in direct contact with said one wall and another portion of one of said surfaces adjacent to said other wall,

said layer of wicking material including a multiplicity of capillary passages, each of small mean cross-sectional area extending in various directions and to various extents, and interconnected to move liquid therethrough from one surface region thereof to another, and including a plurality of openings each of large cross-sectional area in relation to the cross-sectional area of a capillary passage and each extending orthogonally from the surface portion of said layer in direct contact with said one wall to the surface opposite thereto to provide a relatively low impedance path to the passage of vapor therethrough,

said layer of wicking material being saturated with a vaporizable liquid,

said one wall being adapted to be connected to a heat source to cause said liquid in contact with said wall to vaporize,

said other wall being adapted to be connected to a heat sink to cause said vapor in contact therewith to condense,

whereby heat applied to said one wall causes liquid in contact therewith to change to a vapor which passes through said openings and moves in response to the pressure created thereby to the region adjacent said other wall where said vapor is condensed into a liquid, contacts said wicking material and is returned to said one wall.

2. The combination set forth in claim **1** wherein said wicking material is sintered, felted nickel fibers and said plurality of large cross-sectional area openings in said layer is a row and column array of holes of circular cross section.

3. The combination set forth in claim **2** wherein the ratio of the diameter of each said hole to the mean pore diameter of each capillary passage is at least 1/64 : 0.004.

4. The combination set forth in claim **3** wherein in each row and column array of holes there are at least eight holes to the inch.

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