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[54] **THERMAL TRANSFER APPARATUS PROVIDING TRANSFER CONTROL**

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[52] **U.S. Cl.** **165/32,** 165/47, 165/96, 165/105

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

[58] **Field of Search** 165/96, 105

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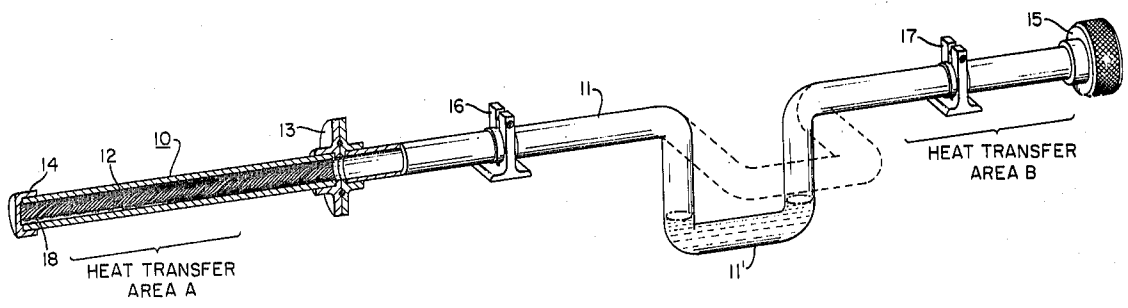
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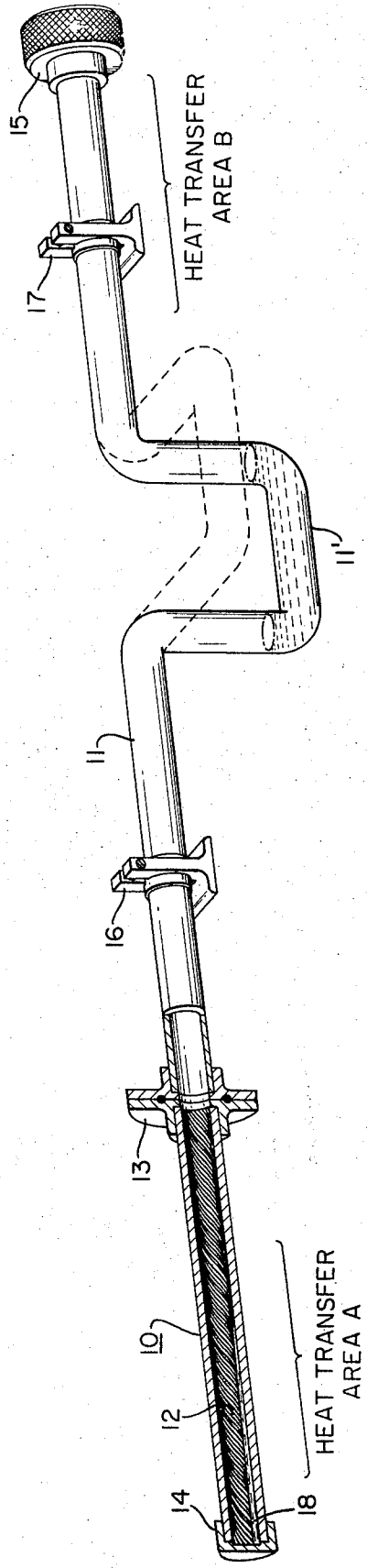
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[57] **ABSTRACT**

Heat pipe apparatus comprising a heat pipe having a first section having spiral fins extruded on its inner surface and a second section having a smooth bore interior. The pipe is sealed at each end after evacuation of all noncondensable gases and contains a vaporizable liquid as the medium for heat transfer. The second section of the pipe has a U-shaped portion which, when liquid filled, acts as a vapor or liquid trap when suspended vertically to prevent heat transfer in either direction. Since no capillary return of condensate is possible through the smooth bore section of the pipe when the trap is in an open position, unilateral heat transfer toward either end of the pipe is made possible.

5 Claims, 1 Drawing Figure




15
17
HEAT TRANSFER AREA B
11'
11
16
13
10
12
14
18
HEAT TRANSFER AREA A

THERMAL TRANSFER APPARATUS PROVIDING TRANSFER CONTROL

BACKGROUND OF THE INVENTION

This invention relates to devices and apparatus for transferring heat from a heat source area to an area of heat dissipation and more particularly to heat pipes adapted to accomplish such heat transfer action by means of closed evaporation-condensation cycles.

Heat pipes adapted to transfer heat away from one area to another area of heat dissipation have long been known in the art. Because of their high efficiency in transferring relatively large quantities of heat with small temperature gradients, heat pipes have been particularly useful, for example, in the temperature control of electronic equipment. A typical prior art heat pipe operates in the following manner. A sealed chamber which, although it may take various forms, for present purposes is assumed to be tubular, has evacuated therefrom all noncondensable gases. At the area from which heat is to be transferred, e.g., a printed wiring circuit board, a fluid within the tube at that point is in its liquid state at the normal operating temperature of the circuit board electronics. The interior of the tube normally contains for its entire length a wick which comprises a cylindrical cluster of fine wire or, as is contemplated in the present invention, the wick may comprise a radially extending, equally spaced plurality of fins spirally extruded on the interior wall of the tube. The free space within the tube contains only the vapor of the fluid at a pressure which corresponds to the saturation pressure of the fluid at the aforementioned operating temperature of the circuit board electronics.

Should for some reason the operating temperature of the circuit board and hence the temperature of the tube at that point, rise from the normal, the liquid boils--at a very small temperature change since the pressure within the tube is very nearly zero. The resulting vapor is at a substantially higher pressure and will migrate toward the cooler end of the tube where it condenses on the cooler surfaces of the tube wall and wick. As the vapor condenses it gives off the heat acquired earlier during vaporization. The extruded fins on the interior of the tube are dimensioned so that the condensate is conveyed back to the heat source area by capillary action where the cycle is repeated until the normal operating temperature of the circuit board is restored. The efficiency of a heat pipe arrangement may be appreciated from the fact that it is able to conduct many hundreds of times as much heat as an excellent conductor such as a copper rod.

In many heat pipe applications it is found advantageous to control the direction of heat transfer within the heat pipe and even to interrupt the transfer altogether. Seasonal temperature changes, for example, may dictate a discontinuance of the heat transfer; interruption in heat transfer may also be required in the temperature testing of electronic circuitry or other apparatus, to name another example. Electronic or other equipment may require protection from momentary heat surges without a reduction of its normal operating temperature.

It is accordingly an object of this invention to control heat transfer and heat transfer direction in a heat pipe cooling arrangement.

SUMMARY OF THE INVENTION

The foregoing and other objects of this invention are realized in one illustrative embodiment thereof comprising a heat pipe formed of a two section tube hermetically sealed at the coupling of the two sections and at the ends of the integral structure thus formed after evacuation of all noncondensable gases. The inner surface of one section has spirally extruded or otherwise formed thereon a plurality of radial, inwardly extending fins. The inner surface of the other section is smooth. The two section structure is longitudinally coaxial; however, the smooth bore section has formed therein a U-shaped portion extending from the longitudinal axis. Although the interior of the tube is very nearly a vacuum, an amount of fluid in liquid form is enclosed within the tube sufficient to fill the base of the U-shaped portion with the tube virtually horizontal and the latter portion suspended downwardly. The pipe assembly is rotatably mounted at opposite ends, permissibly at a slight inclination, by frictional bearing means to permit its at least partial rotation to fixed angular positions.

In one mode of operation, the heat pipe assembly is rotated to position the U-shaped portion substantially downwardly with the result that, by gravitational action, the enclosed fluid in liquid form is collected in the base of the latter tube portion. The quantity of liquid is determined as being sufficient to fill the entire lower cross-section of that tube portion with the result that it acts as a trap to prevent movement of vapor or liquid from either end of the heat pipe to the other. The unavailability of any capillary action in the smooth bore permits this trapping action and no heat transfer is thus possible. In another mode of operation the pipe assembly is rotated to position the U-shaped portion sufficiently horizontally to permit the contained liquid under gravitational force to flow in along the lower inner wall portion of the pipe thereby lowering its level to permit in turn the free movement of vapor in either direction along the heat pipe. The pipe is positioned with both its wick section and its condenser section at individual heat source areas. Assuming the temperature at the wick section to be higher than that of the source of the condenser section, the heat at the former point vaporizes the liquid which conventionally migrates to the condenser section where the vapor gives off its heat as condensation occurs. The inner wall of the pipe at this end is smooth so that the condensate is returned to the wick section by gravitational drainage rather than by capillary action as is the case in conventional heat pipe arrangements.

Should the temperature of the heat source at the condenser end of the pipe be higher than that of the source at the wick section, no heat transfer to the latter section can take place since no liquid is now available at that point for evaporation. The unavailability of capillary action in that direction prevented any prior return of condensate to the greater heat area. This is in contrast with known heat pipe arrangements in which the transfer of heat between two sources would permit the temperature at the area of the lower temperature heat source to rise to the additive level of both that source and the heat transferred from the higher temperature heat source.

It is accordingly a feature of this invention that in a heat pipe assembly, a wick section is combined with a

smooth bore section to permit an open and a closed vapor switch action by means of a trap section and also to make possible unilateral heat transfer between two heat sources.

BRIEF DESCRIPTION OF THE DRAWING

The objects and features of this invention will be better understood from a consideration of the detailed description of the organization and operations of one illustrative embodiment thereof when taken in conjunction with the single FIGURE of the accompanying drawing depicting the structure, in partial cutaway form, of a heat pipe arrangement according to the principles of this invention.

DETAILED DESCRIPTION

A heat pipe arrangement according to this invention is shown in the drawing as comprising a first and a second pipe section **10** and **11.** The sections are cut away to expose their inner surfaces; pipe section **10** has spirally extruded or otherwise formed on its inner surface a plurality of inwardly and radially extending fins **12,** representative ones of which are shown. The inner surface of pipe section **12** is smooth and the section has formed therein a substantially U-shaped portion **11'** which, in the drawing, is shown as suspended downwardly in its position to function as a vapor trap in the manner to be described. The two pipe sections **10** and **11** are coupled coaxially longitudinally by any convenient coupling means **13** which also serves as a seal. The ends of the pipes are capped by hermetically sealing capping means **14** and **15,** the latter means of which may be knurled to provide a convenient grip for rotating the pipe assembly about its axis. The latter rotation may be accomplished in suitable friction bearing and support means such as the exemplary supports **16** and **17** shown in the drawing. Other mounting arrangements and structure may be envisioned as determined by particular installation requirements.

Before finally capping the pipe ends, all noncondensable gases are evacuated from the assembly by means well known in the art and a small amount of fluid **18** in liquid form is introduced. A number of materials are available in the art for performing a coolant function; the one chosen will be determined by the coolant requirements of the apparatus to be cooled and will, of course, be vaporized by the heat of the apparatus to be dissipated. The fluid **18** is shown in the drawing as collected in pipe section **10** as the result of a slight inclination of the pipe assembly. A heat pipe arrangement according to this invention constructed as thus described may typically be used to function in a number of operative modes in relation to a heat source or sources from which the transfer of heat is to be controlled.

In each of the operative modes, assuming the heat source to be located at the wick end, or section **10,** of the pipe assembly indicated in the drawing as heat transfer area A, heat generated at the latter area causes the vaporization of the fluid **18.** Heat absorbed by this vaporization is carried by the vapor as it migrates to the condenser end of pipe section **11** indicated in the drawing as heat transfer area B. Conventionally, the heat is there dissipated by condensation if the temperature at that point is lower than that at area A. Assuming this condition, in a conventional prior art heat pipe arrangement, the condensate is returned to pipe section **10** by capillary action. In accordance with the present invention, such capillary return is prevented by the smooth bore of pipe section **11.** In one mode of operation of this invention, any return of the condensate is prevented altogether by a rotation of the heat pipe assembly so that the U-shaped portion **11'** of pipe section **11** is suspended downwardly as depicted in the drawing. The longitudinal axis of the pipe assembly is contemplated as being arranged at a slight inclination toward the wick end, say, of the order of 2°, for example. The condensate will in this case, under gravitational action, accumulate in the vapor trap formed by the U-shaped portion **11'.** The amount of fluid **18** originally introduced in the pipe assembly is determined as sufficient at least to fill completely the lower pipe cross-section of pipe portion **11'.** Any further circulation of vapor or liquid in either direction is as a result effectively prevented. Has the heat pipe assembly been provided with wick means for its entire length as is the case in conventional practice, capillary action would have permitted a return of the condensate despite the trap. To restore vapor circulation and heat transfer, the pipe assembly is rotated in its friction bearing supports **16** and **17** substantially 90° in either direction to a horizontal position, one of which is indicated by the dashed outline in the drawing. In this position another mode of operation is advantageously possible.

With the trap portion **11'** in its open position, vapor from the condenser section is now free to return to the wick section **10** without, however, as mentioned in the foregoing, the assistance of capillary action. The only manner of return available is a gradual drainage under gravitational action. This action is furthered by the slight inclination of the assembly. With the pipe assembly in its position permitting free vapor circulation, a balancing of heat transfer between two heat sources is also possible. In this operative mode, a first and a second heat source are assumed to be located at heat transfer areas A and B, respectively. In a state in which the temperature of the source at area A is greater than that of the source at area B, normal heat transfer will take place in the direction from area A to area B. At the latter point, condensation will conventionally occur and the condensate will return to the wick section **10** at area A under gravitational action. However, should the temperature of the source at area B rise equal to or above that of the source at area A, no condensation will take place at the condenser section at area B. Since the smooth bore and slight inclination of pipe section **11** prevented any movement of condensate from the now low temperature end either by capillary or gravitational action, there was no fluid at the high temperature end at area B to evaporate. Heat transfer from the latter area to area A is thus again effectively prevented. Heat transfer will resume when the temperature of the source at area B again falls below that of the source at area A. This operation contrasts with the different result encountered by a prior art heat pipe arrangement under the same operating conditions. In the prior art case, condensate would return to the higher temperature area B via capillary action. As a result, to the temperature prevailing at area A due to the heat source there located will be added the heat transferred from area B by the conventional evaporation-condensation process. In the heat pipe arrangement of the present invention, the heat source at area B can make no such contribution to the temperature at area A.

A heat pipe arrangement according to this invention, exemplary operations of an illustrative embodiment of which were described in the foregoing, is advantageously useful for cooling electronic apparatus in a telephone central office, for example. Heat transfer area A would, in such an application, be positioned within the office building. The pipe section **11** is then extended through the building wall with the heat transfer area B exposed to the elements outside of the office building. If the building is unheated and unattended, for example, during a cold season the heat generated by the telephone equipment may be dissipated in the lower ambient temperature of the office building interior. In this case, the additional cooling provided by the heat pipe may not be required and the assembly is rotated to set the trap portion **11'** downwardly in its closed position as shown in the drawing. On the other hand, the temperature of the office building interior may rise to a point where additional cooling of the equipment is required. The pipe assembly is then rotated so that the trap portion **11'** is in its open position to permit free vapor circulation and condensate return is by gravitational action. Should the temperature at the condenser end of the heat pipe at the exterior of the building now rise above that at the equipment end inside of the office building due to sunlight, for example, no vaporization is possible at the now hotter condenser end of the pipe due to the absence of condensate at that end. The exteriorly generated heat can accordingly not be transmitted back in the pipe to add to the heat being generated by the office electronic equipment.

In the drawing the various structural elements of the invention are shown out of the proportions they would assume in its practice for the sake of clarity. Accordingly, it will be appreciated that in a particular application the pipe assembly may be considerably longer with respect to its diameter than as shown in the drawing, for example. It will be further understood that what has been described is considered to be only one illustrative heat pipe arrangement according to the principles of this invention and it is to be further understood that various and numerous other arrangements may be devised by one skilled in the art without departing from the spirit and scope of the invention as defined by the accompanying claims.

What is claimed is:

1. Thermal transfer apparatus comprising a heat pipe means having a capillary evaporator section comprising spiral fins formed on the inner surface of a first portion of said pipe means, a condenser section having a substantially smooth inner surface and having a substantially U-shaped bend in said last-mentioned portion, said pipe means being sealed at each end, a vaporizable liquid contained within said pipe means, and means for rotatably supporting said pipe means at a slight inclination from the horizontal.

2. Thermal transfer apparatus comprising a heat pipe means having an evaporator section including wick means therein, a condenser section having a substantially smooth inner surface and having a substantially "U"-shaped bend formed therein, said pipe means being sealed at each end, and a vaporizable liquid exclusively contained within said pipe means sufficient to fill a cross-section of said bend.

3. Thermal transfer apparatus as claimed in claim **2** in which said wick means comprises a plurality of spiral fins radially extending on the inner surface of said evaporator section.

4. Thermal transfer apparatus as claimed in claim **3** in which said heat pipe means is arranged at a slight inclination from the horizontal along its longitudinal axis, said pipe means being mounted to permit rotation of said bend at least 90° between a downwardly position and a substantially horizontal position.

5. Thermal transfer apparatus comprising a sealed heat pipe means having an evaporator section including wick means therein, a condenser section having a substantially smooth inner surface, vapor trap means comprising a U-shaped bend formed in said condenser section, a vaporizable liquid exclusively contained within said pipe means sufficient to fill a cross-section of said bend, and means for rotatably mounting said heat pipe means at a slight inclination from said condenser section to said evaporator section, said vapor trap means being in a closed position when rotated substantially downwardly and being in an open position when rotated in either direction substantially horizontally.

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