

[54] **HEAT TUBE**

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[22] Filed: **Aug. 24, 1970**

[21] Appl. No.: **66,415**

[30] **Foreign Application Priority Data**

Aug. 25, 1969 Germany.....P 19 43 122.2

[52] U.S. Cl.165/96, 165/104, 165/105, 12.6/400

[51] Int. Cl.F28d 15/00

[58] Field of Search.....165/32, 105, 96

[56] **References Cited**

UNITED STATES PATENTS

1,974,121	9/1934	Normelli.....	165/105 X
2,093,725	9/1937	Hull.....	165/105 X
3,229,759	1/1966	Grover	165/105
2,026,423	12/1935	Fiene.....	165/105 X
2,155,261	4/1939	Fiene.....	165/105 X

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[57] **ABSTRACT**

A heat tube includes a first section adjacent one end which absorbs heat from a heat source, the absorbed heat being transferred to and effecting vaporization of a working fluid within the tube. The vapor is transported through the tube to a second tube section adjacent the other end and which is at a lower temperature thus causing the vapor to condense, giving up its heat at this cold end to the lower temperature surrounding medium and the condensate is then returned to the opposite hot end by way of a capillary structure lining the inside of the tube for re-cycling.

In order to enable the heat tube to be switched over from a heat-conducting state to a heat-nonconducting state the present invention provides for controlling the condensate accumulated at the cold end of the tube such that it can be maintained either out of contact with the capillary structure, in which case the condensate is retained at the cold end and circulation of the working fluid is thus cut off, or alternatively placed in contact with the capillary structure, in which case the condensate continues to flow back through the capillary structure to the hot end and circulation of the working fluid is thus rendered continuous.

4 Claims, 8 Drawing Figures

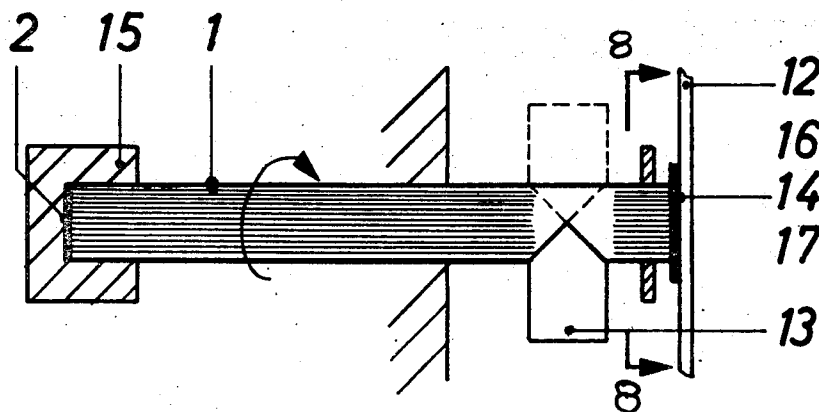


Fig.1

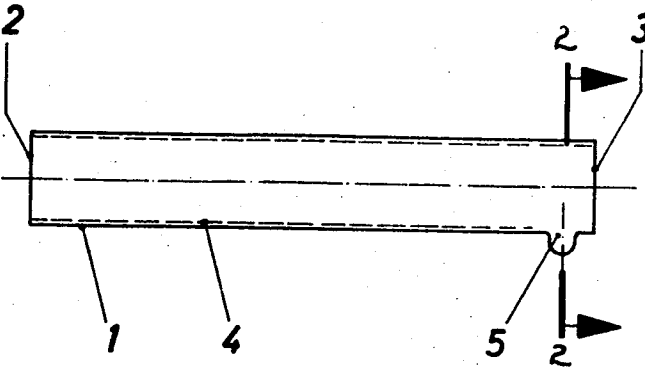


Fig.2

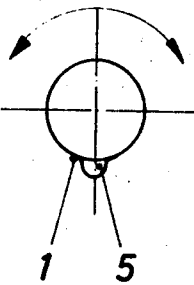
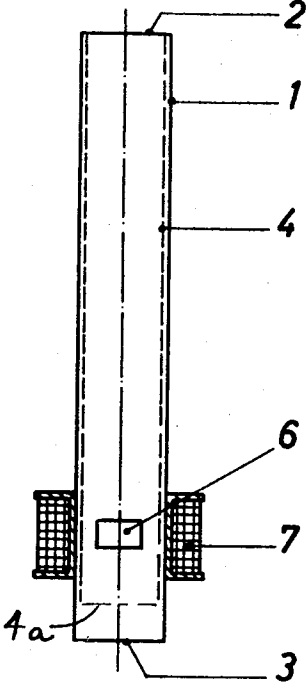
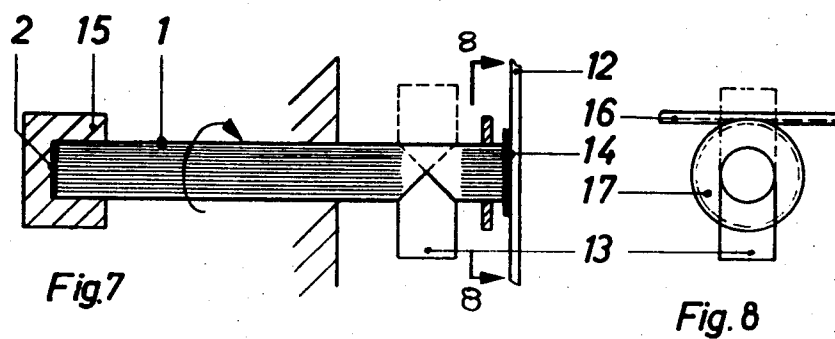
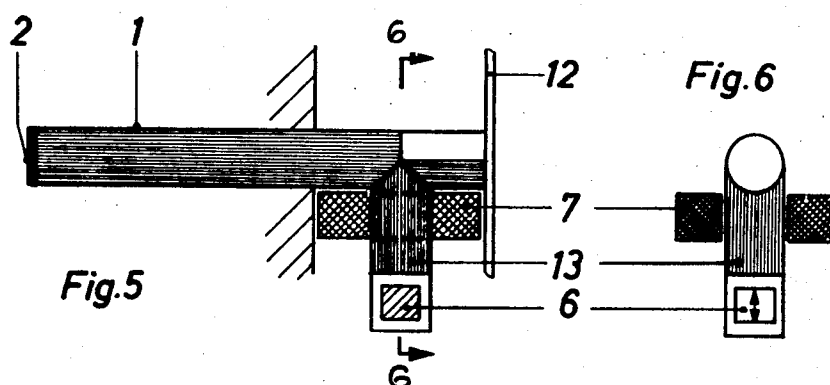
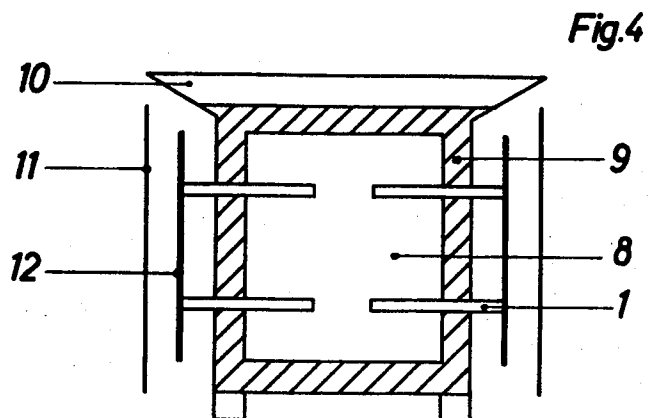


Fig.3



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HEAT TUBE

BACKGROUND OF THE INVENTION

This invention relates to improvements in heat tubes, a heat tube being one having a first section adjacent one end thereof which absorbs heat from a heat source, the absorbed heat being transferred to and which effects evaporation of a working fluid within the tube. The vapor is transported through the tube to a second section of the tube adjacent the other end and which is at a lower temperature causing the vapor to condense giving up its heat to the lower temperature surrounding medium and the condensate is then returned to the opposite end by way of a capillary structure lining the inside of the tube for recycling.

The use of heat tubes of the type described makes it possible to transport large quantities of heat per unit area. The heat tubes operate independently of position and are applicable in a wide temperature range if the operating working fluid is selected accordingly.

A heat tube has already been proposed which transmits a very large, or a very small, quantity of heat as needed. With this heat tube, the thermal conductivity is caused to vary in a sudden manner, as a function of the temperature, caused notably by the use of a special working fluid with a corresponding vapor pressure. In this connection reference is made to the disclosure in German patent application P 19 37 782.3.

SUMMARY OF THE INVENTION

The object of the present invention is also to provide a heat tube having means for selectively changing the amount of heat which it transmits but which can be switched over from a heat-conducting to a heat-non-conducting state over its entire working temperature range, thus eliminating, to a large extent, the effect of temperature as a limiting parameter.

In general, the objective of the invention is attained by the novel concept of controlling the condensate accumulated at the cold end of the tube, i.e. at the heat dissipating end such that it can be maintained either out of contact with the capillary structure in which case the condensate is retained at the cold end and circulation of the working fluid is thus cut-off, or alternatively placed in contact with the capillary structure in which case the condensate flows back through the capillary structure to the hot end and circulation of the work fluid is rendered continuous.

The heat tube is made from a refractory material having an inherently poor thermal conductivity. A drying-out of the heat-absorbing section (hot end) may lead to starting difficulties in switching the tube to a heat-conducting mode, but by novel capillary structures, these have already been overcome.

In accordance with one embodiment of the invention, the heat tube is disposed horizontally and is provided with a localized outward bulge in its wall at the cold end forming a well in which all of the condensate can collect out of contact with the capillary liner structure which does not reach to the well. In this position, the tube is thus in its "switched-off" state since there is no way in which the condensate can flow back through the capillary liner structure to the hot end for re-circulation. In order to change the tube to its "switched-on" state, the tube is simply rotated about its axis causing the condensate to flow out of the well into contact with the capillary structure.

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In accordance with another embodiment of the invention which has the advantage that the tube can be operated to a large extent independent of its attitude, selective control over the condensate at the cold end, either in or out of contact with the capillary structure is effected by means of a displacement body which is immersed in the condensate. Assuming a vertical attitude of the tube, when the body is raised in the tube, the condensate level is lowered and the condensate in the tube does not reach to the capillary liner structure and hence the tube will not operate. Conversely, when the body is lowered into the condensate it causes the condensate level to rise and make contact with the capillary structure thus closing, so to speak the circuit for the fluid so that the condensate now travels back along the capillary structure to the hot point where it is re-vaporized. If the heat tube is to operate in an attitude different from vertical, e.g. horizontal, the displacement body can be located in an arm of the tube which lies at an angle to the longitudinal axis of the tube.

The improved switchable heat tubes according to the invention may be used advantageously in air conditioner equipment, or in heat accumulator furnaces, applications where long switching times may occur. Also, the heat tube can have a circular cross section, or the cross section may be square or any other configuration.

In a further embodiment of the invention, the switching ability on the basis of external control means can be combined with automatic variation of the thermal conductivity, for example on the basis of a temperature-dependent vapor pressure variation of the working fluid.

The foregoing as well as other objects and advantages of the invention will become more apparent from the following detailed description of several different embodiments together with the accompanying drawings wherein:

FIG. 1 is a longitudinal view of one embodiment of a switchable, horizontally disposed, heat tube which is arranged for rotation about its longitudinal axis from a switched-off position, in which condensate is collected in a well provided by an outward bulge in the tube wall at the cold end, out of contact with the capillary structure, to a switched-on position, in which the condensate flows out of the well into contact with the capillary structure.

FIG. 2 is a transverse view taken on line 2—2 of FIG. 1;

FIG. 3 is a longitudinal view of another embodiment of the switchable heat tube, the tube being disposed vertically with the cold end at the bottom and the hot end at the top. In this embodiment, a magnetically actuated displaceable body is located within the tube adjacent the lower end and is arranged for upward and downward movement with respect to the pool of condensate collected at the lower end so as to lower, or raise respectively the level of the condensate relative to the lower end of the capillary liner structure. When the displaceable body occupies its raised position, the condensate level is low and does not reach to the lower end of the capillary structure and the tube is then in its "switched-off" position, conversely when the displaceable body occupies its lower position immersed in the condensate, the level of the latter is then raised sufficiently to contact the capillary structure and the tube is then in its "switched-on" position.

FIG. 4 is a sectional view through a heat accumulator core to which a plurality of the heat tubes in accordance with the invention have been applied in order to remove heat from the core to the outside;

FIG. 5 is a longitudinal view of an embodiment of the invention wherein the cold end of the heat tube is provided with a tubular arm at a right angle to the longitudinal axis, and wherein a magnetically actuated displaceable body for switching the tube from "off" to "on" is located in the arm;

FIG. 6 is a transverse section taken on line 6—6 of FIG. 5;

FIG. 7 is a longitudinal view of another embodiment of the invention wherein the cold end of the heat tube is provided with a tubular arm at a right angle to the longitudinal axis, and wherein the tube is rotated about its axis by means of a rack and gear drive to effect collection of condensate in the arm when in one position and to expell condensate from the arm when in another position, thus to switch the heat tube from its "off" position to its "on" position, or vice versa; and

FIG. 8 is a transverse section taken on line 8—8 of FIG. 7.

With reference now to the embodiment of the invention as illustrated in FIGS. 1 and 2, the heat tube 1 is seen to have a circular cross-section, occupies a horizontal position and is arranged to be rotated about its axis by any suitable means not illustrated. End 2 of the tube is the so-called hot end and is placed in heat transfer relation with the heat source from which heat is desired to be removed. The opposite end 3 of the tube is the so-called cold end and is placed in heat transfer relation with a colder medium to which the heat is transferred. This cold end 3 of the tube is provided with an outward bulge in the wall which provides a well 5 within which condensate can collect when the tube occupies a position wherein the bulge is directed downwardly. The capillary structure which lines the inside surface of tube 1 and which serves to carry back the condensate to the hot end for re-vaporization is indicated at 4 and, as depicted in FIG. 1, when the tube is in that position the condensate in the well 5 is out of contact with the capillary structure, since the capillary structure does not reach into the well proper. The heat tube is thus in a switched-off state since the circulation path for the working fluid is interrupted. However, when tube 1 is rotated about its axis, the condensate spills out of the well 5 onto the surface of the capillary structure 4 and thus closes the circuit for the working fluid which then flows back through it to the hot end of the tube for re-vaporization and transfer as vapor back once more to the cold end where it is condensed and started once again back to the hot end through the capillary structure 4.

The embodiment depicted in FIG. 3 shows the heat tube 1 in a vertical position with the hot end 2 located at the top for receiving heat and the cold end 3 at the bottom for dissipating it. Surrounding the tube in the vicinity of the bottom is a coil 7 which is arranged to be connected to a source of current through a suitable switch, not shown, in order to energize the same and produce a magnetic field. Located within the lower part of tube 1 and under the influence of the magnetic force created upon energization of coil 7, is a round magnetic body 6 which has a diameter so much smaller

than the inside diameter of tube 1, that in the switched-off position of the tube, the condensate can collect in the bottom of the tube free from contact with the lower end 4a of the capillary liner structure 4, and in operation the heat transfer is not adversely changed at the cold point. The switched-off position of the heat tube is obtained by energizing coil 7 which attracts the magnetic body 6 upward to the position depicted in FIG. 3 in which it is entirely free from the condensate collected at the bottom of the tube. The level of the condensate drops and thus does not reach to the lower end of the capillary liner structure 4. The switched-on position of the heat tube is obtained by de-energizing coil 7 thus permitting the magnetic body 6 to drop into the pool of condensate thus displacing condensate upward so that its level reaches the end of the capillary liner structure 4 and through which it then returns to the hot end 2 for re-vaporization.

An alternative mode of effecting movement of the displacement body 6 would be to utilize a mechanical return spring connected to the body which would bias the same to its upper position when coil 7 was not energized. Energization of the coil would then serve to draw the body 6 downward into the pool of condensate and raise its level thus to contact the lower end of the capillary structure 4 and switch the heat tube to the "on" position.

FIG. 4 illustrates an application of heat tubes in accordance with the invention to a compact heat accumulator core 8 which is enclosed by a wall of insulation material 9, which is so dimensioned that very little heat is lost through it. A cover 10 fills the clear dimensions of the accumulator. The front and back are each formed by a covering sheet 11, resulting in a chimney effect. The heat is conducted out of the accumulator core 8 by way of several of the heat tubes 1. The hot ends of the tubes 1 are of course located within the core 8, the tubes themselves pass through the insulation 9, and the cold ends of the tubes are connected to a sheet-like convector 12. The heat tubes used for removing heat from the accumulator core 8 are preferably of the constructions shown respectively in FIGS. 5-6 or FIGS. 7-8.

In the embodiment according to FIGS. 5-6, it will be seen that the cold end portion 3 of the horizontal tube 1 secured to the sheet-like convector 12 is provided with a tubular arm 13 extending at a right angle to the longitudinal axis of the stationary tube and which faces downwardly. Located within this arm portion is a magnetic displaceable body 6 which is under the influence of a coil 7 which surrounds the tubular arm part 13. When coil 7 is not energized, the body 6 falls to the lower portion of the arm where no capillary liner structure (designated by the closely spaced lines on the drawing) exists displacing the liquid condensate accumulated therein in an upward direction so as to force the condensate into the capillary structure 4 and thus turn the heat tube to the switched-on position in which the circulation (condensate-vapor-condensate) circuit is closed. Conversely, when coil 7 is energized, the displacement body 6 is raised from the condensate thus interrupting its connection with the capillary structure as the level of the condensate drops below the lower end of the capillary structure 4 in the arm 13.

If the embodiment of FIGS. 7-8 is utilized, operation is similar to that of the embodiment according to FIGS. 1-2. That is to say, the horizontally mounted heat tube 1 is mounted for rotation about its longitudinal axis in bearings 14, 15, and a rotation of the tube about its axis and hence also of the arm part 13 which stores the condensate is effected by means of a ring gear 17 surrounding and secured to tube 1 and which is actuated by a rack gear 16. In the vertically downward position of arm 13 depicted in FIG. 7 by a solid line, condensate collects in the arm which as indicated on the drawing is not lined with the capillary structure 4 and the heat tube is in its switched-off position since the working fluid collected and trapped in the arm is then out of contact with the capillary structure. In the alternative position wherein tube 1 has been rotated to place arm 13 in the upward position, condensate flows out of the arm 13 and makes contact with the capillary structure thus switching the tube to its "on" position.

When the heat tubes in accordance with the invention are used in heat accumulator furnaces, there is advantageously no need to provide air conduction channels in the brickwork of the furnace. Therefore the existing space is better utilized. The heat conduction from the brick to the heat-yielding surface, i.e. convector 12 is effected noiselessly and controllably.

Also, in devices for air conditioning apparatus, for example heat pumps, heat tubes may offer advantages especially when they are of the switchable type. If the air conditioning equipment is equipped with Peltier elements, they have air heat exchangers attached on both sides for the cold and hot sides which communicate respectively with the room air and outside air. For this purpose, wall openings of large cross-section have heretofore been necessary; often because of structural reasons the units had to be installed in the window openings. When heat tubes are utilized, wall openings of only relatively small dimensions are necessary—usually not larger than a normal size water pipe. Also, since the function of the heat tube is reversible, the direction of heat flow through the tube can easily be switched from inside to outside, or vice versa, or turned off completely, by means of a switchable heat conduction tube, as needed.

The described uses of the heat tube in accordance with the present invention are by way of example only. They may be used in space travel, for cooling of semiconductor converter assemblies, for heat transfer in high-temperature accumulators, on motors, etc. thus for all problems of heat transmission for which heat tubes are advantageously employed.

We claim:

1. A heat tube for operation in a horizontal attitude comprising a hot section adjacent one end thereof which absorbs heat from a heat source, the absorbed heat being transferred to and which effects vaporization of a working fluid within the tube, a cold section adjacent the other end of the tube and which is at a lower temperature, the vaporized working fluid being transported through the tube to said other tube end where it condenses, a capillary structure lining the inside surface of said tube and through which condensate can be returned to the hot end for re-cycling, said tube including a depending arm located at said cold section and wherein at least the lower portion thereof is not

lined with said capillary structure thus to provide a well for collection of returning condensate out of contact with the remainder of the capillary liner structure of the heat tube thereby to interrupt the circulation path of the working fluid between the cold and hot ends of said heat tube, and control means operable to re-establish contact between the condensate collected in the well provided by said arm and the remainder of said capillary liner structure thereby to reclose the circulation path of the working fluid.

2. A heat tube for operation in a horizontal attitude comprising a hot section adjacent one end thereof which absorbs heat from a heat source, the absorbed heat being transferred to and which effects vaporization of a working fluid within the tube, a cold section adjacent the other end of the tube and which is at a lower temperature, the vaporized working fluid being transported through the tube to said other tube end where it condenses, a capillary structure lining the inside surface of said tube and through which condensate can be returned to the hot end for re-cycling, said tube including a depending arm located at said cold section and wherein at least the lower portion thereof is not lined with said capillary structure thus to provide a well for collection of returning condensate out of contact with the remainder of the capillary liner structure of the heat tube, a magnetizable body disposed within said arm and immersible in the condensate, said magnetizable body being movable in relation to the condensate collected in said arm so as to change the level thereof in relation to the remainder of said capillary liner structure, and an electrical coil surrounding said arm, said coil when energized serving to raise said magnetizable body to a position wherein the level of the collected condensate does not reach the remainder of said capillary liner structure thereby to interrupt the circulation path of the working fluid between the cold and hot ends of said heat tube, and said coil when in a de-energized state permitting said magnetizable body to lower itself into the condensate thereby raising the level thereof to a position where it does reach the remainder of said capillary liner structure thereby to reclose the circulation path of the working fluid.

3. A heat tube for operation in a horizontal attitude comprising a hot section adjacent one end thereof which absorbs heat from a heat source, the absorbed heat being transferred to and which effects vaporization of a working fluid within the tube, a cold section adjacent the other end of the tube and which is at a lower temperature, the vaporized working fluid being transported through the tube to said other tube end where it condenses, a capillary structure lining the inside surface of said tube and through which condensate can be returned to the hot end for re-cycling, said tube including a depending arm located at said cold section and wherein at least the lower portion thereof is not lined with said capillary structure thus to provide a well for collection of returning condensate out of contact with the remainder of the capillary liner structure of the heat tube thereby to interrupt the circulation path of the working fluid between the cold and hot sections thereof, and means for turning said heat tube about its longitudinal axis to a position wherein the condensate is spilled out of said arm thereby to re-establish contact with the capillary liner structure and re-close the circulation path of the working fluid.

4. A heat tube as defined in claim 3 and wherein said means for turning said tube about its longitudinal axis to effect spillage of the condensate out of said arm includes bearing means supporting the tube at the opposite ends thereof, a ring gear surrounding said tube 5 and secured thereto, and a drive gear meshed with said ring gear.

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