

[54] **ARRANGEMENT FOR TRANSMITTING HEAT**

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

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

[58] Field of Search.....**165/105**

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[57] **ABSTRACT**

An arrangement for transmitting heat using a tubular member defining a chamber in which an evaporable and wetting liquid substance and at least one capillary body for conducting the liquid substance are present includes an inner wall having grooves defined therealong which extend crosswise to the direction of flow of the liquid in the capillary body. The capillary body or wick may be in the form of a narrow meshed wire netting and the arrangement advantageously includes one or more capillary webs which touch the evaporable liquid present in the grooves of the chamber wall. The capillary body is advantageously formed as a tube or jacket, for example, from a single piece of a wire netting or of a metal sheet provided with capillary passages. The capillary tube may be formed of a plurality of segments or partial wall areas which are joined together over the capillary webs which extend from the tubes out to the grooves of the wall of the chamber.

13 Claims, 19 Drawing Figures

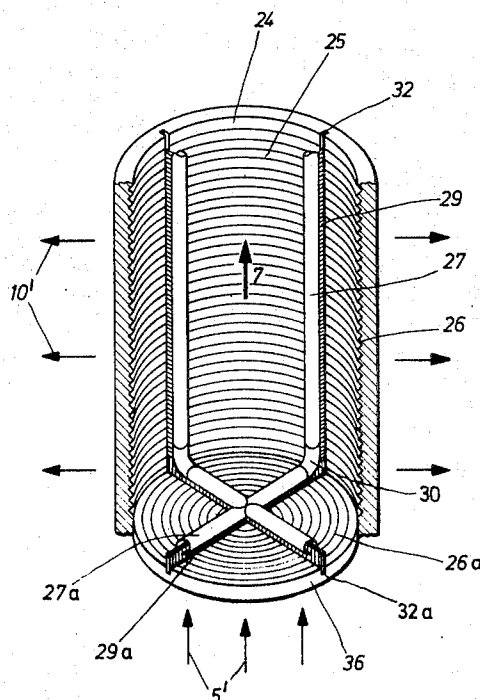


Fig. 1

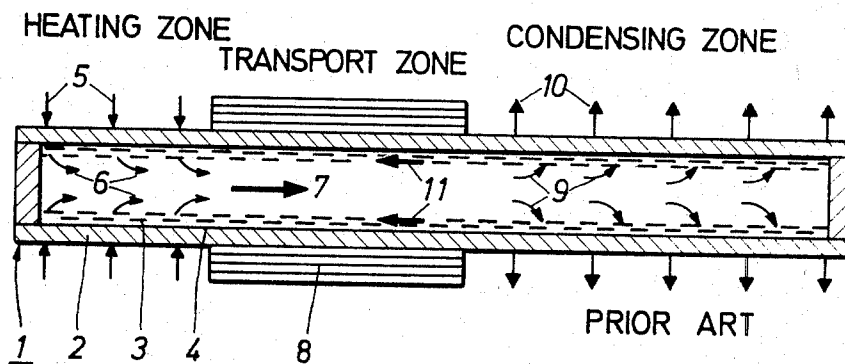


Fig. 2

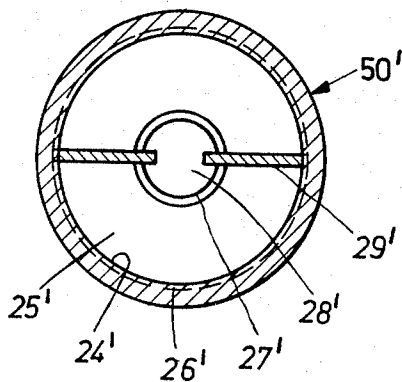


Fig. 3

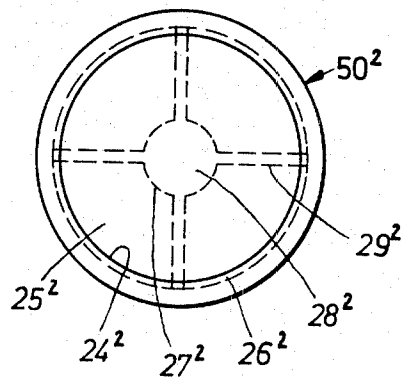


Fig. 4

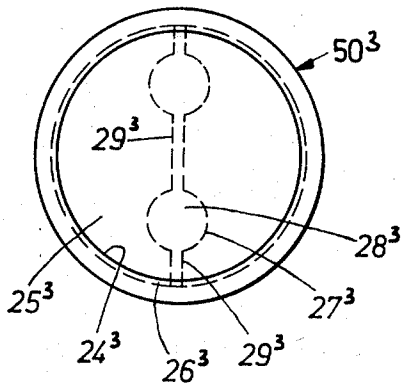
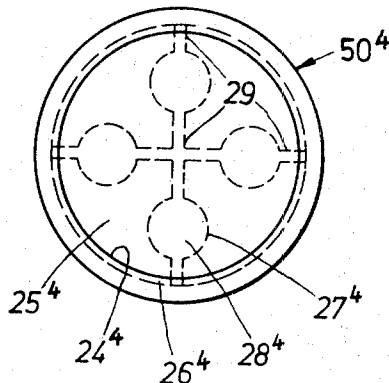


Fig. 5



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Fig. 6

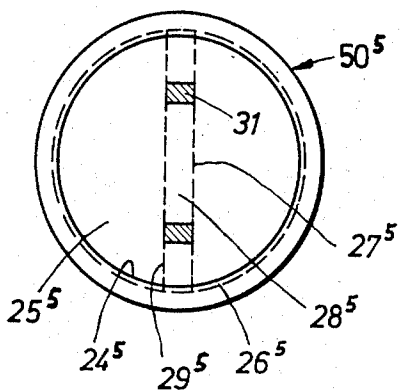


Fig. 7

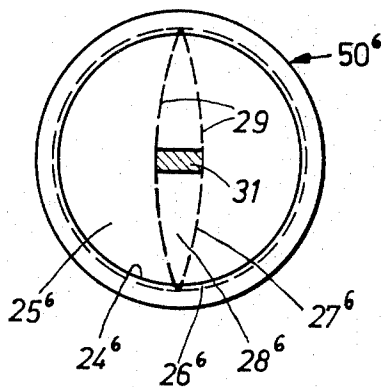


Fig. 8

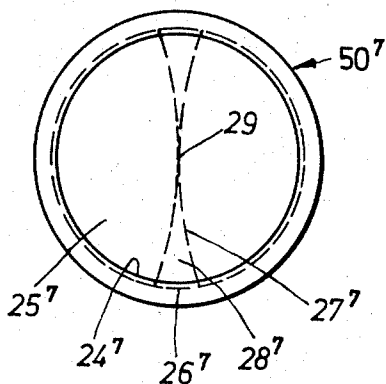


Fig. 9

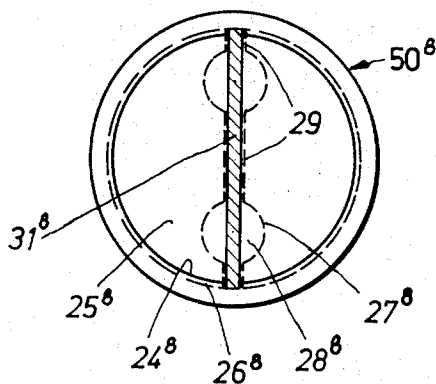


Fig. 10

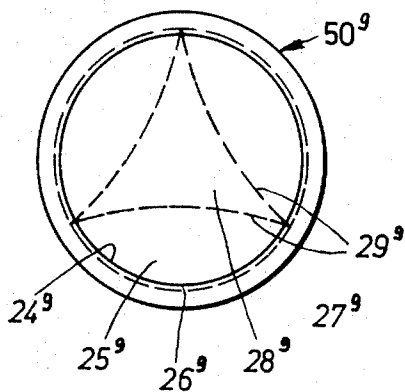
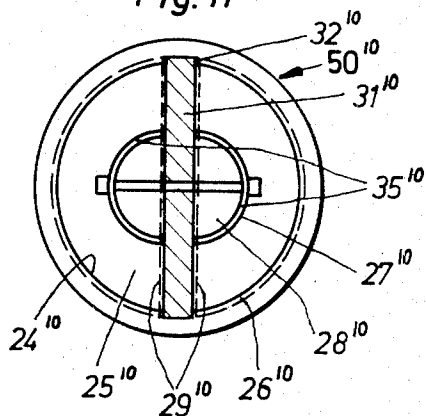


Fig. 11



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Fig. 12

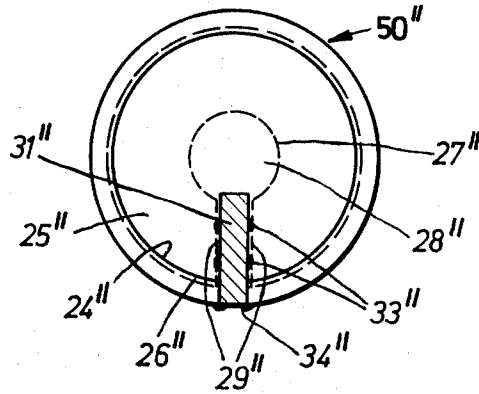


Fig. 13

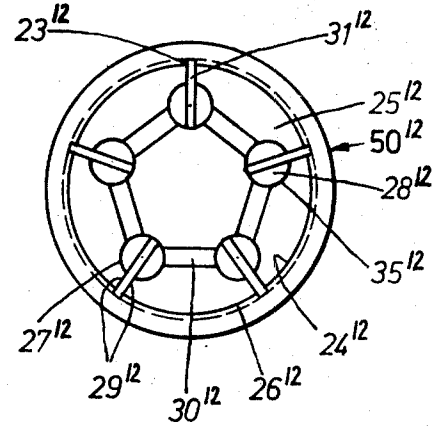


Fig. 14

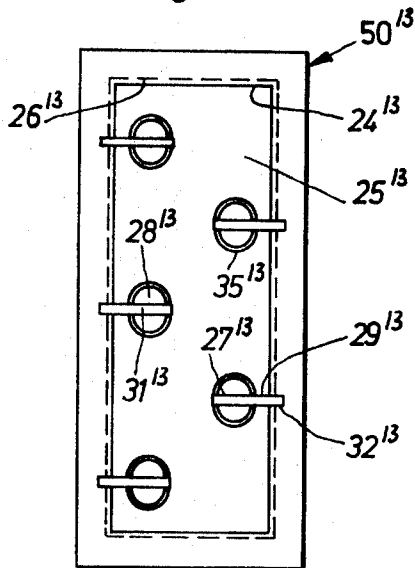


Fig. 16 a



Fig. 16 b



Fig. 16 c



Fig. 16 d



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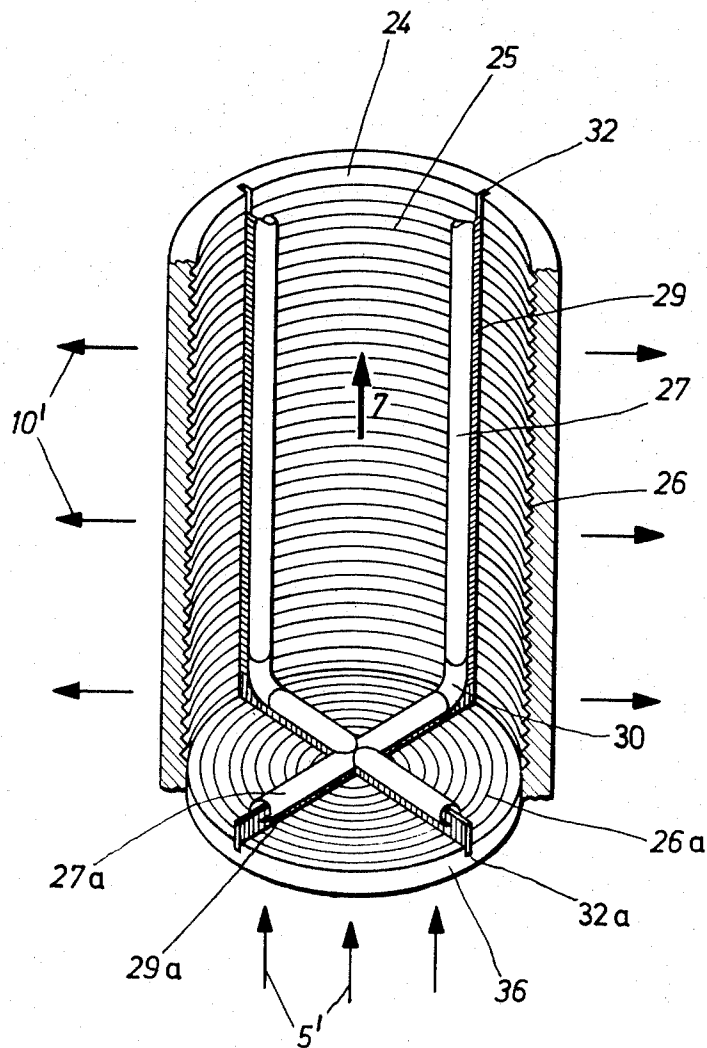
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Fig. 15



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ARRANGEMENT FOR TRANSMITTING HEAT

SUMMARY OF THE INVENTION

This invention relates in general to heat transmitting devices and in particular, to a new and useful arrangement for transmitting heat by means of a tubular member defining a chamber in which an evaporable and wetting liquid substance and at least one capillary body for conducting the liquid are located.

Heat conductors and heat exchangers of the type with which the present invention is concerned have the advantage of being able to transport relatively large heat currents at relatively low temperature differences. Thus, using such arrangements, black bodies, required for the calibration of optical temperature measuring instruments, or pyrometers can be obtained at relatively low industrial expenditure. A difficulty in the use of black bodies is such that temperature at each point of the hollow space must be kept constant. The present invention finds particular application in respect to black bodies for relatively high temperatures which can be formed at relatively low mechanical expenditure. A similar application and a similar advantage results when using the inventive construction on instruments for space travel wherein the action of one sided sun radiation is to be cancelled. Such an arrangement is also suited particularly for carrying away the heat of fission from nuclear reactors. In such an installation, it is necessary to transport the heat of fission on a highest possible temperature level from the reactor to the thermionic transformers, or to carry their waste heat to the radiator. This results in substantial savings in weight and technical apparatus as opposed to devices which contain cooling circuits operating with liquid metals and electromagnetic pumps. In addition the above described arrangement permits a subdivision into a multitude of heat transporting devices so that, as opposed to other devices, an increased safety against damage from striking of meteorites can be obtained when such devices are used for space travel.

Known constructions of so-called heat pipes comprise generally a pipe which is closed at both ends and forms a chamber. A capillary body is arranged within the chamber and either touches the entire inner walls of the pipe or only the inner wall along the surface of the capillary body. The capillary body has a tubular shape and generally it is made from a wire netting which is saturated with a liquid, evaporable substance. If any one point of the chamber wall is heated, the liquid will evaporate at this point from the capillary body. The vapor will flow to the unheated or cooled chamber walls and will condense there giving off its heat of evaporation. The condensate is transported back to the evaporator within the capillary body through the utilization of the capillary force. Here too the pressure drop in the vapor and the liquid flow are exactly equal to the capillary force. These pressures are in practice substantially negligible as opposed to the controlling system pressure. By such an arrangement one is therefore able to transport larger amounts of heat from a heated to a cooled chamber wall and both walls take up (except for a few degrees) the same temperature, namely, the saturated vapor temperature corresponding to the controlling pressure in the system.

At high heating surface load the known devices are prone to vapor bubble formation which leads to an interruption of the flow in the capillary body for example

at points where the capillary body has detached itself from the wall of the chamber and forms a pocket. It may also lead to drying out of the capillary body with long heating zones. Both cases of failure can lead to a loss of the device by burn out. In the known forms of execution of such devices, these dangers could be counteracted only through the use of complicated manufacturing processes and the adherence to high degrees of precision and for this reason such devices are relatively expensive.

In accordance with the invention, the disadvantages of the prior art devices are eliminated by forming the inner wall of the tubular member defining the chamber with one or more grooves which extend crosswise to the flow of liquid in the capillary bodies. In contrast to devices wherein the inner wall of the chamber has grooves in axial directions the arrangement of the grooves cross to the liquid flow assures that the capillary body can be provided at any point with liquid under all operating conditions and therefore a drying out will be avoided.

In accordance with a further feature of the invention, the capillary body is arranged at a distance from the inner wall of the chamber and has a connecting web or fillet which is provided with capillaries which touch the evaporable liquid which is present in the grooves of the chamber wall. Through this measure in particular, the formation and propagation of the vapor bubbles is counteracted.

In a further development of the invention, the capillary body is provided in the form of a pipe having a jacket which is formed as a single piece of wire netting or metal sheet material dotted with capillaries in conjunction with the web. The capillary body may also comprise a pipe having segments which are formed around each side of the connecting webs and arranged in a manner to achieve very good utilization of capillary properties. At least one channel made from sheet metal with a smooth surface may be arranged against the web of the capillary tube along its edges. Such an embodiment permits an especially simple and inexpensive production of capillary bodies. If needed a fastening along one surface line of the channel defining the capillary body may be provided in order to achieve a higher mechanical strength.

In accordance with a further arrangement of the invention, a single chamber may be provided with several capillary bodies which are interconnected through capillary webs or tubular elements. In particular, with relatively large systems it is possible to achieve a compensation of the pressure conditions and the uniform provision of the capillary bodies with liquid by such an arrangement. The latter is true particularly when, according to a further feature of the invention, a wire netting or a sheet provided with capillaries is a constituent of several capillary bodies and/or capillary webs.

The grooves formed in the chamber wall run crosswise to the direction of flow of the vapor and they are preferably formed in chambers having a tubular cross section. In the simplest manner they may be formed as an interior threading of the tubular member forming the chamber. The capillary body, or its web, may form a spring which is inserted with a prestressing into the chamber to provide considerable savings in manufacturing costs. The precise creation of a suitable contact between the capillary body on the one hand and the interior wall of the chamber on the other hand requires

in known devices a very high expenditure for machining costs.

The invention also provides a construction in which the capillary body or the capillary webs are provided with a support, and the arrangement of these parts can be adapted to the particular requirements of each installation designed. The chamber can also be formed with grooves which run crosswise to the direction of vapor flow and additional grooves which penetrate these grooves approximately at right angles and into which a support body provided with capillaries is inserted. This form of execution assures a safe provision of the capillary body with liquid and is furthermore relatively inexpensive.

Accordingly, it is an object of the invention to provide an improved arrangement for transmitting heat by means of a chamber in which an evaporable wetting liquid substance and at least one capillary body conducting the liquid substance are present, and wherein the walls of the chamber are provided with grooves which extend crosswise to the direction of the flow of the liquid or vapor.

A further object of the invention is to provide an arrangement for transmitting heat by means of a tubular member defining a chamber which includes various arrangements of capillary tubes and connecting web elements which are formed separately or combined for mutual support and which engage into grooves formed on the walls of the tube and which may be operated without the propagation of vapor bubbles and wherein the tubular member includes an end wall or front which is heated.

A further object of the invention is to provide a device for heat transmission for example, for forming black bodies for the calibration of optical temperature measuring instruments which is simple in design, rugged in construction and economical to manufacture.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is an axially sectional view of a tubular member forming a chamber for heat transmission constructed in accordance with the prior art;

FIGS. 2 to 14 are sectional views, each of a separate embodiment of a device for transmitting heat constructed in accordance with the invention;

FIG. 15 is a front partially perspective and partially sectional view of a heat transmitting device constructed in accordance with the invention; and

FIGS. 16a to 16d are partial axial sectional views of the wall portions of various embodiments of the heat transmitting device.

GENERAL DESCRIPTION OF THE PREFERRED EMBODIMENTS

The prior art is indicated in FIG. 1 which includes a heat transporting device generally designated 1 which comprises a tube 2 which is closed at each end. A capil-

lary body 3 in the form of a tube is arranged against the inner wall 4 of the tubular member 2. The capillary body 3 which is referred to as a wick or artery comprises as a rule, a narrow-mesh wire netting or a perforated sheet metal material. The diameter of the capillary body 3 can be considerably smaller than the inner diameter of the tubular member 2 and it is eccentrically arranged within the tube 2 and lies only along one surface line against the inner wall 4. The device 1 includes a heating zone in which heat is conveyed to the device as indicated by arrows 5 adjacent one end. This heating causes steam to exit at the places indicated by the curved arrows 6 from the capillary body 3. The steam or vapor produced from an evaporable liquid contained in the capillary body wets the inner wall 4 of the tube 2 and changes into the vapor upon being heated. The vapor flows in the direction of the arrow 7 in the inner space of the capillary body through the zone of transportation which is provided with a heat insulation 8. From a cooler or cooled point of the tube a condensation zone is formed in which the vapor upon release of its heat of evaporation condenses and again enters into the capillary body 3. The giving off of heat from the device is indicated by the outwardly directed arrows 10 in the condensing zone and the arrows 9 directed into the capillary body 3 indicate the entry of the condensed vapor into the capillary body. The condensate is transported back in the direction of the arrows 11 from the condensation zone to the heating zone through capillary force action.

In operation, particularly with relatively high radial heat flow such arrangements tend to form vapor bubbles between the capillary body 3 and the inner wall 4 of the tube 2. These bubbles spread out or else tend to move out of the capillary body at certain points so that it does not remain sufficiently saturated with liquid and thus dries out and such a failure is likely to lead to a destruction of the device. To counteract such shortcomings there are hitherto employed without any real success relatively expensive machining processes for the production of the devices. For example, an axially parallel grooving of the inner wall of the tube and a rolling on and pressing on or centering on or welding of the capillary body was effected.

In accordance with the present invention a device for the transmission of heat generally designated 50 is provided which requires only relatively low manufacturing costs and permits a higher operational safety and performance. (see FIG. 15). The apparatus 50 is a front-side heated arrangement which includes a cylindrical tubular member 2' which is closed at each end and which includes an inner wall 24 surrounding a chamber 25. In accordance with the invention grooves 26 are defined around the inner wall 24 and they extend crosswise to the direction of the vapor flow. The grooves 26 may comprise either closed or opened or interrupted ring grooves and preferably when the chamber 25 is of circular cross section they are made or developed in the manner of the forming of a threaded bore.

The cross section, depth and spacing of the grooves 26 can be fixed with purely technical deliberations in consideration of technically sound construction principles corresponding to the operational conditions of the arrangement and the contemplated form of execution of the capillary body. In FIGS. 16a to 16d, various types of groove formations are indicated at 20, 21, 22 and 23, respectively. The groove forms 20, 21, and 22 have the

advantage of being able to produced with inexpensive processes, for example, as internal threads of the walls forming a chamber such as the cylindrical chamber 25. The grooves 23 may be formed, for example, by etching and have the advantage that despite the small effective capillary diameters they have a relatively large flow cross section for the evaporable liquid. As shown in FIG. 15, a plurality of capillary bodies or wicks 27 are provided, and, in the embodiment illustrated, they are of tubular configuration and have a hollow interior space 28. This space extends substantially in the direction of vapor flow. Such capillary bodies are made as a rule from narrow meshed wire nettings or from perforated and/or furrowed metal sheets and they are referred as arteries. The tubular bodies 27 are engaged, such as by longitudinal slotting associated capillary webs 29 which extend outwardly from the capillary tubes 27 and engage in the grooves 26 of the wall 2'. They are also arranged so that they form a bridge between two tubular capillary bodies. In cooperation with the grooves 26 they ensure that the capillary bodies 27 are provided with evaporable liquid.

Various embodiments of heat transmitting devices are shown in FIGS. 2 to 14 which are generally designated 50-1, 50-2, 50-3, etc. Parts corresponding to the parts indicated in FIG. 15 have been designated with the same number with an exponent 1, 2, 3, etc. to indicate the particular distinct arrangement in the various FIGS. as set forth. Particularly with relatively large devices it is advisable to provide several capillary bodies such as capillary bodies 27-4, 27-12, 27-13 and 27 as indicated in FIGS. 5, 13, 14 and 15, respectively. The capillary bodies are interconnected by arteries in the form of webs such as the webs 29-4 as indicated in FIG. 5, or webs or tubular conductions 30-12 as in FIG. 13 in order to equalize any increased liquid requirement which occurs because of an overlaid capillary body.

As best indicated in the embodiments of FIGS. 3 through 8 and 10, the elasticity of the capillary bodies 27-1, 27-2, etc. which are employed together with the supporting elements or webs 29-1, 29-2 is sufficient to maintain the bodies in the position selected. It has been observed that, even with relatively high loads, through radial heat currents the capillary bodies 27, 27-1, etc. or the grooves 26 of the chamber wall can be adequately provided with liquid from the hollow interiors 28 of the capillary bodies. The use of the supporting bodies such as the supporting body 31 for the purpose of increasing the firmness of the capillary body 27 or its web 29 is illustrated, for example, in the embodiment shown in FIGS. 6, 7, and 9. With heat transportation devices of relatively large dimensions, it is also possible to arrange grooves 32-10, 32-12, 32-13 and 32 so that they extend in an axial direction and hold the supporting bodies 31-10, 31-12, 31-13 and 31, respectively, as shown in FIGS. 11, 13, 14 and 15.

In FIG. 12 a heat transportation device 50-11 includes a capillary body 27-11 having fillets or webs 29-11 which is spot welded at points 33-11, to a supporting body 31-11. Supporting body 31-11 penetrates along one surface line the wall of the chamber and a welding seam 34-11 joins the supporting body 31 to the chamber wall. This arrangement is particularly suited for chamber walls made up of plane metal sheets into which the grooves are rolled.

It is also possible to add supporting elements 35-10 to the capillary body 27-10 which is arranged around

each side of a fillet or web 29-10 and to join them in a suitable manner as for example, in the manner indicated in FIGS. 11, 13, 14 and 15. For this purpose, a divided or slit tube having smooth surfaces (thus without capillaries) may be arranged to engage the centrally position web 29-10 which is formed from a narrow meshed wire netting and which is reinforced with a supporting body 31. With the embodiments indicated in FIGS. 11 through 15, the capillary fillets 29-10, 29-11, 29-12, etc. and the supporting body 31-10, 31-11, etc. can also be formed from a single piece of sheet metal having grooves running from the grooves 26 of the chamber wall to the capillary body 27-10, etc.

In FIG. 15, the chamber 25 is indicated at the front side or heatable end, and the heat is conveyed thereto through this end as indicated by the arrows 5'. The heat is removed as indicated by the arrows 10', along the length of the device. Depending on the particular application, not only the inner wall 24 of the tubular jacket but also the heatable front wall 36 is provided with grooves 26 and 26a, respectively, for the taking up of the liquid. The grooves 26a at the front wall are shown as spiral grooves which may be either arranged concentrically or parallelly. The end walls are also penetrated by further cross grooves 32a into which capillary webs 29a engage. The capillary tubes 27 and 27a are interconnected by elbow tubes 30. When choosing either a quadratic or rectangular chamber cross section, for example, it is of no consequence for the operation of the arrangement when the front side mounted grooves 26 consist partially of non-cohering arcuate segments.

What is claimed is:

1. A heat transmitting device, comprising an axially elongated tubular member defining an evaporable and wetting liquid chamber, at least one capillary body extending along said chamber for conducting liquid therealong, said tubular member having an interior wall with a plurality of capillary grooves thereon extending crosswise to the direction of liquid flow in the capillary body, said capillary body being held at a distance from said interior wall, and including at least one web having capillaries which touches the evaporable liquid present in the grooves of the chamber wall and extends to said capillary body.

2. A heat transmitting device, according to claim 1, including means for adding heat to said tubular member adjacent one portion thereof and defining a heat zone at said portion, means for withdrawing heat from said tube at a portion thereof spaced from said heating zone and defining a condensing zone, and an intermediate transport zone between said heating zone and said condensing zone having means for insulating said tubular member at such location.

3. A heat transmitting device, according to claim 1, wherein said capillary body comprises a tube having an axially extending slot, and a capillary web member disposed in the slot of said tube, said tube and said capillary web member comprising a metal element having capillaries.

4. A heat transmitting device, according to claim 1, wherein said capillary body comprises a segmented tube and at least one capillary web member formed on said tube and communicating therewith and with the grooves of said interior wall and made metal sheet having capillaries.

5. A heat transmitting device, according to claim 1, including at least one web member having capillaries

extending through said capillary body and into close proximity of the grooves of said interior wall, said capillary body comprising a sheet having smooth surfaces touching said web member along its edges.

6. A heat transmitting device, according to claim 1, wherein there are a plurality of said capillary bodies within said chamber, and means joining said capillary bodies together having a plurality of capillaries.

7. A heat transmitting device, according to claim 6, wherein said capillary bodies and said means joining said capillary bodies comprise a metal material provided with capillaries.

8. A heat transmitting device, according to claim 1, wherein said plurality of grooves comprises one continuous spiral groove extending along the axis of said tubular member.

9. A heat transmitting device, according to claim 1, wherein said capillary body forms a spring prestressed within said chamber.

10. A heat transmitting device, according to claim 1, wherein said capillary body carries at least one web member having capillaries which extend into proximity with said interior wall and provides a support for said capillary body on said inner wall.

11. A heat transmitting device, according to claim 1, 25

wherein said tubular member interior wall includes a plurality of cross members extending substantially axially along said interior wall and crossing said grooves, and a web member having capillaries extending from said capillary body to each of said grooves.

12. A heat transmitting device, according to claim 1, including means for heating said tube adjacent one end thereof, said one end having a wall provided with parallelly arranged grooves, and a plurality of cross grooves running approximately at right angles to said parallelly arranged grooves, and a web member extending from said capillary body into each of said cross grooves.

13. A heat transmitting device, comprising an axially elongated tubular member defining an evaporable and wetting liquid chamber having an interior wall, at least one capillary body extending along said chamber for conducting liquid therealong and being located at a spaced location from said interior wall, said tubular member having at least one capillary groove extending crosswise to the direction of liquid flow in the capillary body, and a web comprising capillaries and located in said chamber between said wall and said capillary body and defining a capillary connecting bridge between said interior wall and said capillary body.

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