

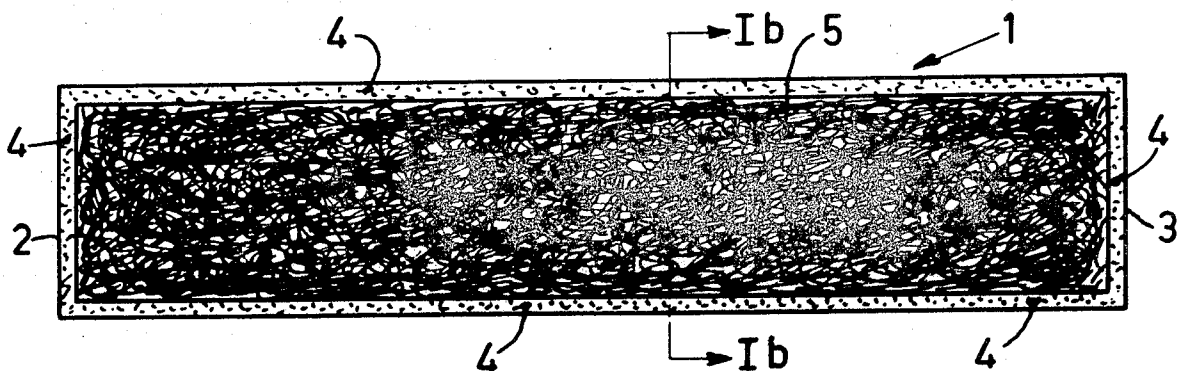
- [54] **HEAT TRANSPORTING DEVICE**
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[52] U.S. Cl. **165/105, 267/147**
[51] Int. Cl. **F28d 15/00**
[58] Field of Search **165/105; 267/147**

- [56] **References Cited**
UNITED STATES PATENTS
3,613,778 10/1971 Feldman, Jr. 165/105
3,435,889 4/1969 Bienert 165/105
3,603,767 9/1971 Scicchitano 165/105 X

Primary Examiner—Albert W. Davis, Jr.
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[57] **ABSTRACT**
A heat transporting device comprising a closed container having at least one first and at least one second heat transmission wall, and a heat transporting medium which absorbs thermal energy through the first heat transmission wall while changing from the liquid phase into the vapor phase and supplies thermal energy to the second heat transmission wall while changing from the vapor phase into the liquid phase; the container furthermore comprises a porous mass which connects the second to the first heat transmission wall in such manner that the medium condensed through said mass on the second heat transmission wall can flow back to the first heat transmission wall due to capillary action. One or more supporting elements are arranged in the container for supporting the walls of the container against pressure forces exerted thereon from without, which supporting elements permit the flow of medium vapor in the direction of heat transport.

4 Claims, 8 Drawing Figures



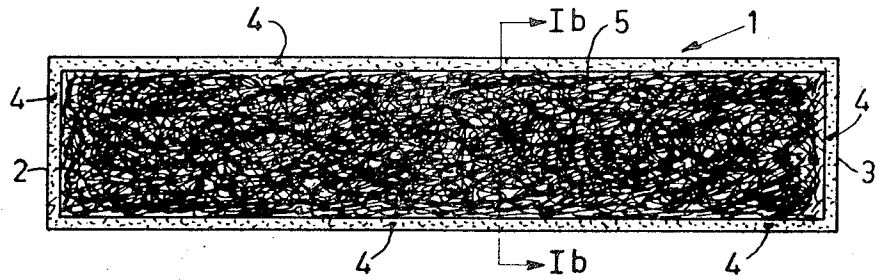


Fig. 1a

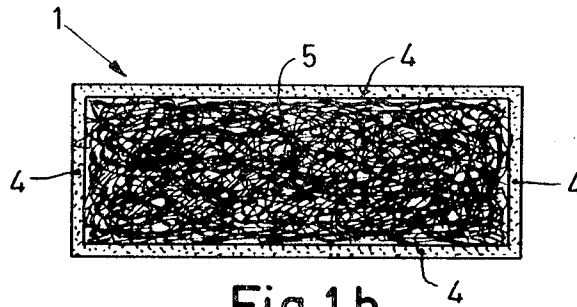


Fig. 1b

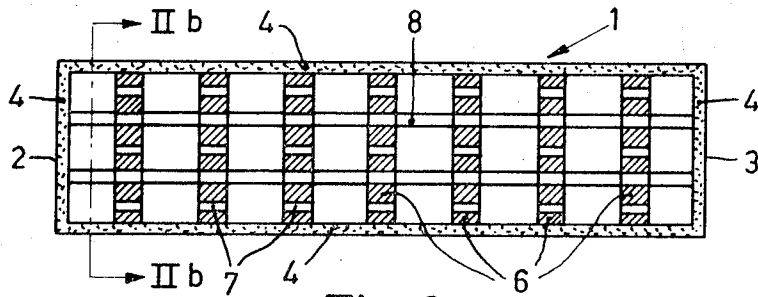


Fig. 2a

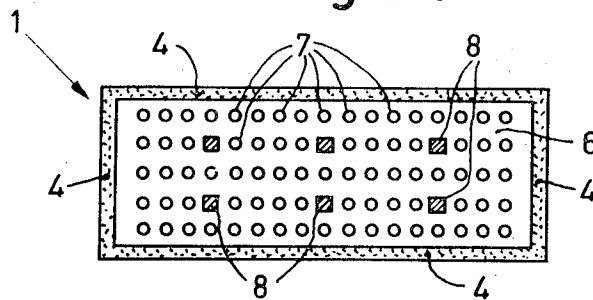


Fig. 2b

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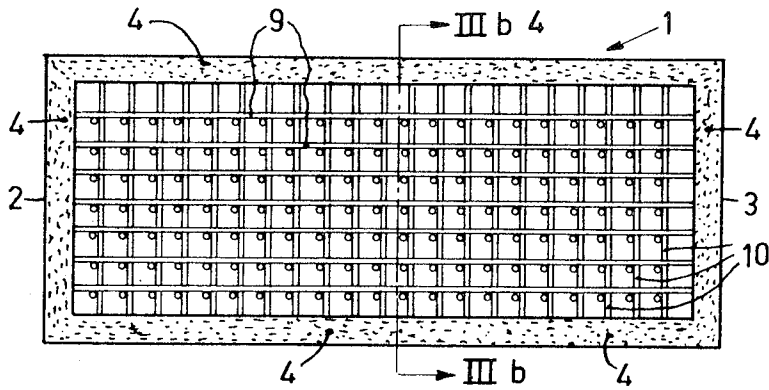


Fig. 3a

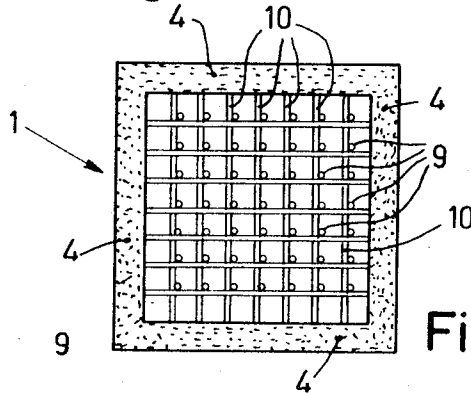


Fig. 3b

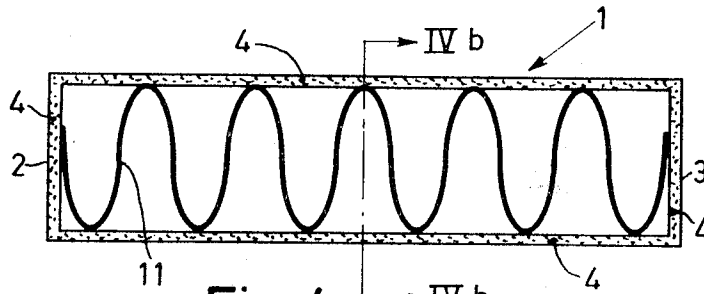


Fig. 4a

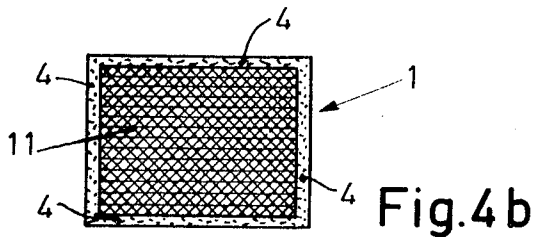


Fig. 4b

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HEAT TRANSPORTING DEVICE

The invention relates to a heat transporting device comprising a closed container having on the one hand at least one first and on the other hand at least one second heat transmission wall, said container comprising a heat transporting medium which absorbs thermal energy through the first heat transmission wall while changing from the liquid phase into the vapour phase and supplies thermal energy to the second heat transmission wall while changing from the vapour phase into the liquid phase, the container furthermore comprising a porous mass which connects the second to the first heat transmission wall in such manner that through said mass the medium condensed on the second heat transmission wall can flow back to the first heat transmission wall due to capillary action.

Devices of this type are known from the U.S. Pat. Nos. 3,229,759 and 3,402,767. With such devices, large quantities of thermal energy can be transported substantially without fall in temperature and without making use of a pumping device and without further moving components. Liquid heat transporting medium which evaporates at the first heat transmission wall moves in the vapour phase to the second heat transmission wall as a result of the lower vapour pressure prevailing there as a result of the temperature which is slightly lower at the area. The vapour then condenses on the second heat transmission wall while supplying heat of evaporation to said wall, after which the condensate is returned to the first transmission wall via the porous mass by capillary action and while making use of the surface tension of the condensate and is evaporated there again.

The porous mass ensures in all circumstances that condensate can flow back from the second to the first heat transmission wall so even against gravity or without the effect of gravity. Porous masses are to be understood to mean within the scope of the present invention not only masses which consist, for example, of ceramic materials, gauzes of wire or ribbon-shaped material, but also arrangements of pipes and systems of grooves in the wall of the container, whether or not in combination with one of the above-mentioned alternatives. The porous mass which connects the first to the second heat transmission wall may cover the whole wall surface or only part of it.

In order that the evaporation-condensation process of the heat transporting medium in the container can run off smoothly, said container is normally evacuated. A problem is that in a number of cases, dependent upon the heat transporting medium chosen, the vapour pressure of the heat transporting medium in the container lies below the ambient pressure not only at room temperature but also at the high operating temperature of the heat-transporting device. For example, when the evacuated container contains sodium as a heat transporting medium, the vapour pressure at 800° K is 8 Torr (1 Torr = 1 mm mercury pressure), and at 1,100° K is 450 Torr. This means that in particular in the case of containers having large dimensions and large flat walls, said walls are subject to a considerable mechanical load as a result of the atmospheric pressure, which load will be even larger when the heat transporting device forms part of a larger construction, which usually is the case, and other structural components exert forces on the container, for example, by their own

weight. Notably at high operating temperatures, at which the rigidity of the container walls is considerably lower than at room temperature, does this lead to deformation (sagging) or cracking of the container walls with the possibility of implosion.

The porous mass may work loose from the wall of the container and/or its capillary structure may be damaged to such an extent that it is no longer useful for the return of condensate.

A choice of thicker and hence more rigid container walls often is not possible for reasons of weight, cost-price, admissible dimensions and by requirements regarding the flatness of the walls notably of the heat transmission walls, which latter are moreover restricted to certain thickness limits in connection with the thermal resistance.

It is the object of the present invention to provide a heat transporting device of the above-described type, in which the said drawbacks are mitigated in a simple and cheap manner.

In order to realize the end in view, the heat transporting device according to the invention is characterized in that one or more supporting elements are arranged in the container so as to support the walls of the container against pressure forces exerted on them from without, said supporting elements permitting flow of medium vapour in the direction of heat transport.

Since in the device according to the invention the walls of the container are supported, they will maintain their original shape and cracking of the walls, implosion, or damage to the capillary structure of the porous mass is prevented. Although normally there is a possibility that as a result of thermal stresses between the walls of the container and the porous mass or due to shocks or vibrations said porous mass works loose from the wall, the supporting elements in the device according to the invention also ensures that the porous mass is maintained in its place.

The supporting elements may be constituted, for example, by perforated metal plates which are interconnected or are not interconnected, by metal gauzes folded in a zigzag manner or by a structure of rods or pipes.

In a favourable embodiment of the heat transporting device according to the invention, the supporting elements are formed by a compressed porous filling mass of wire or ribbon-shaped material, the pores of which have such a size that the relationship

$$2\gamma \cos \theta / R - \Delta p - \sigma gh > 2\gamma \cos \theta / R_1$$

is satisfied, in which

γ = surface tension of liquid heat transporting medium

θ = angle of contact for liquid heat transporting medium in the pores of the porous mass,

R = hydraulic radius of the pores in the porous mass,

θ_1 = angle of contact for liquid heat transporting medium in the pores of the filling mass

R_1 = hydraulic radius of the pores in the filling mass

Δp = pressure loss of liquid heat transporting medium in the porous mass between the second and the first heat transmission wall as a result of the resistance to flow of the said mass,

σ = density of liquid heat supporting medium

g = acceleration of gravity,

h = difference in height between the first and the second heat transmission wall.

The container can be filled with such a filling mass in a simple and cheap manner. The wires or tapes can be provided in bulk in the container and then be compressed, which is of advantage in containers in which certain parts of the space inside are difficult of access, or the compression whether or not followed by sintering, can be carried out previously.

The left-hand term of the above relationship represents the resulting capillary force on liquid heat transporting medium in the porous mass, in which the hydraulic radius R is defined as $2 \cdot \text{surface/circumference}$ of the pores.

The angle of contact θ namely the angle between the liquid surface and the wall of the pore, depends for a given liquid on the material of the wall of the pore and the nature of the surface of the wall. If in the present case the material of the porous filling mass differs from that of the porous mass whilst the hydraulic radius is the same, the capillary rise may differ mutually.

By ensuring that the above relationship is fulfilled, the porous mass will have a capillary suction action for liquid which is so much larger than that of the porous filling mass that at the area of the second heat transmission wall all the condensate is absorbed by the porous mass and nothing by the filling mass, while also farther on in the direction from the second to the first heat transmission wall, condensate will not be transmitted from the porous mass to the filling mass.

Therefore, vapour transport from the first to the second heat transmission wall through the filling mass takes place substantially without hindrance.

All this means in practice that the pores of the filling mass have a larger hydraulic radius than the pores of the porous mass. Comparatively large dimensions of the pores of the filling mass are also desirable to minimize the flow losses of the vapour and hence the temperature gradient between the first and the second heat transmission wall.

According to the invention, steel wool is preferably used as a material for the filling mass.

Steel wool presents the advantage of a low price, can easily be compressed in all kinds of shapes and, in the compressed condition, can absorb considerable pressures per surface unit.

In order that the invention may be readily carried into effect, it will now be described in greater detail, by way of example, with reference to the accompanying drawings, FIGS. 1 to 4 of which show diagrammatically and not to scale four embodiments of the heat transporting device.

Referring now to FIG. 1 which is a longitudinal cross-sectional view (FIG. 1a) and a cross-sectional view (FIG. 1b) taken on the line 1b—1b of FIG. 1a, reference numeral 1 denotes a closed container having on the one hand a first heat transmission wall 2 and the other hand a heat transmission wall 3. For the rest the container is thermally insulated from the atmosphere. On the inner wall of the container 1 a porous mass 4 is provided which has a capillary structure. The container is otherwise filled with a porous filling mass 5 serving as a supporting element and in this case consisting of a compressed steel wool, the structure of which is coarser than that of the porous mass 4, that is to say, the pores in the filling mass 5 have larger passages than the pores in the mass 4.

The container furthermore contains a suitably chosen quantity of sodium as a heat transporting medium and is otherwise evacuated.

During operation, liquid sodium absorbs thermal energy through the first heat transmission wall 2 from a heat source not shown, so that said sodium evaporates. The vapour then flows through the pores in the compressed steel wool to the second heat transmission wall 3 as a result of the lower vapour pressure there, due to the slightly lower temperature at the area, and condenses on said wall while delivering the heat of evaporation absorbed in the first heat transmission wall 2. The condensate flows through the porous mass 4, due to capillary action while using the surface tension of the condensate, back to the first heat transmission wall 2 to be evaporated again there. Return of condensate takes place irrespective of the position of the container so even against gravity or without the effect of gravity.

Since the pores in the porous mass 4 have smaller cross-sections than the pores in the filling mass 5, all the sodium condensed on the second heat transmission wall 3 is drawn into the pores of the porous mass 4. So no return of condensate to the first heat transmission wall 2 takes place through the filling mass 5, so that all the pores in the filling mass remain available for sodium vapour transport from the first to the second heat transmission wall.

Both when the heat transporting device is out of operation and the container is at room temperature and during operation at operating temperatures of, for example, 600°–800° C, the vapour pressure of the sodium in the container is much lower than the atmospheric outside. Notably the upper and lower walls of the container 1 with their large wall surface areas hence experience a considerable mechanical load. The porous filling mass 5 formed in this case by compressed steel wool ensures that the container walls are supported. The filling mass has a sufficient resistance to pressure to ensure that the container walls not bend inwards, tear and provide a possibility of implosion or damage the capillary structure of the porous mass 4, respectively cause said mass 4 to work loose from the walls and be removed therefrom.

In FIGS. 2 to 4, the same reference materials are used as in FIG. 1 for corresponding components. The operation of the heat transporting devices shown in these figures is identical to that shown in FIG. 1, so that it need not be described in detail.

In the heat transporting device shown in FIG. 2, the supporting elements are constituted by a number of metal plates 6 arranged transverse to the heat transporting device and comprising a number of apertures 7 through which heat transporting medium in the form of vapour can flow from the first to the second heat transmission wall. The plates 6 are rigidly secured to supporting beams 8 which likewise serve as supporting elements.

FIG. 3 shows a heat transporting device in which the supporting element consists of a construction of beams 9 and cross beams 10 which are rigidly connected together. Transport of the heat transporting medium in the form of vapour from the first heat transmission wall 2 to the second heat transmission wall 3 takes place in a direction parallel to the beams, through the rectangular apertures bounded by the cross beams 10.

FIG. 4 shows a heat transporting device in which a gauze 11 folded in a zigzag manner serves as a support-

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ing element. Vapour of heat transporting medium flows through the meshes of the gauze 11 from the first to the second heat transmission wall. The forces exerted on the large surfaces of the upper and lower wall of the container 1 by the atmospheric pressure, are at least partly received via the gauze 11 by the two heat transmission walls 2 and 3.

Although only four embodiments of the supporting elements are shown, all kinds of other constructions are of course possible without departing from the scope of the present invention. Nor is the use of the supporting elements restricted to heat transporting devices, in which the container has a rectangular cross-section but they may equally readily be used for all kinds of other shapes of said container, for example, a cylindrical shape or a U- or V-profile having or not having a cylindrical, rectangular or polygonal cross-section, and so on.

What is claimed is:

1. A heat pipe device operable with a heat-transporting medium having a vapor phase when heated sufficiently and a liquid phase then sufficient heat is extracted therefrom, this device being operable to receive thermal energy from a source and to supply thermal energy to a sink, and being subject to external pressure, the device comprising walls which define a closed container and inner surfaces of the walls defining a space therein, two of said walls being first and second spaced apart heat-transmitting walls, a quantity of said heat-transporting medium situated within said container, a porous mass along said inner surfaces the mass having structure permitting capillary flow of said liquid phase medium therethrough, and support means being a resilient mass and having strength in compression and situated within said container and contacting and providing substantially uniform pressure against said walls thereof for resisting said external pressure thereto, said supporting means being porous for permitting a flow of said vapor phase medium therethrough.

2. A heat pipe device as claimed in claim 1, characterized in that the supporting means are formed by a

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compressed porous filling mass of wire or ribbon-shaped material, the pores of which have such a size that the relationship

$2\gamma \cos\theta/R - \Delta_p - \sigma gh > 2\gamma \cos\theta_1/R_1$ is satisfied, in which:

γ = surface tension of liquid heat transporting medium

θ = angle of contact for liquid heat transporting medium in the pores of the porous mass

R = hydraulic radius of the pores in the porous mass

θ_1 = angle of contact for liquid heat transporting medium in the pores of the filling mass,

R_1 = hydraulic radius of the pores in the filling mass

Δ_p = pressure loss of liquid heat transporting medium in the porous mass between the second and the first heat transmission wall as a result of the resistance to flow of the said mass

σ = density of liquid heat transporting medium.

g = acceleration of gravity

h = difference in height between the first and the second heat transmission wall.

3. A heat pipe device as claimed in claim 2, characterized in that the material is steel wool.

4. A heat pipe comprising walls which define a closed container and inner surfaces of the walls defining a space therein, two of said walls being spaced-apart first and second heat-transmitting walls, heat transporting medium having vapor and liquid phases when heated and cooled respectively within said container, a porous mass along said inner surfaces interconnecting said heat transmitting walls, this mass permitting capillary flow of said liquid phase medium therethrough, support means having compression strength situated within and substantially filling space and contacting said walls inner surfaces for providing compression strength to said container, said support means being a resilient mass and being porous permitting flow of said vapor phase medium therethrough between said heat transmitting walls.

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