United States Patent

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[54] **HEAT TRANSFER DEVICE**
10 Claims, 11 Drawing Figs.

[52] U.S. Cl. **165/105,** 165/134
[51] Int. Cl. **F28d 15/00**
[50] Field of Search 165/134, 105, 107

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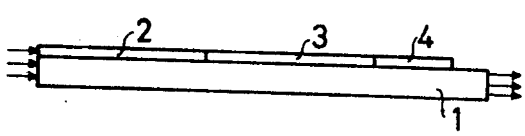
ABSTRACT: A heat pipe of the kind having a heat-carrying vehicle such as a metal which circulates inside a closed pipe with a cycle of evaporation and condensation is provided with one or more auxiliary heat pipes for use, in starting up from cold, to melt the vehicle of the main heat pipe.



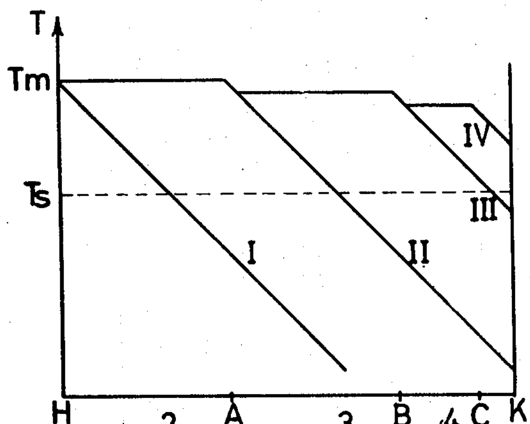


FIG.1a.

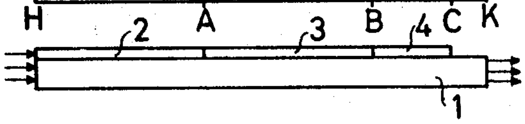


FIG.1b.

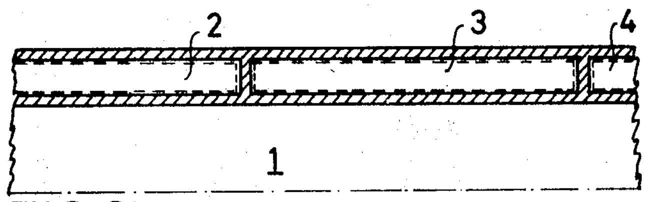


FIG.2a.

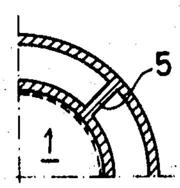


FIG.2b.

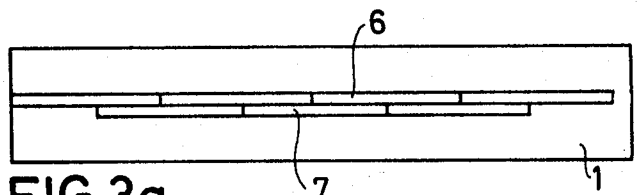


FIG.3a.

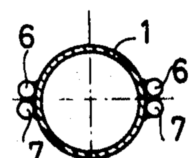


FIG.3b.

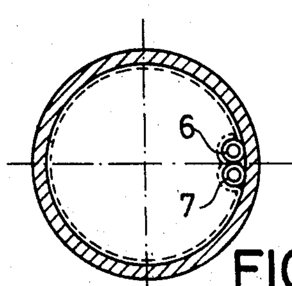


FIG.4.

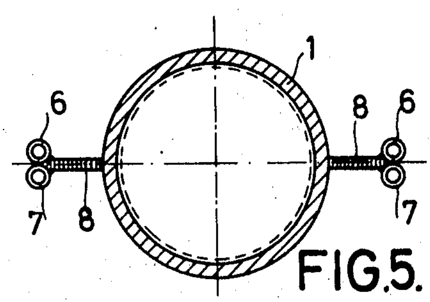


FIG.5.

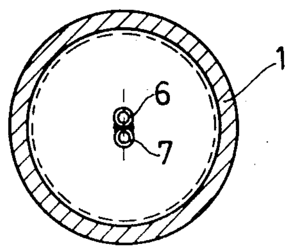


FIG.6.

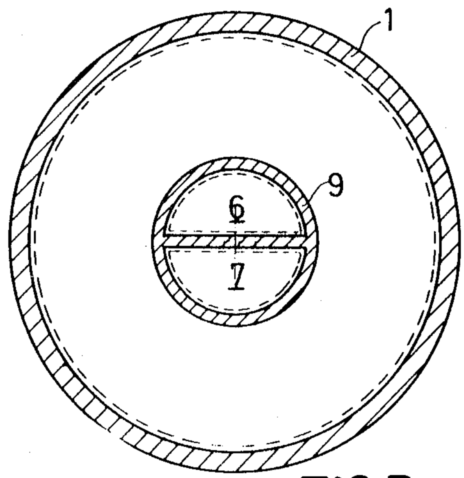


FIG.7.

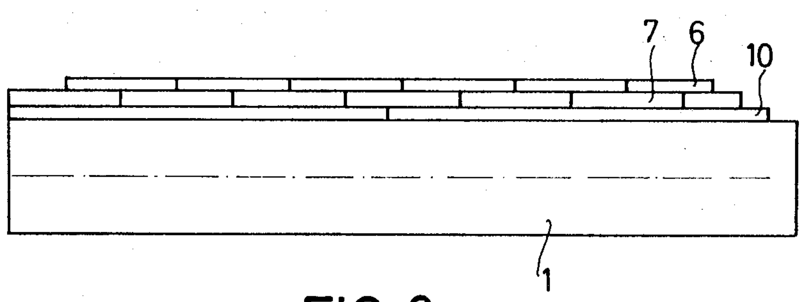


FIG 8.

HEAT TRANSFER DEVICE

The invention relates to heat pipes using a hermetically closed pipe in which a heat-carrying vehicle circulates by a natural cycle of evaporation and condensation at operating temperature. Such heat pipes have a high heat flow density and low temperature losses. The flow of the condensed vehicle may be by capillary action.

The usual practice is for heat pipes to be used for temperatures starting in the region of 1,000° C., the heat vehicle being a metal which at temperatures of this order can circulate naturally be evaporation and condensation. Metals of this kind are solid at ordinary ambient temperatures, e.g., room temperature, and more especially in cases in which heat pipes are used in space with its much lower ambient temperatures.

The problem with which the invention is concerned arises in the starting of the startup heat pipe. Since heat is conveyed in the wall structure of the pipe and in the solidified heat-carrying vehicle at a rate much less than in normal operating conditions, is difficult to heat the pipe over its whole length to the melting point T_s of the heat-carrying vehicle. Previously, therefore, recourse has been had to extra heating facilities, such as a high-frequency coil, to heat the pipes over their whole length and only then to start full operation. Another solution of the problem is to make the temperature in the heating zone so high that the critical temperature T_s is achieved at the coolest place of the pipe despite the temperature drop therealong; unfortunately, this solution is impracticable, at least so far as relatively long heat pipes are concerned, for the maximum heating temperature then becomes excessive.

The invention provides an improved heat pipe having means which, without needing extra heating sources, can bring the heat pipe to the required operating condition just by heating of the heating zone. The invention is also of use for very long heat pipes.

In its broad form the invention provides a heat pipe characterized by at least one auxiliary heat pipe which is shorter in length than the main pipe and of which the heating zone is in the region of the heating zone of the main heat pipe and the cooling zone is in thermal connection with the main heat pipe at a position intermediate in the length thereof whereby during starting of the main heat pipe heat is transferred by the auxiliary heat pipe from the heating zone to the said position.

More specifically the invention provides a heat pipe using a hermetically closed pipe in which a heat vehicle circulates by a natural cycle of evaporation and condensation at maximum operating temperature, the heat vehicle being solid at the start of operations, characterized in that at least one extra shorter heat pipe having a lower heat carrying capacity than the main heat pipe is disposed in parallel therewith and thermally bridges part of the length of the main heat pipe.

Preferably, at least two auxiliary heat pipes are so connected in series as to bridge thermally at least a major part of the length of the main heat pipe. Preferably, the series of auxiliary heat pipes is in intimate thermal engagement with the main tube heating zone; also, at least the two ends of each pipe may be thermally connected to the wall of the main pipe.

In one form of the invention, the auxiliary heating pipes take the form of annular cavities in the main heat pipe wall; the auxiliary pipes being therefore in very intimate thermal engagement over their whole length with the main pipe. According to another feature, of use more particularly for heat pipes radiating heat over their whole length, the thermal connection between the auxiliary pipes and the main pipe is such (i.e., so poorly conductive) that when the auxiliary heat pipe the average corresponds approximately to the maximum main pipe operating temperature, the main pipe only just warms up to the melting point of its heat-carrying vehicle. Advantageously, a number of series systems, i.e., chains of auxiliary heating pipes are disposed in staggered relation parallel to one another and in good heat contact with the one another, in which event the connections between any two adjacent pipes of a chain may always be bridged thermally by a heat pipe of the other or another chain. Conveniently, in the case of very long main heat pipes, the average length of the heat pipes of one chain is considerably greater than the average length of the heat pipes of the other or another chain, so that the shorter pipe chains can provide starting assistance for the longer pipe auxiliary chains.

Some specific examples of heat pipes embodying the above and other features of the invention will be described hereinafter with reference to the drawings, wherein:

FIG. 1*a* is a temperature diagram:

FIG. 1*b* is a diagrammatic view of a heat pipe;

FIGS. 2*a* and 2*b* are orthogonal section through a heat pipe;

FIG. 3*a* is a diagrammatic view of another heat pipe;

FIG. 3*b* is a cross section through the heat pipe shown in FIG. 3*a*;

FIGS. 4 to 7 are cross sections through other heat pipes according to the invention, and

FIG. 8 is a diagrammatic view of another heat pipe according to the invention.

The underlying idea of the invention will now be described with reference to FIG. 1. FIG. 1*a* denotes the temperature pattern over the length of a heat pipe during heating up, in a case in which heat is supplied from a heating zone H. Let the maximum permissible temperature for the heat pipe be T_m. In the absence of the auxiliary pipes employed in the invention, inadequate heat transmission would result in a rapid temperature drop along the pipe, as indicated by temperature pattern I. It might therefore be impossible to heat the cool zone K of the pipe to the temperature T_s without exceeding the temperature T_m in the heating zone. Consequently, the heat pipe 1 shown diagrammatically in FIG. 1*b* has, as a starting aid in accordance with the invention, auxiliary heat pipes in thermal engagement with the main pipe wall. In the present example the starting aid comprises an arrangement of three auxiliary pipes 2–4 which are connected in series, one of the auxiliary pipes being in direct connection with the heating zone H. The overall length of the series arrangement can be either exactly the same as that of the main pipe or can be shorter, since the temperature drop in a heat pipe in normal operation is negligible and there is no need to make the cool zone hotter than the temperature T_s.

If only the single auxiliary heat pipe 2 immediately adjacent the heating zone were present, the temperature pattern would be as represented by curve II i.e., there would be substantially no temperature drop in the main pipe in the part extending alongside the auxiliary pipe, but then the temperature would drop, just as in the absence of an auxiliary pipe, due to noncirculation of the heat vehicle. When a second auxiliary pipe is connected to the end of the first pipe (place A), the only temperature drop at such a place is the one arising at the connection between the two heat pipes. In this case the temperature remains constant as far as position B where the second auxiliary pipe 3 ends (temperature curve III). Only when the three auxiliary pipes are all connected in series as far as position C is an overall temperature curve IV produced such that the cooling zone K becomes hotter than the temperature T_s.

This series arrangement can therefore be used to start up the main heat pipe 1. The various auxiliary e.g., should be of lengths such that they can be started without their heating zones overheating and without requiring auxiliary heating.

The underlying idea of the invention is of use for main heat pipes whose generated surface is cooled, e.g., by radiation, and also for main pipes cooled only on the end face remote from the heating zone. An embodiment of the latter kind is shown in FIG. 2, where auxiliary heat pipes 2, 3 and 4 separated by circumferential partitions are disposed all round a main pipe 1 whose entire generated surface is double-walled, so that annular chambers are left which longitudinal bulkheads 5 subdivide into sections. The main pipe 1 and the auxiliary pipes 2–4 are lined with capillaries for ready return of the condensate.

The main pipe need not of course be round and can be a hollow member of substantially any shape. The auxiliary pipes can be provided in only a part of the main tube walls and they can just be soldered to the outside or inside thereof. The auxiliary pipes need not be in thermal engagement along their whole length with the main pipes; such engagement can be at discrete places or even just at the beginning and end of each auxiliary pipe. In any case, the connection between individual auxiliary pipes in a chain should be very efficient, and one way of achieving this aim is shown in FIG. 3 where there can be seen two auxiliary-pipe chains **6**, **7** wherein the junctions between any two "links" or pipes of each chain are bridged by a heat pipe of the other chain. In this case the links of the two chains are in thermal contact with one another as well as with the main pipe **1**. FIG. 3*b* is a view in section of an arrangement of this kind wherein two chains each are soldered to the outside of the main pipe **1** along two opposite generatrices; FIG. 4 on the other hand shows a heat pipe wherein auxiliary chains **6**, **7** are soldered to the inside of the main pipe.

In the case of a main heat pipe adapted to radiate heat over its whole length, the temperature to which the main pipe is heated during starting should be very little above the temperature T_s, to ensure that the energy radiated during warming up is reduced. One way of doing this is to operate the auxiliary pipes at a temperature below the normal working temperature T_m. Unfortunately, the auxiliary pipes, which do heat up to the higher temperature T_m anyway after starting, must in this case withstand a very high vapor pressure during operation of the main pipe, and so auxiliary starting pipes used in this way must have very thick walls and be very stable.

It is preferable to design the auxiliary pipes anyway for operation at the temperature T_m and to devise such a poor connection between the auxiliary pipes and the main pipe that the latter heats up only to T_s while the auxiliary pipes are at T_m. FIG. 5 shows a basic arrangement of this kind using two chain pairs **6**, **7** similar to the arrangement shown in FIG. 3*b*, the main difference from which is that in FIG. 5 the auxiliary pipes are not directly welded to the main pipe wall but are disposed on a web or fin or rib or the like **8** whose heat conductivity is selected to suit the temperature conditions just set forth.

Another way of achieving a similar aim is shown in FIG. 6, where the auxiliary chains are disposed inside the main pipe **1** near the axis thereof, so that heat exchange from the auxiliary pipes to the main pipe is by radiation and the thermal coupling is as poor or low as in FIG. 5.

FIG. 7 is a view in cross section through a main pipe **1** having at its center, and disposed in a common tube **9**, two chains of auxiliary heat pipes **6**, **7**, heat being transferred to the main pipe wall by way of tube **9**.

FIG. 8 shows a development of the underlying idea of the invention, of use for very long main pipes **1**. It may be advisable in such cases to parallel a number of chains of auxiliary pipes whose individual lengths vary, the shortest auxiliary pipes coming into the operative state first and the longer pipes coming into operation seriatim until the main pipe reaches its working temperature. Consequently, the cumulative heat losses in the chain due to the presence of a large number of "links" are reduced by the fact that any one auxiliary pipe always bridges a number of such links. FIG. 8 shows a combination of two chains **6**, **7** which have links of substantially the same length and which are in overlapping or staggered relationship with one another, in the manner first shown in FIG. 3; also visible in FIG. 8 is a chain **10** comprising two auxiliary pipes each bridging substantially half the length of the main pipe.

The invention is not of course limited to the embodiments shown. In particular, the number of chains and the length of the various chain links, the position and the thermal coupling of the chains relatively to the main pipe, and the geometric shape of the heat pipes, can be adapted in a broad range to suit practical requirements. THe materials used for the main pipe wall and the main pipe heat vehicle need not be the same as the auxiliary pipe vehicle or vehicles and wall material or materials, even though the use of similar materials will probably be advantageous. For instance the heat-carrying vehicle of the auxiliary pipes may be a metal having a lower melting point than the metal used as vehicle in the main pipe. If the temperature difference between T_m and T_s is large enough and the temperature drop when the vehicle is solid is small enough, just a single auxiliary pipe bridging much (e.g., a major part) of the length of the main pipe can be used to carry the invention into practice. However, conditions like this are likely to be found only in the case of relatively short main pipes.

The embodiment shown in FIG. 7 can be carried into practice on the basis of the following technical data;

Main heat pipe	
Material	Nb–1Zr
Heat Vehicle	Na(T_s=98° C.)
T_m	700° C.
Length	2 m.
External diameter	10 cm.
Total radiation capacity of outside surface	0.8
Power radiated at T_m	26kW
Auxiliary heat pipes (semicircular shape)	
Material	
Heat vehicle	as for main heat pipe
Length	30 cm. each
Combined to form a circular structure 3 cm. in diameter.	

I claim:

1. A heat transfer device comprising a heat pipe using a hermetically closed pipe in which a heat vehicle circulates by a natural cycle of evaporation and condensation at maximum operating temperature, the heat vehicle being solid at the start of operations, and comprising furthermore at least one auxiliary heat pipe which is shorter and has a lower heat carrying capacity than the main heat pipe, said auxiliary pipe being parallel to and thermally bridging part of the length of the main heat pipe, the thermal connection between the auxiliary heat pipe and the main heat pipe being such that when the auxiliary heat pipe temperature corresponds approximately to the maximum main pipe operating temperature, the main pipe only heats up to the melting point of its heat vehicle.

2. A heat transfer device as set forth in claim **1**, in which at least one arrangement comprising at least two auxiliary heat pipes in series thermally bridging a substantial part of the length of the main heat pipe.

3. A heat transfer device as set forth in claim **2**, in which at least one series arrangement of auxiliary heat pipes is in intimate thermal engagement with the main pipe heating zone, and at least the two ends of each auxiliary heat pipe are thermally connected to the main pipe wall.

4. A heat transfer device as set forth in claim **3**, in which the auxiliary heat pipes are in intimate thermal and mechanical engagement over their whole length with the main heat pipe wall.

5. A heat transfer device as set forth in claim **4**, in which the auxiliary heat pipes take the form of annular cavities in the main heat pipe wall.

6. A heat transfer device as set forth in claim **1**, in which the thermal connection is effected by heat radiation.

7. A heat transfer device as set forth in claim **6**, in which the auxiliary pipes are disposed inside the main pipe near the pipe axis.

8. A heat transfer device as set forth in claim **2**, in which there are at least two series arrangements or chains of auxiliary heat pipes and the chains are so staggered that the connection between any two adjacent pipes of a chain are always bridges thermally by a heat pipe of another chain.

9. A heat transfer device as set forth in claim **8**, in which the average length of the heat pipes of one chain is considerably greater than the average length of the heat pipes of the other or another chain.

10. A heat transfer device as set forth in claim **1**, in which the heat vehicle in the auxiliary heat pipe or pipes is a metal having a lower melting point than the main pipe heat vehicle.