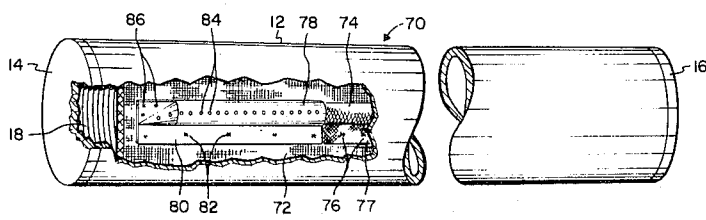


[54] HEAT-PIPE ARTERIAL PRIMING DEVICE
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[73] Assignee: TRW Inc., Redondo Beach, Calif.
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[21] Appl. No.: 411,955
[52] U.S. Cl. 165/105
[51] Int. Cl. F28d 15/00
[58] Field of Search 165/105
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Primary Examiner—Albert W. Davis, Jr.
Attorney, Agent, or Firm—Daniel T. Anderson; Jerry A. Dinardo; Willie Krawitz

[57] ABSTRACT
The artery of a heat pipe includes a closed tube mounted at the evaporator end of the artery and having one or more venting pores located in a thin-walled section of the tube. The wall section containing the venting pore is so thin as to cause meniscus coalescence of liquid tending to fill the pore when it borders a gas bubble. By the action of meniscus coalescence, the pore remains open to vent any gas bubbles that are present within the artery during priming thereof.

16 Claims, 10 Drawing Figures



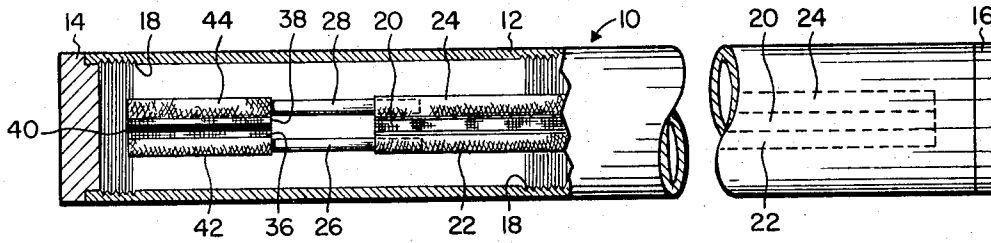


Fig. 1

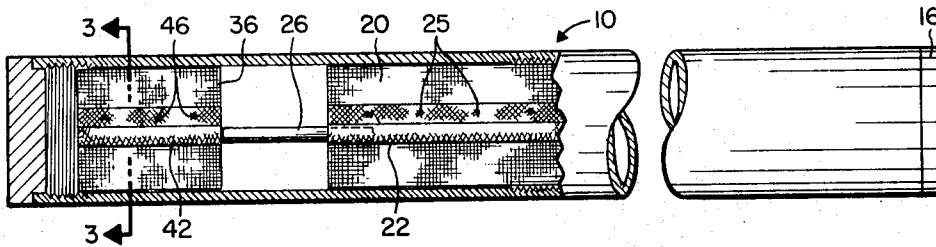


Fig. 2

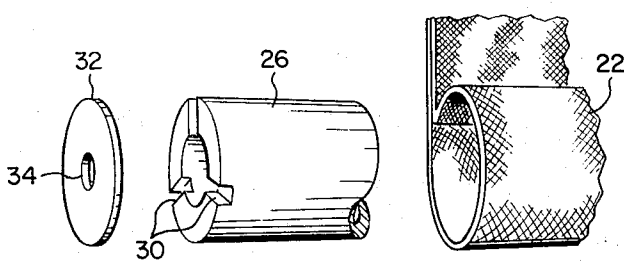


Fig. 4

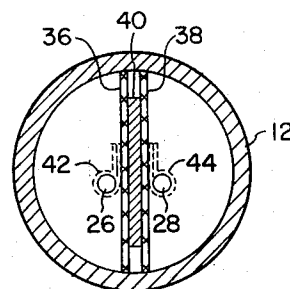


Fig. 3

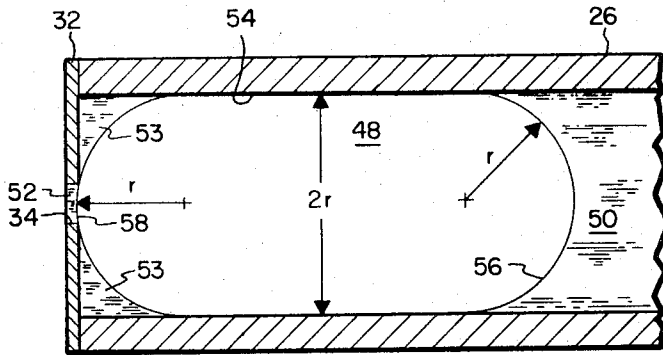


Fig. 5

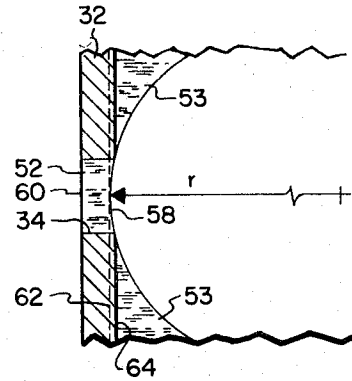


Fig. 6

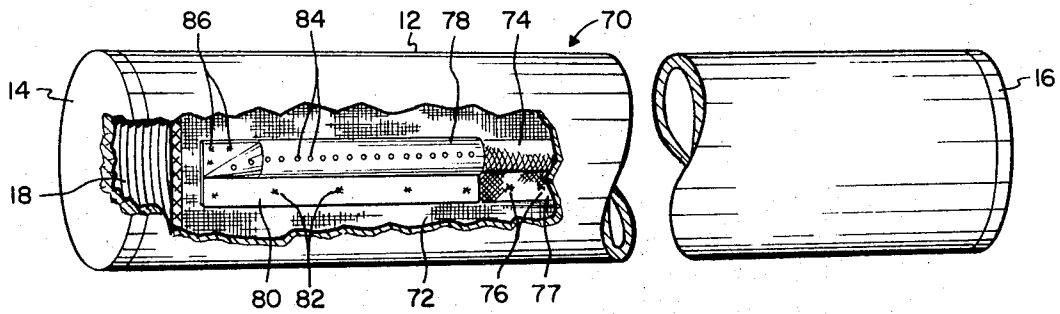


Fig. 7

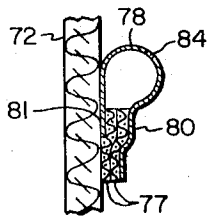


Fig. 8

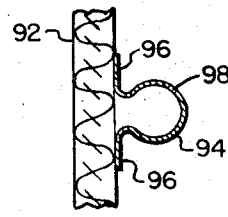


Fig. 10

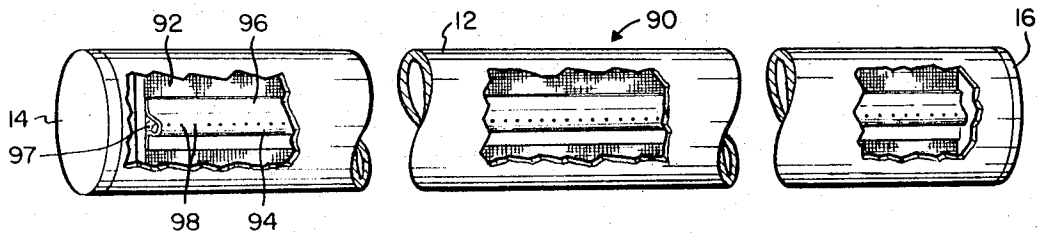


Fig. 9

HEAT-PIPE ARTERIAL PRIMING DEVICE

The invention herein described was made in the course of or under a contract or subcontract thereunder with the Department of the Air Force.

BACKGROUND OF THE INVENTION

This invention relates to improvements in heat pipes, and more particularly to improved arterial structures for such heat pipes.

Heat pipes are devices used for transferring heat at high rates between a hot region and a cold region. Inside a heat pipe liquid is evaporated at the wall in the hot region, known as the evaporator, the vapor flows to the cold region, known as the condenser, where it condenses, and the condensate then returns to the evaporator through a wick under the action of capillary forces.

The wick must satisfy two main requirements. First, it must be capable of generating a high capillary pressure. The capillary pressure of a wick is a term that is used to define the ability of the pore structure of the wick to withstand the pressure difference between the vapor and liquid. The maximum capillary pressure is the maximum pressure difference between the vapor and the liquid in the wick that the wick can withstand without causing the liquid menisci in the pores to collapse.

The second requirement for the wick is that it must have a low liquid-flow resistance. The liquid-flow resistance is a measure of the pressure drop the liquid experiences when flowing at a given flow rate from the condenser to the evaporator. With increasing heat input, the liquid flow rate increases so as to increase the pressure drop in the liquid. The thermal capacity of the heat pipe is reached when the pressure drop is so great that the maximum capillary pressure of the wick pores in the evaporator region is exceeded and the wick ultimately dries out.

The wick can be designed and fabricated in a tight structure with small pore size to achieve a high capillary pressure. However, the smaller the pore size of the wick, the greater will be its flow resistance.

To overcome the above conflicting wick requirements of high capillary pressure and low liquid flow resistance, designers of heat pipes have resorted to the use of arteries to handle very high heat loads. Generally, an artery is a closed tube filled with liquid and having at least a portion of its wall structure porous and in communication with the wick. In the artery, the maximum capillary pressure is determined by the pore size of the wall, whereas the flow resistance is determined by the diameter of the tube. Thus, these two parameters can be adjusted independently.

Although arteries can provide an order of magnitude increase in heat-pipe capacity, they suffer a serious disadvantage in that they are extremely difficult to prime and reprime reliably without entrapment of a bubble. An arterial bubble is intolerable because far before maximum capacity is reached, the bubble grows and the artery empties of liquid.

Bubbles present problems only if the heat pipe contains noncondensable gas as well as the heat-pipe working fluid, since a pure-vapor bubble will spontaneously collapse. It is unlikely, however, that heat-pipe fluid can be maintained so free of noncondensable gas that bubbles will not be a problem. Also, there is an impor-

tant class of heat pipes that are intentionally filled with some noncondensable gas for purposes of heat-pipe control.

The reason an arterial bubble is formed is that a liquid sheath on the artery wall prevents gas from venting during the priming process which usually proceeds from the condenser to the evaporator.

SUMMARY OF THE INVENTION

The heat-pipe arterial priming device according to the invention solves the problem of bubble entrapment by assuring that at least one pore in the extreme evaporator end of the artery remains open at all times during the priming process so as to vent any gas bubble that might be present in the artery.

According to one embodiment at least a portion of the length of the artery extending from the evaporator end comprises a closed tube that is provided with at least one pore in a thin-walled section of the tube. The diameter of the pore is sized to accommodate the maximum capillary pressure desired. The thickness of the wall containing the pore is made thin enough to prevent a small amount of liquid to plug the pore. The wall is sized so thin that the two menisci that potentially exist on opposite sides of the liquid in the pore coalesce to keep the pore open.

During the priming procedure, the pore in the thin-walled section remains open to vent any noncondensable gas that may be present in the artery. When the artery is fully primed, the liquid filling the artery closes the pore.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a top view, with portions removed and partly in section, of a heat pipe incorporating arterial priming structure according to the invention;

FIG. 2 is a front view thereof, with portions removed and partly in section;

FIG. 3 is a section taken along line 3—3 of FIG. 2;

FIG. 4 is a greatly enlarged exploded view showing some of the details of the arterial priming structure of FIGS. 1 and 2;

FIGS. 5 and 6 are greatly enlarged views, partly sectional and partly diagrammatic, illustrating the principle of meniscus coalescence in an arterial pore;

FIG. 7 is a perspective view, with portions removed and partly in section, showing a second embodiment of the arterial priming structure;

FIG. 8 is a sectional view showing a portion of the arterial priming structure of FIG. 7;

FIG. 9 is a perspective view, with portions removed and partly in section, showing a third embodiment of the arterial priming structure; and

FIG. 10 is a sectional view showing a portion of the arterial priming structure of FIG. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1—4, there is shown a heat pipe 10 having a cylindrical wall 12 closed by end walls 14 and 16. Conventionally, the heat pipe 10 is evacuated to a low pressure and filled with a sufficient quantity of working fluid to completely saturate all wick surfaces therein and also fill all the arteries therein. In addition, a quantity of noncondensable gas may be intro-

duced therein to provide some degree of temperature control, as is well known.

The interior surface of the cylindrical wall 12 is provided with a capillary structure 18 that extends along the entire length and circumference thereof. The capillary structure 18 is preferably shown as a continuous helical groove with turns that are finely cut and spaced. However, other capillary structures may be used such as porous coatings, mats, screens, webs, or the like.

In addition to the capillary structure 18 provided on the interior surface of the cylindrical wall 12, the heat pipe 10 contains a diametral slab wick 20 extending diametrically between the heat-pipe wall 12 and longitudinally along the wall 12. The width of the slab wick 20 is such as to provide a snug fit of the wick 20 against the capillary structure 18 on the interior surface of the heat pipe wall 12. The slab wick 20 extends substantially along the entire length of the heat pipe 10, one end of the wick 20 being disposed close to the end wall 16 at the condenser end, and the other end of the wick 20 terminating a sufficient distance from the other end wall 14 at the evaporator end to accommodate the arterial priming device to be described later herein. The slab wick 20 is preferably made of metal felt with a high degree of porosity.

A pair of main arteries 22 and 24 are mounted on opposite sides of the slab wick 20. The arteries 22 and 24 are coextensive with the slab wick 20 and are located below the central longitudinal axis of the slab wick 20. The arteries 22 and 24 have porous walls that are preferably made of fine screen mesh.

The arteries 22 and 24 may be conveniently formed and mounted by wrapping a long rectangular strip of fine screen metal mesh around a long metal rod or mandrel of small diameter, lapping the ends of the strip mesh together, spot welding the lapped ends of the strip mesh to the slab wick 20 at spaced points along the length thereof, such as at weld points 25 in FIG. 2, and removing the long metal rod mandrel. The arteries 22 and 24 are mounted low enough on the slab wick 20 such that the relatively low capillary pressure generated by each artery diameter is sufficient to completely fill the artery with working liquid once it has been successfully vented of gas.

The arteries 22 and 24 are provided with arterial priming means constructed according to the invention. The arterial priming means are attached to the ends of the main arteries 22 and 24 adjacent to the evaporator region. Two short lengths of tubing, which form auxiliary arterial tubes 26 and 28, are mounted with open ends inserted a short distance within the arteries 22 and 24, respectively. The tubes 26 and 28 have nonporous walls in contrast to the porous walls of the arteries 22 and 24.

Both of the tubes 26 and 28 are identically constructed. The construction of one of the tubes 26 is shown in greater detail in the enlarged exploded view of FIG. 4. The inside diameter of the tube 26 is smaller than that of the artery 22 into which it is inserted and the outside diameter of the tube is about the same as the inside diameter of the artery. The free end of the tube 26 is provided with equally spaced drain notches 30, there being three drain notches shown in this embodiment. The same free end of the tube 26 is closed by a thin foil disk 32, leaving the notches 30 open behind the disk. The disk 32 has at least one small vent opening or pore 34 centrally located. More than one

pore may be provided, the pore or pores serving to vent any noncondensable gas that may be present within either artery 22 or 24 during the priming thereof.

Referring back to FIGS. 1-3, the tubes 26 and 28 are mounted on short lengths of slab wick that function as drain wicks, there being a drain wick 36 for the tube 26 and another drain wick 38 for the tube 28. The drain wicks 36 and 38 are spaced apart from each other by a non-porous shim or spacer 40. The drain wicks 36 and 38 are shorter than the length of the tubes 26 and 28 so that a space is left between the ends of the drain wicks 36 and 38 and the slab wick 20.

The tube 26 and 28 are each partially covered with a porous sheath, such as sheaths 42 and 44. The porous sheaths 42 and 44 are of the same length as the drain wicks 36 and 38 and are similar in construction to the arteries 22 and 24. That is, they are made of fine screen mesh, are wrapped around the tubes 26 and 28, and have lapped ends spot welded to the drain wicks 36 and 38, such as at weld points 46 in FIG. 2. The porous sheaths 42 and 44 cover the respective drain notches 30 of the tubes 26 and 28 and thereby provide communication between the interior of the tubes 26 and 28 and the drain wicks 36 and 38.

The function of the venting pore 34 is to allow the escape of any noncondensable gas that may be present in either of the arteries 22 and 24 during the priming thereof. The artery wall, though porous, fills with liquid and traps within it any gas bubbles that may be present. If the gas bubble is not allowed to escape it will grow and eventually force all the liquid out of the artery.

The venting pore 34, while it is of capillary size to withstand the desired maximum capillary pressure when the artery is filled with liquid, and for that reason is dimensioned to have a diameter no smaller than the pore size of the artery wall, nevertheless is located in a wall section so thin as to be incapable of being filled by a small amount of liquid in the pore only. For an understanding of the physical principle involved in the design of the venting pore, reference is now made to the diagrams of FIGS. 5 and 6. The dimensions are somewhat exaggerated and not necessarily drawn to scale for the sake of a clearer understanding of the principles underlying the invention.

FIGS. 5 and 6 show the end of the tube 25 during the priming process with a gas bubble 48 entrapped therein between the liquid column 50 and the foil disk 32. The liquid adjacent to the foil disk 32 includes a liquid plug 52 filling the venting pore 34 and liquid fillets 53 in the corners between the inside wall 54 of the tube 26 and the inside surface of the foil disk 32. The inside cylindrical wall 54 of the tube 25 is shown as an entirely closed surface, whether it be from liquid filling the pores, as would be the case in the region of the notches 30, or whether it be due to the non-porous nature of the tube wall. In any case, the tube 26 functions as an artery and can be considered an extension of the main artery 22, despite any dimensional difference in their inner diameters.

It is in the nature of all liquid menisci bordering a gas bubble in an artery to assume a radius of curvature that is equal to radius of the artery, if it is assumed that the liquid has a zero wetting angle relative to the artery wall. Accordingly, the radius of curvature of the meniscus 56 formed at the end of the liquid column 50 is equal to the inside radius r of the tube 26, the diameter of the tube 26, of course, being equal to $2r$. Likewise,

the radius of curvature of the meniscus 58 formed by the liquid fillets 53 and by the liquid plug 52 filling the venting pore 34 is equal to the inside radius r of the tube 26. The outside meniscus 60 of the liquid plug 52, in one limit, has a relatively large radius of curvature and can be considered to be substantially flat, or have an infinite radius of curvature, if the wetting angle of the liquid is considered to be zero.

Now referring to the enlarged view of FIG. 6, it can be seen that if the wall of the foil disk 32 is reduced in thickness, as by moving the outside surface of the wall progressively closer to the inside surface, the two menisci 58 and 60 will also be brought closer and closer together. At some stage the foil wall will reach such a thinness that the two menisci 58 and 60 will intersect or coalesce. When this occurs, the venting pore 34 can no longer retain the liquid plug 52 and the pore 34 opens. The separation between the outside surface of the foil disk 32, as represented by the dashed line 62, and the inside surface 64 of the foil disk 32 represents the critical thickness at which meniscus coalescence occurs.

The invention is predicated on the realization that such a critical thickness in the wall can be predetermined which will keep the pore open for venting any noncondensable gas in the artery. It is further realized that the critical or maximum thickness (t) of the wall in which the venting pore is located is related to the artery diameter D_A and the pore diameter D_P by the following expression:

$$t = D_A [1 - \sqrt{1 - (D_P/D_A)^2}]$$

The above expression is based on a simple theory that assumes a zero wetting angle between the working fluid and the foil wall and assumes an equally curved meniscus on the outer side of the liquid plug, which potentially may fill the pore. In the case of a finite wetting angle greater than zero, the above formula can be used by substituting D_A' for D_A , where $D_A' = (1/\cos \text{wetting angle}) D_A$.

It may also be mentioned in connection with the discussion above relating to the equality between the radii of all menisci bordering a gas bubble in an artery and the radius of the artery, that in the case of a non-zero wetting angle between the liquid and the artery wall, the menisci bordering the bubble will have a radius that is greater by a factor of $1/\cos \text{wetting angle}$. Methanol is an example of a working fluid that typically has a zero wetting angle with stainless steel and copper, whereas water has a finite wetting angle of about 45°.

The diameter of the venting pore is related to maximum capillary pressure it can generate when the artery is fully primed with liquid and also the surface tension of the liquid-vapor interface, according to the following:

$$P_V - P_L = 2\sigma/r,$$

where

P_V is the pressure of the working-fluid vapor

P_L is the pressure of the working-fluid liquid

σ is the surface tension of the liquid-vapor interface

r is the radius of curvature of the meniscus in the pore.

The minimum value for the radius of curvature of the meniscus is the radius of the pore. If the radius of curvature of the meniscus attempts to assume a smaller

value than the minimum in order to balance a greater pressure difference ($P_V - P_L$), the meniscus will fail. Thus, the pore diameter governs the maximum capillary pressure. Stated differently, once the maximum capillary pressure is set by the heat-pipe design requirements, the diameter of the pore is determined by the above expression. Having determined the pore diameter, the maximum thickness of the foil wall to achieve meniscus coalescence as previously described may be determined.

The thin metal foil containing the venting pore 34 must be located at least at the evaporator end or region, that is, the region where normally the heat input is applied. It will be noted that the solid walled tubes 26 and 28 fit into the ends of the two main arteries 22 and 24 respectively. The inside diameter of each tube is smaller than the diameter of its associated artery and therefore has a greater pumping power relative thereto. It is therefore possible that the liquid will remain in the tube even before the main artery is primed. This liquid must be drained from the tube before the artery can be primed. The necessary preliminary drainage is accomplished through the drain notches 30 and the separate drain wicks 36 and 38 by way of the porous sheaths 42 and 44. A low level of heat input is applied to the evaporator region, or the region adjacent the tubes 26 and 28. The low level of the heat may be about 10% of the thermal capacity of the heat pipe and is applied for a sufficient time to drain the tubes 26 and 28 by evaporation of the liquid.

After a sufficient time has elapsed to drain the tubes 26 and 28 of any liquid originally present therein, the heat load is reduced below 2 or 3% of the thermal capacity of the heat pipe. With the heat load reduced the liquid is allowed to fill the arteries 22 and 24 and after forcing any gas bubbles through the venting pore 34, also fill the tubes 26 and 28.

The drain wicks 36 and 38 are separated from the main slab wick 20 to prevent drawing liquid from the main part of the heat pipe rather than draining the tubes 26 and 28. Furthermore, the intervening shim 40 that separates the two drain wicks 36 and 38 serves to isolate the two arteries 22 and 24 so that a drain wick will not draw liquid from one artery that has been successfully primed rather than draining liquid from the tube of the unprimed artery.

The design specifications for a typical heat pipe constructed according to embodiment of FIGS. 1-6 are as follows:

All materials	stainless steel
Working Fluid	methanol
Heat-pipe tube (12)	.50" O.D., .0428" wall thickness, 5 feet long
Circumferential Grooves (18)	100/inch, "Vee" groove, .007" opening; 38° angle.
Main wick (20)	felt metal, porosity 84%, fiber diameter — .00085 inches, .050 inch thick slab.
Artery (22)	150 mesh screen, .063 inch inside diameter
Tube (26)	.063 O.D., .030 I.D., 2 inches long
Foil (32)	.0005" thick with pore (34) diameter .010 inches
Drain wicks (36)	Same material as main wick, .020" thick, 1 inch long
Shim (40)	.010" thick
Notches (30)	width .010", depth at inside of tube .006"
Gap between wicks	3/4"
Heat-pipe capacity	180 watts at 80°F

Referring now to FIG. 7, there is shown a different embodiment of the invention employing a single main artery and a thin foil arterial priming tube provided with a plurality of venting pores longitudinally spaced along its length. The heat pipe 70 has a cylindrical wall 12, end walls 14 and 16, and cylindrical capillary structure 18, similar to those described for the heat pipe 10 of FIGS. 1-6. A unitary slab wick 72 extends substantially along the entire length of the heat pipe 70.

A single porous main artery 74 is attached to one side of the slab wick 72. As in the previous embodiment, the artery 74 is made of fine screen metal mesh and is attached to the slab wick 72 at weld points 76 spaced along the length of the flat strips 77 comprising two thicknesses of metal mesh from which the artery 74 is formed.

A thin foil auxiliary arterial priming tube 78 is inserted over the end of the artery 74 to form a continuation thereof. The artery 74 itself extends only a short distance into the priming tube 78 but the flat strips 77 of metal mesh extend the whole length of the priming tube. As shown more clearly in cross section in FIG. 8, the priming tube 78 is formed from a curved strip of thin metal foil with the long edges brought together to form two legs 80 and 81 of unequal length. The rear leg 81 closest to the slab wick 72 is shorter than the front leg 80 that is spaced from the slab wick 72. Sandwiched between the two legs 80 and 81 are the two thicknesses of metal mesh comprising the flat strips 77 which extends beyond the end of the artery 74. The flat strips 77 of metal mesh provide communication between the slab wick 72 and the interior of the priming tube 78. The priming tube 78 is fixed to the slab wick 72 by welding the legs 80, 81 and metal mesh strips 77 together, as at weld points 82.

The priming tube 78 is provided with a series of venting pores 84 of equal diameter in its cylindrical wall and equally spaced along the length thereof. The venting pores 84 are located preferably at an angle of about 45° relative to the slab wick 72. The remote end of the priming tube 78 is closed, as by crimping or flattening the end of the tube 78 and welding the flattened end at weld points 86.

The venting pores 84 perform the same function as the single venting pore of the previous embodiment, namely to allow the escape of gas bubbles from the artery and thereby facilitate priming.

The diameter of the venting pores 84 is designed to accommodate the maximum capillary pressure. The thickness of the foil wall of the priming tube 78 is sufficiently thin to cause meniscus coalescence of any minuscule amount of liquid that attempts to fill the venting pores 84.

To prime the artery 74, a heat load is applied to the evaporator region of the heat pipe 70, that is, the region surrounding the priming tube 78. A sufficient heat load is applied to establish the normal heat pipe operating condition wherein the evaporator region is devoid of excess liquid and the condenser region is saturated with liquid. The heat load is then reduced to allow the liquid-vapor interface in the artery 74 to proceed gradually first to fill the artery 74, and then while filling the priming tube 78, force the vapor or gas out of the venting pores 84. In this embodiment, the priming tube 78 will not prime before the artery 74 because of its larger diameter.

Where more than one artery of the kind described in this embodiment is desired, it is simply added to the slab wick 72 without the necessity of any additional structure to isolate the priming tubes from each other and from the main wick. Because the priming tube in this embodiment has a larger diameter than the main artery, it will empty the working liquid when the artery fails or deprimizes.

The design specification for a typical heat pipe constructed according to the embodiment of FIG. 7 is as follows:

All materials	stainless steel
Working fluid	methanol
Heat-pipe tube (12)	.50" O.D., .0428" wall thickness, 5 feet long
Circumferential Grooves (18)	100/inch, "Vee" groove, .007" opening; 38° angle
Wick (72)	felt metal, porosity 84%, fiber diameter .00085 inches
Artery (74)	.050 inch thick slab
Foil (78)	150 mesh screen, .063 inch inside diameter
	.0005" thick with pores (48) of .013" diameter spaced .030" center-to-center. Length of foil 1"
Heat-pipe capacity	140 watts at 80°F

The embodiments thus far described rely on operating the heat pipe before and during priming such that the liquid-vapor interfaces proceeds uniformly from the condenser to the evaporator. The embodiments next to be described is not subject to this restriction and will permit priming to proceed in any direction.

Referring now to FIGS. 9 and 10, the heat pipe 90 has a cylindrical wall 12, end walls 14 and 16, and a helically grooved capillary structure as in the previous embodiments. A diametral slab wick 92 is also similarly provided.

A single artery 94 extends substantially along the entire length of the slab wick 92. In this embodiment the artery 94 comprises a strip of metal foil or other rigid non-porous material that is suitably bent or otherwise formed into a U-shaped tube or trough, and with the edges bent outwardly and flattened to form flanges 96 for attachment to the slab wick 92 by welding. Thus the artery 94 includes the bent U-shaped portion and the surface portion of the slab wick 92 lying between the flanges 96. The artery 94 may be closed at both ends by crimping or flattening the ends as in the previous embodiments, or by inserting metal plugs, such as plug 97, in the end openings of the artery 94 and welding the plugs.

The curved portion of the artery wall is provided with a single row of venting pores 98 equally spaced along the entire length of the artery 94. Preferably, the pores 98 lie in a straight line. However, they may be arranged in a single helix, if desired. More than one row of pores 98 would simply retard the priming process without appreciably improving the ability to vent gas. Here again, as in the embodiment of FIG. 7, the venting pores 98 are located at about 45° relative to the slab wick 92.

The diameter of the venting pores 98 is smaller than the spacing between the pores 98, and the pore diameter is much smaller than the artery diameter. As previously described, the U-shaped wall portion of the artery 94 is sufficiently thin to achieve the condition of meniscus coalescence that is necessary to keep the venting pores 98 open for the escape of gas bubbles during priming.

Because of the symmetry of the artery 94 along its length, the heat pipe 90 can conduct heat in either longitudinal direction. That is, heat can be applied at either end and it will conduct to the opposite end. Furthermore, it is not necessary, for priming, to apply a heat load preferentially at the end chosen to be the evaporator, as in the previous embodiments. In fact, it is possible to prime this heat pipe 90 without applying any heat load at all. To prime the heat pipe 90, it is necessary merely to level the heat pipe and reduce the heat load. It will prime from both ends of the artery 94 in directions towards the middle thereof.

While the artery 94 has been described as having a U-shape cross-section, it is apparent that a single artery having the shape of the priming tube 78 of FIGS. 7 and 8 may be used. Any suitable shape may be used for the artery incorporating venting pores along its entire length, provided that at least a portion of its perimeter be in liquid communication with the main wick structure along its entire length.

What is claimed is:

1. A heat pipe having a condenser region and an evaporator region and containing a working liquid; said heat pipe being provided with at least one artery of substantial length for transporting said working liquid between said condenser and evaporator regions;

means forming at least one venting pore in said artery, said means in said artery being constituted at least in part by a thin-wall portion having at least one pore of capillary size formed therein;

said wall portion being so thin as to keep said pore open through the action of meniscus coalescence of any meniscus amount of said working liquid tending to fill said pore when said pore borders a gas bubble within said artery;

whereby said action of meniscus coalescence permits said pore to remain open for venting noncondensable gas that may be present within said artery during the priming thereof and until such time that said artery is fully primed with said working liquid.

2. The invention according to claim 1 where said thin-wall portion comprises a disk closing a terminal end of said artery.

3. The invention according to claim 1, wherein said thin-wall portion comprises a tubular extension of said artery, said venting pore being one of several similar pores formed in said tubular extension and spaced along the length thereof.

4. The invention according to claim 1, wherein said thin-wall portion comprises an elongated member, said venting pore being one of a plurality of similar pores formed in said elongated member and spaced longitudinally along the entire length thereof.

5. The invention according to claim 1, wherein said thin-wall portion has a maximum thickness that is determined by the following relationship:

$$t = D_A [1 - \sqrt{1 - (D_P/D_A)^2}],$$

where

t is the maximum thickness of said thin wall portion,
 D_A is the diameter of said artery,
 D_P is the diameter of said venting pore.

6. A heat pipe comprising:

tubular enclosure means;

a slab wick within said enclosure means and extending substantially the entire length of said enclosure means except for a minor portion thereof;

a pair of main arteries mounted on opposite sides of said slab wick and coextensive in length therewith;

a pair of drain wicks of slab construction mounted within said minor portion of said enclosure means and spaced from the end of said slab wick;

non-porous shim means mounted between and separating said drain wicks;

a pair of auxiliary arterial tubes mounted individually on said drain wicks and attached individually to said main arteries so as to form extensions thereof;

a working liquid within said enclosure means of sufficient quantity to saturate all wick and arterial structures therein; and

means forming at least one venting pore in each of said arterial tubes, said venting pores being sized to remain open by the action of meniscus coalescence for venting noncondensable gas from said arteries and said arterial tubes until they are filled with said working liquid.

7. The invention according to claim 6, wherein said venting pore is formed in a thin foil disk closing the end of each of said arterial tubes.

8. The invention according to claim 6, wherein each of said arterial tubes is provided with notches spaced peripherally about the end closed by said thin foil disk, and further including wick means covering said arterial tubes and said notches so as to provide liquid communication between the interior of said arterial tubes and said drain wicks.

9. A heat pipe comprising:

a tubular enclosure means;

a slab wick within said enclosure means and extending substantially the entire length thereof;

a main artery mounted on a side of said slab wick and coextensive in length therewith except for a minor end portion;

means providing liquid communication between the interior of said artery and said slab wick;

an auxiliary arterial tube mounted on said end portion of said slab wick and attached to said main artery so as to form an extension thereof, said arterial tube being closed at its terminal end;

a working liquid within said enclosure means of sufficient quantity to saturate all wick and arterial structures therein; and

means forming a series of venting pores in said auxiliary arterial tube and spaced along the length thereof, said venting pores being dimensioned to remain open by the action of meniscus coalescence for venting noncondensable gas from said artery and said arterial tube until they are both filled with said working liquid.

10. The invention according to claim 9, and further including means providing liquid communication between the interior of said auxiliary arterial tube and said slab wick.

11. The invention according to claim 10 wherein said liquid communication means for said auxiliary arterial tube comprises an extension of the liquid communication means for said artery.

12. The invention according to claim 9, wherein said venting pores are located at an angle of approximately 45° relative to the plane of said slab wick.

13. A heat pipe comprising:

tubular enclosure means;

a slab wick within said enclosure means and extending substantially the entire length thereof;

11

an artery mounted on a side of said slab wick and substantially coextensive in length therewith; said artery comprising a tubular member having two ends spaced apart and being of generally U-shape cross section with its longitudinal edges mounted spaced apart on said slab wick side so as to provide liquid communication between said slab wick and the interior of said artery;
means closing at least one end of said tubular member;
a working fluid within said enclosure means of sufficient quantity to saturate all wick and arterial structures therein; and
mean forming a series of venting pores in said tubular

12

member and spaced along the length thereof, said venting pores being of such size as to remain open by the action of meniscus coalescence for venting noncondensable gas from said artery until it is filled with said working liquid.

14. The invention according to claim 13, wherein said venting pores are located along a straight line.

15. The invention according to claim 14, wherein said venting pores are located at angle of approximately 45° relative to the plane of said slab wick.

16. The invention according to claim 13 and further including means closing the other end of said tubular member.

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