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[54] HEAT PIPE
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ABSTRACT: A heat pipe in which a vapor duct is mounted in the heat output zone to separate the vaporized working medium from the capillary walls of the heat output zone while the vapor is moving in a direction opposite to fluid capillary motion in the walls.

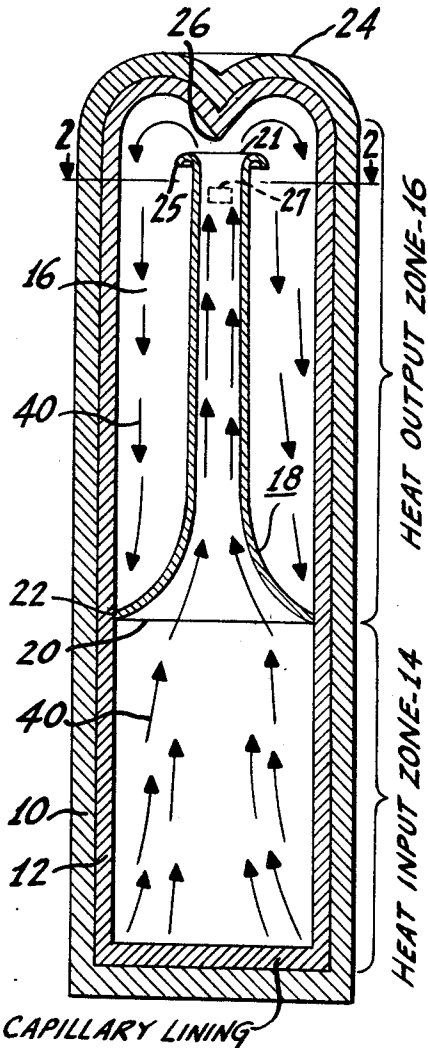


Fig. 1.

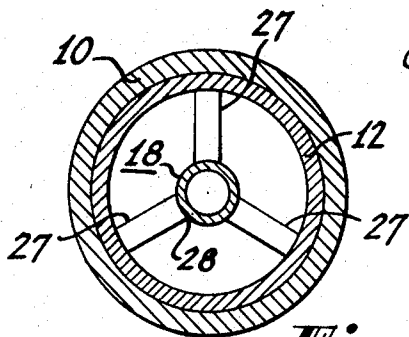
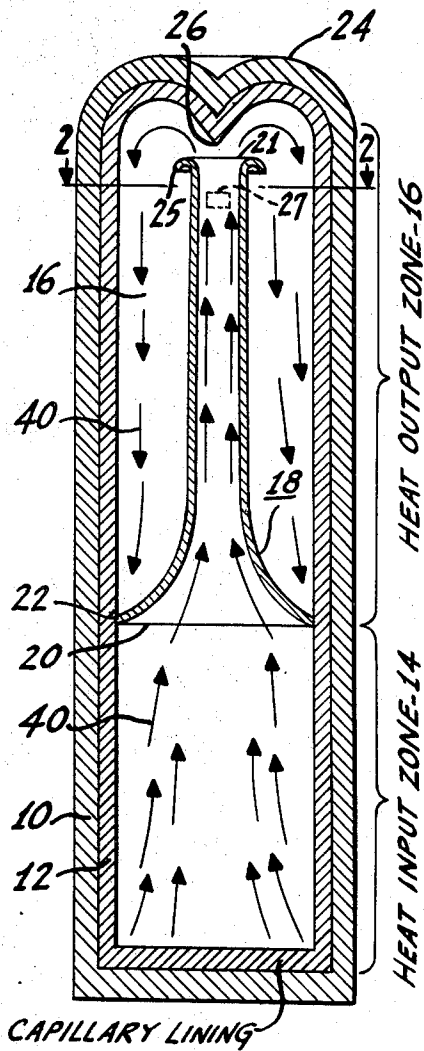
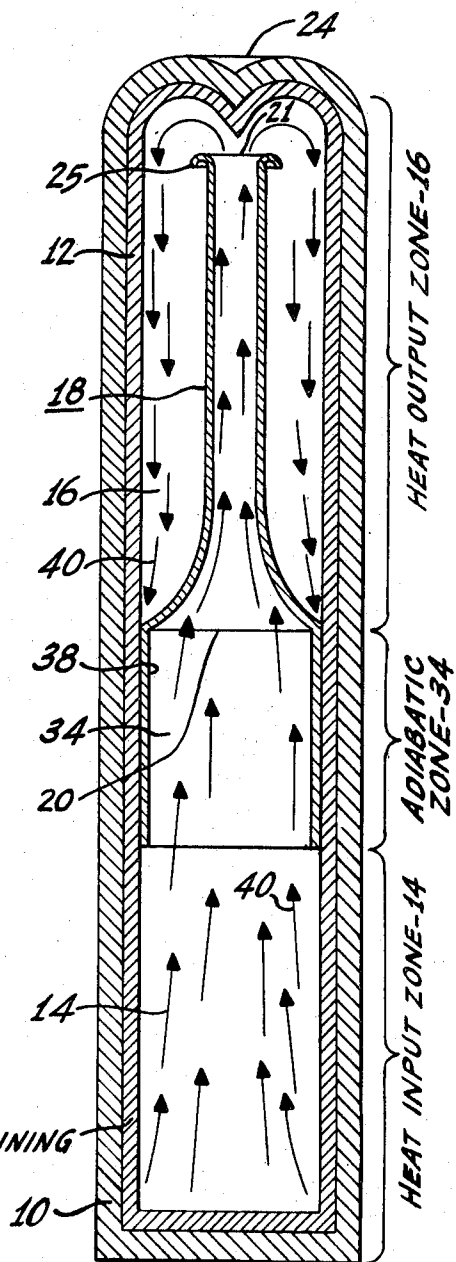


Fig. 2.

Fig. 3.



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HEAT PIPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to an improved heat transfer apparatus and particularly to improved heat pipe apparatus which provides improved heat transfer efficiency.

2. Description of the Prior Art

A heat pipe is a vapor device which is used to convey heat from a heat source to a heat output or dissipation zone. Such a device is described in general terms in an article entitled "Structures of Very High Thermal Conductance" by G. M. Grover in Volume 35 of the Journal of Applied Physics, pages 1990 and 1991. The heat pipe usually comprises a closed tubular structure having a lining of capillary material and a vaporizable heat transfer or working medium therein. The capillary lining can consist of wire cloth, porous matrix materials or channeling in the walls of the heat pipe itself. The working medium is selected to have a vaporization temperature equal to the desired operating temperature of the heat pipe. For example, lithium may be used as a working medium for high temperature applications and water can be used for lower operating temperatures. For most efficient operation all undesirable foreign gases are removed from the heat pipe envelope and the working medium.

Before heat is applied, preferably substantially all of the working medium is present in liquid form in the capillary walls of the heat pipe. Heat is applied from a heat source to the heat input zone of the heat pipe causing the liquid working medium in the capillary walls of this zone to vaporize and fill the interior of the heat pipe. The vaporized medium expands and then condenses on the inner walls of the heat output or heat dissipation zone of the heat pipe, giving up its latent heat of vaporization. The condensed liquid working medium is then transported by capillary action along the heat pipe wall from the heat output zone to the heat input zone to fill the area vacated by the vaporized working medium. In this way heat is transferred from a heat source to a heat output zone while the working medium is circulated through the heat pipe. Since the heat pipe is a closed system and has no moving parts to wear out, it is useful for applications such as space where maintenance is difficult. Heat pipes are also useful in enclosed spaces and in airless environments where other cooling techniques are difficult to use.

In prior art heat pipes, some loss in heat pipe efficiency resulted from the friction occurring between the vaporized working medium which moves from the heat input zone to the heat output zone of the heat pipe and the fluid working medium which moves along the walls of the heat pipe from the heat output zone to the heat input zone. These opposing flows tend to retard each other along the capillary walls of the heat output zone.

SUMMARY OF THE INVENTION

The foregoing problems of oppositely flowing gaseous and liquid media are overcome by an improved heat pipe which includes a vapor duct mounted to extend into the heat output zone of the heat pipe and arranged so that substantially all the vaporized working medium must pass through it to reach the remote end of the heat output zone of the heat pipe. The vapor is thus separated from the capillary inner walls of the heat output zone while it is moving in a direction opposed to the liquid flow in these walls. The vapor duct is open at both ends allowing the vapor to leave the duct at the remote end of the heat output zone. The end of the heat pipe in the heat output zone has a reentrant arch of rotation configuration which smoothly reverses the vapor flow and directs the vapor close to the capillary walls of the heat output zone where it condenses. In this way vapor flow is in substantially the same direction as liquid flow when the vaporized working medium reaches the capillary walls of the heat output zone.

Heat pipes incorporating the invention can be used to convey heat from a heat source to an area where the heat is utilized or dissipated.

If heat dissipation is desired, fins or other radiating means can be attached to the exterior of the heat output zone of the heat pipe. For example, heat pipes can be used to cool an electron tube and other heat sources or to transfer heat to components in the cold environments of space or to a thermoelectric generator from a radioactive source or other heat source.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of a preferred embodiment of the improved heat pipe;

FIG. 2 is a sectional view taken along the line 1-1 of FIG. 1; and

FIG. 3 is a longitudinal sectional view of a second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The outer envelope 10 of the heat pipe preferably is a tubular structure closed at both ends. It can be constructed of any suitable good heat conducting material. Molybdenum is often used for high temperature heat pipes and copper for those which operate at lower temperatures. A lining 12 of capillary material covers the entire inside surface of the heat pipe. This lining can be wire mesh screening, a porous matrix material, or even can be channeling in the walls of the heat pipe. The heat pipe is divided into two zones, a heat input zone 14 and a heat output or dissipation zone 16.

A funnel-shaped vapor duct 18 is mounted to extend into the heat output zone 16 of the heat pipe. It is preferably fabricated of the same metal as the outer envelope 10. The duct 18 consists of a pipelike structure of a uniform diameter over most of its length which diameter is substantially less than the inner diameter of the capillary lining 12. The end 20 of the duct 18 adjacent to the heat input zone 14 is flared outwardly so that its outer edge is in contact with the capillary lining 12 along a line 22 at the approximate dividing line between the heat input zone 14 and the heat output zone 16. The relatively narrower end 21 of the vapor duct 18 is located adjacent to the remote end 24 of the heat output zone of the heat pipe. This narrow end 21 of the vapor duct 18 has a rim 25 which extends outwardly and curves downwardly to inhibit the vaporized working medium from flowing down the sides of the vapor duct 18 and to direct it relatively close to the capillary walls 12. The remote end of the heat pipe 24 in the heat output zone is formed by a reentrant arch of rotation about a point 26 located adjacent to and coaxially with the center of the narrow end 21 of the vapor duct 18.

To retain the vapor duct 18 at a proper position in the heat pipe, the outer edge of its flared end 20 is attached to the capillary lining 12 of the heat pipe along a line 22 by welding or other appropriate means. Further mechanical stability is provided, if desired, by the addition of three rigid metal radial braces 27 extending from the capillary lining 12 to the vapor duct 18 at points 28 adjacent to the narrow end 21 of the duct as shown in FIG. 2. These braces 27 are usually fabricated of the same material as the body of the vapor duct 18 and may be made an integral part of the duct 18. The outer ends of the radial braces 27 are in contact with or may be fastened to the capillary lining 12 of the heat pipe walls by welding or other suitable means.

The second embodiment of the invention shown in FIG. 3 has an adiabatic zone 34 between the heat input zone 14 and the heat output zone 16. The temperature remains substantially constant in the adiabatic zone, and the capillary lining 12 is in this zone need not be free to release vapor or absorb condensing liquid. In this embodiment, the vapor duct 18 terminates in a sleeving 38 at its flared end 20. This sleeving 38 constitutes a part of the vapor duct 18 and has a diameter large enough to fit tightly against the capillary lining 12 in the adiabatic zone 34. The sleeving 38 is attached to the capillary walls 12 of the heat pipe by welding or other suitable means. This will provide adequate mechanical support for the vapor

duct 18 without further bracing. Other features of this embodiment are identical to those described for the first preferred embodiment.

In either embodiment heat is applied to the heat input zone 14 causing the working medium contained in the capillary walls 12 to vaporize and expand throughout the heat pipe. The vaporized working medium 40 is forced to move through the vapor duct 19 since the flared end 20 of the vapor duct 18 completely blocks off other portions of the interior of the heat pipe. The vapor 40 moves through duct 18 and passes out of the duct at the narrow end 21. The curved rim 25 around the narrow end 21 of the vapor duct 18 and the reentrant arch of rotation configuration of the end 24 of the heat pipe smoothly reverses the flow of the vaporized working medium 40 so that most of the vapor flows close to the capillary walls 12 of the heat output zone 16 where it condenses on the capillary walls 12. Both the vaporized working medium and the liquid in the capillary walls flow in substantially the same direction in the heat output zone 16. Liquid working medium then moves through the capillary walls from the heat output zone 16 to the heat input zone 14 to fill areas vacated by the heated vaporized working medium 40.

The vapor duct 18 provides more efficient circulation of the working medium because the vaporized working medium 40 moving toward the heat output zone 16 is separated from the capillary walls 12 of the heat output zone 16 in which liquid working medium is moving in the opposite direction. Without the vapor duct 18 these opposing flows would tend to retard each other decreasing the heat transfer capability of the heat pipe.

Little of the efficiency of the capillary walls 12 is lost by attaching the vapor duct 18 to them. Liquid working medium moves past line 22 where the vapor duct is attached to the capillary walls through the interior portions of the capillary lining to react the heat input zone 14 of the heat pipe.

I claim:

1. A heat pipe comprising:

- a. a hollow envelope having a sealed wall structure, said wall structure including a heat input zone and a heat output zone;
- b. capillary means contiguously disposed on at least a portion of the inner surface of said wall structure, said portion including said heat input zone and said heat output zone;
- c. a working medium within said envelope vaporizable below the operating temperature of said heat pipe; and
- d. a vapor duct mounted within said envelope, said vapor duct having a larger end adjacent to the boundary between said heat input and said output zones and contiguous with said capillary means, and a narrower end located adjacent to the enclosed end of said heat pipe in said heat output zone.

2. A heat pipe as described in claim 1 wherein said vapor duct comprises:

- a. a tubular structure having a flared end adjacent to the boundary between said heat input and said heat output zones, the outer edge of said flared end being contiguous with said capillary means, and a narrower end located at a

point adjacent to the enclosed end of said heat pipe in said heat output zone; and

- b. said tubular structure having a uniform diameter substantially smaller than the inside diameter of said capillary means at all points except at said flared end.

3. A heat pipe as described in claim 2 wherein said vapor duct includes:

- a. a rim around said narrower end of said vapor duct which extends outwardly and is curved to form a lip around said narrower end of said vapor duct; and
- b. a configuration of the end of said heat pipe in said heat output zone forming a reentrant arch of rotation about a point located adjacent to and coaxially with the center of said vapor duct at said narrower end.

4. A heat pipe as described in claim 2 wherein said vapor duct is attached to said capillary means at said flared end, and radial braces extend from said capillary means to said vapor duct adjacent to said narrower end of said vapor duct.

5. A heat pipe comprising:

- a. a hollow envelope having a sealed wall structure, said wall structure including a heat input zone, a heat output zone, and an adiabatic zone between said heat input and said heat output zones;
- b. capillary means contiguously disposed on at least a portion of the inner surface of said wall structure, said portion including said heat input, said heat output, and said adiabatic zones;
- c. a working medium vaporizable below the operating temperature of said heat pipe; and
- d. a vapor duct mounted within said envelope, said vapor duct having a larger end adjacent to the boundary between said adiabatic and said heat output zones, extending into said adiabatic zone, and contiguous with said capillary means, and a narrower end located adjacent to the enclosed end of said heat pipe in said heat output zone.

6. A heat pipe as described in claim 5 wherein said vapor duct comprises:

- a. a tubular structure having a narrower end adjacent to the enclosed end of said heat pipe in said heat output region, a flared end terminating in a cylindrical tube having a diameter approximately equal to the inside diameter of said capillary means, said cylindrical tube extending through said adiabatic zone; and
- b. said tubular structure having a uniform diameter substantially smaller than the inside diameter of said capillary means at all points within said heat output zone except at said flared end.

7. A heat pipe as described in claim 6 wherein said cylindrical tube at the flared end of said vapor duct is attached to said capillary means within said adiabatic zone.

8. A heat pipe as described in claim 6 wherein said vapor duct includes:

- a. a lip around said narrower end of said vapor duct; and
- b. a configuration of the end of said heat pipe in said heat output zone forming a reentrant arch of rotation about a point located adjacent to and coaxially with the center of said vapor duct at said narrower end.