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Staudhammer et al.

[11] 3,762,011

[45] Oct. 2, 1973

[54] **METHOD OF FABRICATING A CAPILLARY HEAT PIPE WICK**

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[52] **U.S. Cl.** .... **29/157.3 R,** 165/105

[51] **Int. Cl.** **B21d 53/02,** B21p 15/26

[58] **Field of Search** .... 29/157.3 R, 157 R; 165/105

[56] **References Cited**

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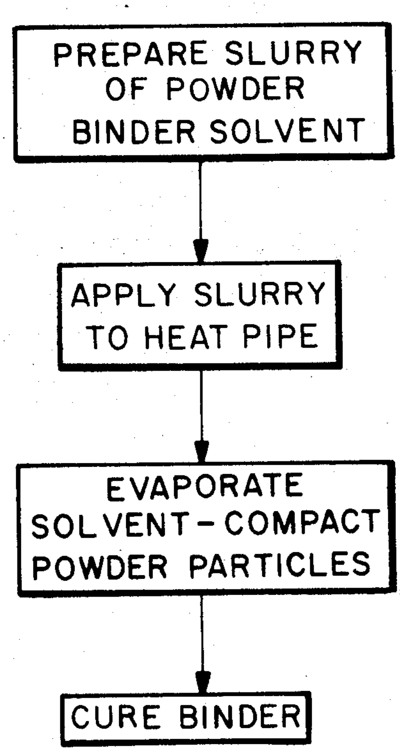
[57] **ABSTRACT**

A conformal capillary wick for a heat pipe is fabricated by preparing a slurry composed of an organic solvent containing an organic binder in solution and powder particles of relatively high thermal conductivity in suspension; applying a layer of the slurry to the inner wall surface of the heat pipe casing, evaporating the solvent from the layer to recover the binder and utilize the surface tension forces of the binder to draw the particles together into a highly compacted condition wherein the particles are bonded to one another and to the casing wall by the binder, and the particles and binder define a myriad of capillary passages extending throughout and opening through the surfaces of the layer; and curing the binder to form a dimensionally stable capillary structure providing a capillary wick for transporting working fluid condensate from the condenser section to the evaporator section of the heat pipe.

2 Claims, 3 Drawing Figures



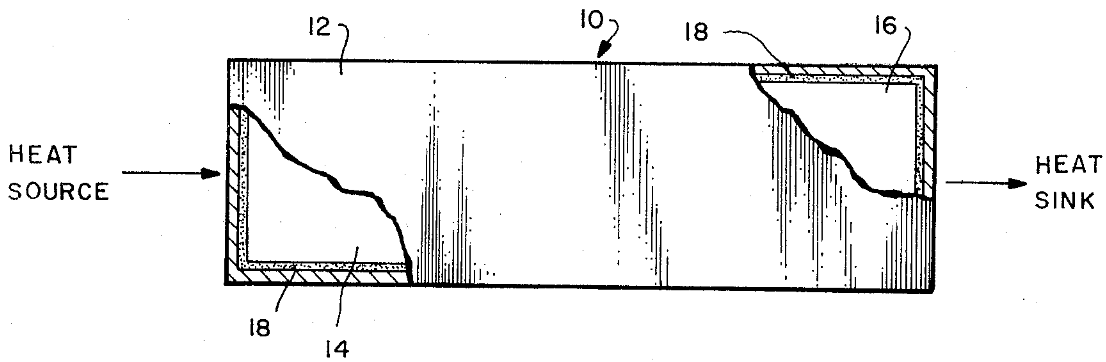


Fig. 1

Fig. 2

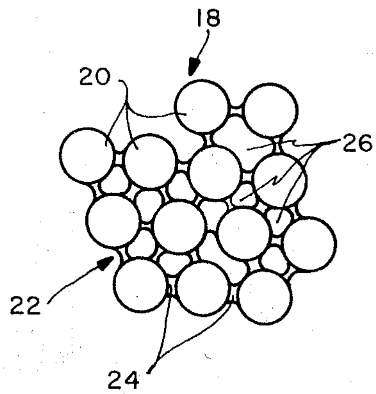
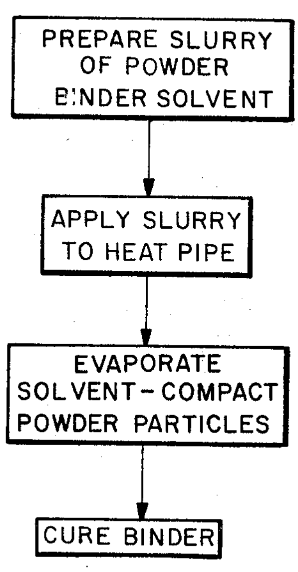


Fig. 3



METHOD OF FABRICATING A CAPILLARY HEAT PIPE WICK

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

This disclosure relates generally to the field of heat transfer and more particularly to a novel heat pipe and method of forming the capillary wick structure of the heat pipe.

2. Prior Art

Essentially, a heat pipe is a thermal transport device having a hermetic casing with evaporator and condenser sections and containing a working fluid and a capillary wick structure extending between the evaporator and condenser sections. When the evaporator and condenser sections are placed in heat transfer relation to a heat source and a heat sink, respectively, thermal energy is transmitted through the heat pipe from heat source to the heat sink by a closed thermodynamic cycle of the working fluid. This thermodynamic cycle involves vaporization of the working fluid witin the evaporator section by heat inflow from the heat source and condensation of the fluid within the condenser section by heat rejection to the heat sink.

Continuous operation of the heat pipe requires continuous flow of working fluid vapor from the evaporator section to the condenser section and continuous condensate flow from the condenser section to the evaporator section. The vapor pressure differential between the evaporator and condenser sections provides the force for transporting vapor continuously from the evaporator section to the condenser section. Capillary force is utilized to transport the working fluid condensate from the condenser section to the evaporator section.

To this end, a heat pipe is equipped with an internal capillary structure extending between the evaporator and condenser sections. Such capillary structures are commonly referred to as capillary wicks, or simply wicks, and are constructed of various porous materials. At the present time, the most widely used wick materials are woven quartz, wire mesh, and sintered metal powders and fibers. Listed below are prior art patents of interest in this connection:

1,938,170	3,111,396	3,413,239
2,996,389	3,285,873	3,485,296
3,090,094	3,288,615	3,563,309

At the present time, heat pipe wicks are generally fabricated externally of the heat pipes and then mounted or secured within the pipe casings in various ways, as by bonding, spot welding, brazing, or sintering or with the aid of suitable positioning means.

The existing wicks and mounting methods possess certain disadvantages which the present disclosure overcomes. Among the foremost of these disadvantages are the following. A bonding agent which is used to secure the wick to the heat pipe wall often infiltrates and plugs the capillary passages in the wick, thereby restricting capillary flow of condensate through the wick. It is difficult and often impossible to apply the existing wicks to heatpipes of complex surface geometry. Regulation of the wick porosity, i.e., capillary pore size, is difficult.

SUMMARY OF THE DISCLOSURE

According to one of its aspects, the disclosure provides a heat pipe with a novel capillary wick structure or wick applied to the wall of the heat pipe casing. The wick is composed of powder particles of relatively high thermal conductivity joined to one another and to the casing wall by a binder. The particles are highly compacted and define with the binder a myriad of capillary passages extending throughout and opening through the surfaces of the wick. A unique feature of the wick resides in the fact that the binder serves the dual function of joining the particles to one another and joining the wick to the wall of the heat pipe casing.

Another aspect of the disclosure is concerned with a unique method of fabricating the wick. According to this method, a slurry is prepared composed of an organic solvent containing an organic binder in solution and powder particles of relatively high thermal conductivity in suspension. A layer of this slurry is brushed, sprayed or otherwise applied to the inner wall surface of the heat pipe casing. This solvent in the layer is evaporated to recover the binder and utilize the surface tension forces of the binder to draw the particles together into a highly compacted condition wherin the particles and binder define a myriad of interconnecting capillary passages extending throughout and opening through the surface of the layer. The binder is then cured to form a dimensionally stable capillary wick structure.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 illustrates a heat pipe with a capillary wick according to the invention;

FIG. 2 is an enlargement of the capillary wick; and

FIG. 3 is a diagram of the present method of forming the capillary wick.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The heat pipe **10** shown in FIG. 1 has a hermetic casing **12** with evaporator and condenser sections **14** and **16.** Applied to the inner wall of the heatpipe casing is a capillary wick structure or wick **18** extending between the evaporator and condenser sections. A working fluid (not shown) is confined within the casing.

Turning to FIG. 2, the wick **18** is composed of powder particles **20** bonded to one another and to the inner wall surface of the heat pipe casing **12** by an organic binder **22,** which forms fine interconnecting bonds **24** between the particles. These particles and bonds define a myriad of interconnecting capillary passages **26** which extend throughout and open through the surfaces of the wick. A unique feature of the wick resides in the fact that the binder **22** provides both the bonds between the particles **20** and the bond between wick and the casing wall.

In operation of the heat pipe **10,** its evaporator and condenser sections **14, 16** are placed in heat transfer relation to a heat source and a heat sink, respectively. Heat inflow into the evaporator section **14** from the heat source vaporizes the working fluid within the section. The vapor pressure differential between the sections **14, 16** causes flow of the resulting fluid vapor to the condenser section where the vapor is condensed by heat rejection to the heat sink. The resulting condensate then returns to the evaporator section to repeat the process by capillary flow through the wick **18.** Thus, the working fluid transports thermal energy from the heat source to the heat sink by a closed thermodynamic cycle involving continuous evaporation of the fluid in the evaporator section and condensation of the fluid in the condenser section.

Reference is now made to FIG. 3 which is a diagram of the present method of forming or fabricating the capillary wick **18.** The initial step of the method involves preparation of a slurry composed of an organic solvent containing the powder particles **20** in suspension and the organic binder **22** in solution. A layer of this slurry is applied to the inner wall surface of the heat pipe casing **12** by brushing, spraying or any other convenient method of application. After application of the layer, the solvent in the layer is evaporated, leaving the powder particles **20** and the binder **22** in FIG. **2.** During this evaporation, the surface tension forces of the binder draw the particles together into the highly compacted state of FIG. **2** to form the capillary passages **26.** The binder is then cured to a dimensionally stable state to provide the final capillary wick **18.** The binder also bonds the wick to the wall of the heat pipe casing.

A variety of powder particles, binders, and solvents may be employed in the practice of the disclosure. The preferred powders are those of aluminum oxide, silicon carbide, aluminum, copper, magnesium, zinc, calcium, silver, gold, titanium, niobium, tungsten, zirconium, vanadiam, chromium, iron, and cobalt and alloys of the listed materials. The preferred binders are methacylates, polyesters, polyimides, phenolics, acrylics, collodion, and Duco cement. The preferred solvents are Toulene, methyl ethyl ketone, methyl benzye ketone, amyl acetate, acetone, and dimethyl formamide.

It will be understood that the powder particles, binder, and solvent used in the practice of the invention will be compatible with one another and with the working fluid and operating requirements and parameters of the heat pipe. That is to say, the solvent used must be appropriate for the powder but not dissolve, degrade, or otherwise adversely affects the binder. Also, the particles and binder must be chemically inert to the heat pipe working fluid, and must be immune to degradation and other adverse affects at temperatures at least up to the maximum operating temperature of the heat pipe. Moreover, in some applications, involving the cooling of electrical components, such as transistors, the particles and binder must produce a wick of high dielectric strength such that the wick will not short out the components when the latter are exposed directly to the heat pipe working fluid. Both thermosetting and thermoplastic binders may be used in the disclosure, the thermoplastic binders, of course, being restricted to heat pipes whose operating temperature is below the softening temperature of the binder. Curing of the thermosetting binders is accomplished by heating. Curing of thermoplastic binders is accomplished by drying and cooling, if necessary.

Wicks according to the disclosure have been successfully fabricated. These wicks were fabricated from powders of aluminum oxide, silicon carbide, aluminum, copper, and nickel using the following binder/solvent combinations: collodian/amyl acetate, Duco cement/acetone, polyimide/dimethyl formamide. In each case, the slurry prepared from the selected particles, binder, and solvent was applied to the heat pipe wall after which the solvetn was allowed to evaporate. The binder wws then cured by the application of heat. These wicks utilized a binder/solvent solution containing on the order of 10 percent binder and 90 percent solvent by volume and powder particles of a mesh size in the range of 50 – 200.

As noted earlier, an important advantage of the disclosure is its ability to provide a capillary wick conforming to virtually any heat pipe surface geometry from the most simple to the most complex. Moreover, the wick thickness may be easily controlled by controlling the thickness of the slurry layer which is initially applied to the heat pipe casing. The wick porosity may be regulated and controlled by varying the particle size and/or the concentration of solvent to binder used in the slurry.

What is claimed as new in support of Letters Patent is:

1. The method of forming a capillary wick for a heat pipe, comprising the steps of:

selecting powder particles of relatively high thermal conductivity and an organic binder both compatible with the working fluid and operating requirements of the heat pipe and an organic solvent for the binder;

preparing a slurry composed of said solvent containing said binder in solution and said particles in suspension;

applying to the inner wall surface of the heat pipe casing a layer of said slurry extending from the evaporator section to the condenser section of the casing;

vaporising the solvent from the layer to recover said binder and utilize the surface tension forces of the binder to draw said particles together into a highly compacted condition wherein the particles are bonded to one another and to the casing wall surface by the binder, and the particles and binder define a myriad of interconnecting capillary passages extending throughout and opening through the surface of said layer; and

curing said binder to form a dimensionally stable capillary structure providing said wick.

2. The method according to claim **1** wherein:

said powder particles are particles of a structural metal selected from the class consisting of aluminum oxide, silicon carbide, aluminum, copper, nickel, magnesium, zinc, calcium, silver, gold, titanium, niobium, tungsten, zirconium, vanadium, chromium, iron, and cobalt, or an alloy of the same;

said binder is selected from the class consisting of methacylates, polyester, polyimides, phenolics, and acrylics; and

said solvent is selected from the class consisting of toluene, methyl ethyl ketone, methyl benzyl ketone, amyl acetate, acetone, and dimethyl formamide.

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