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Droughton et al.

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[54] **METHOD FOR PRODUCING HEAT PIPES**

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

[51] **Int. Cl.** **B21d 53/02,** B23p 15/26

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

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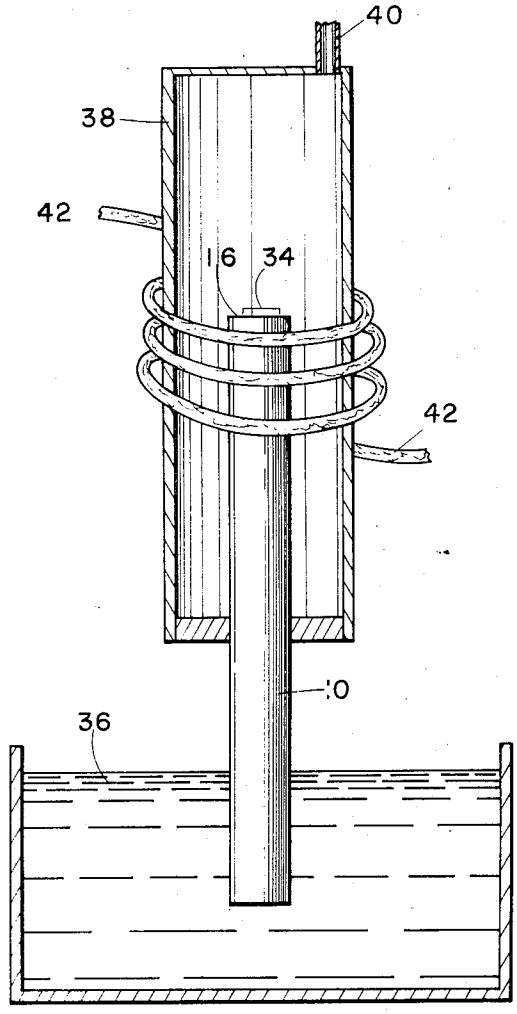
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Assistant Examiner—D. C. Reiley, III
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[57] **ABSTRACT**

A method for producing heat pipes comprising the steps of providing a heat pipe with one end closed in the ordinary fashion, inserting the closed end of the heat pipe into a solution whose temperature is maintained below the triple point of the working fluid of the heat pipe charging the heat pipe with the working fluid which freezes near the bottom of the heat pipe, capping the open end of the heat pipe with a plug having a through passage, placing solder braze or weld material on the plug, evacuating the heat pipe to a desired low pressure, and activating heating means such as an induction coil to cause the solder material to flow into the clearance between the heat pipe wall and the plug and to flow into the passage in the plug to seal the formerly open end of the heat pipe with a positive metal seal.

6 Claims, 3 Drawing Figures



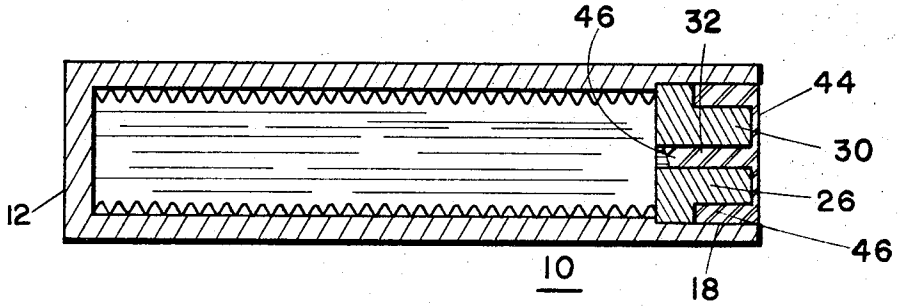


Fig. 1

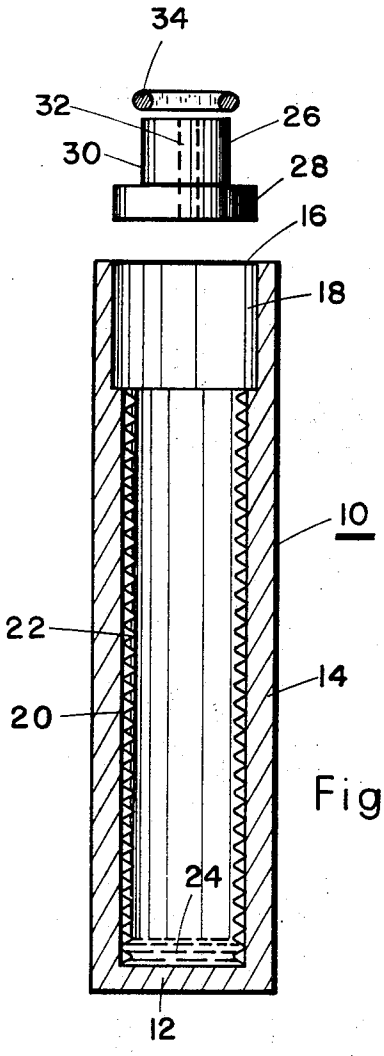


Fig. 2

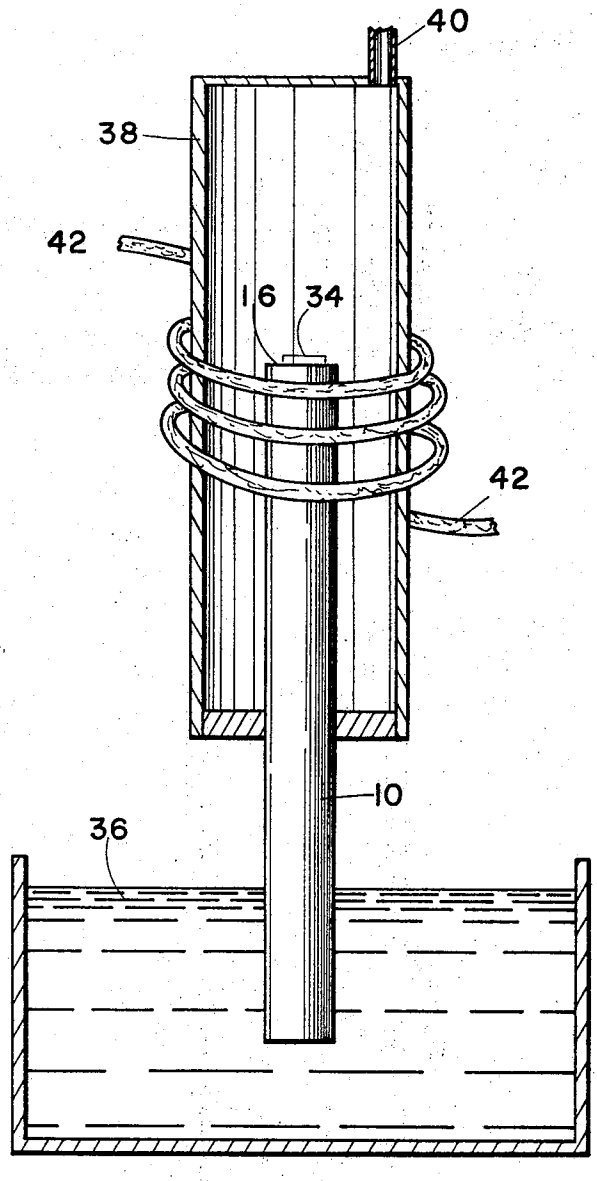


Fig. 3

METHOD FOR PRODUCING HEAT PIPES

BACKGROUND OF THE INVENTION

Heat pipes are well known in the art. Heat pipes normally consist of highly conductive evacuated metal tubes in which there has been placed a working fluid. The working fluid is in a liquid vapor equilibrium state with the liquid being contained in a wick and the vapor occupying the core of the heat pipe. If the heat pipe is brought in thermal contact with a source of heat energy, the liquid in the wick is vaporized and this vapor rapidly travels to the cooler sections of the pipe where it is condensed, giving up its heat. These heat pipes are used as temperature sensors, heat exchangers, heat sinks, etc. Because the working fluid is maintained in an equilibrium condition, the liquid is highly volatile, and thus the addition of heat causes the highly volatile liquid to vaporize, expanding to fill the tube and transmit the heat applied to one section of the pipe to the other cooler sections of the pipe.

In manufacturing heat pipes, it was difficult to heat-seal the open end thereof because the tube was under evacuated conditions prior to sealing, and any attempt to heat-seal would cause volitization of the working fluid and loss of the working fluid prior to complete sealing of the tube.

Accordingly, in the past, heat tubes were sealed by techniques which did not require the addition of heat, such as by crimping one end of the tube. Thus the heat pipes had a crimped end which was not sightly; was non-uniform and thus less adaptable to standard fittings; and a crimped seal was often not perfect creating a large number of rejects.

SUMMARY OF THE INVENTION

The present invention is directed to a method of producing heat pipes with a smooth capped end without loss of the working fluid during the sealing operation. The heat pipe is manufactured as follows:

A heat pipe is partially constructed by conventional method until it consists of a container with only one open end. The container may or may not contain a capillary wick structure.

The closed end of the heat pipe is then inserted into a solution whose temperature is maintained below the triple point of the heat pipe working fluid. The open end of the heat pipe is then capped with a plug having a through passage therein.

The heat pipe is then charged with the working fluid which freezes rapidly near the bottom of the heat pipe.

Solder, braze, or weld material is then placed on the plug and a completed assembly is inserted into a vacuum chamber which seals the sides of the tubes with the cap being brought into close proximity to induction coils.

While keeping the working fluid frozen, a vacuum pump is energized until the entire system, the chamber within which the heat tube is placed and the interior of the heat pipe, is evacuated to the desired pressure, usually, but not necessarily, below 100 microns.

When the desired vacuum has been obtained, the induction coils are activated causing the solder, braze, or weld material to flow into the capillary voids provided by the clearance between the heat pipe wall and the plug and into the through passage in the plug. This seals the formerly open end of the heat pipe with a positive metal seal. The induction coil is then deactivated and a completed heat pipe is removed from the cold solution and the vacuum chamber. It should be noted that the plug need not be made with a clearance since a solder seal can be obtained without clearance between the heat pipe wall and the plug. The through passage in the plug need not be a drilled hole. It can consist of any open passage in either the plug or the heat pipe wall or any combination of these which allows for the evacuation of the interior of the heat pipe and the flow of the solder, braze, or weld material to provide the solid metal seal.

The solid metal seal itself need not necessarily mean a completely homogeneous seal since small voids and impurities may be present without harmful effects to the finished product. The induction coils themselves can be located either outside or inside the vacuum chamber.

It should be noted that the resultant product is one which has a sealed end achieved without any pressure thereon. The end can thus avoid the problems of a crimped or pressure sealed end such as was present in the prior art devices. That is, a more positive seal is achieved with less chance of defects and, furher, the finished heat pipe can have any configuration and has not been deformed so that it may be used with standard fittings.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross sectional view of a heat pipe manufactured in accordance with the method of the present invention.

FIG. **2** is an exploded view of the heat pipe of the present invention at the first step in manufacture of the finished product of FIG. **1.**

FIG. **3** is a diagrammatic showing of one method of practicing the present invention.

In FIG. **2** there is shown a heat pipe assembly of the present invention before the cap or plug is inserted. The heat pipe assembly comprises a tube made of a heat conductive material such as copper generally designated by the numeral **10.** The tube **10** has a flat closed bottom end **12** and a tubular side wall **14.** At the upper open end **16** of the tube **10** there is provided an enlarged surface opening **18.** The remaining inner surface **20** of the tube **10** has a smaller diameter than the enlarged surface **18.** A suitable wick **22** extnds around the inner surface **20** of the tube **10.** The wick **22** forms a capillary section and could be, alternatively, axially extending grooves, a screen, fibers, or any other porous structure which will act as a capillary for the working fluid. In many applications the wick is not necessary. The working fluid **24** is placed at the bottom end of the tube **10.** The working fluid can be liquid metal such as sodium or lithium; oils; paraffin; wax, water, or any other working fluid which has the necessary properties for effective heat pipe operation.

A cap or plug **26** is provided having an enlarged bottom portion **28** and a smaller diameter top portion **30.** The diameter of the enlarged bottom portion **28** is substantially equal to the diameter of the top inner surface **18** of the tube **10** so that the cap **28** will fit snugly into the top end of the tube **10.** The cap **26** has an axially extending through passage **32** extending therethrough. A suitable solder ring **34** is placed on the top of the upper portion **30** of the cap **26.** The solder ring **34** can be any fusable metal or brazing compound which will flow upon the application of heat thereto. The ring-

shape is utilized so as to provide clearance for the axial passage **32.** The inner diameter of the ring **34** is less than the diameter of the upper portion **30** so that it may rest thereon so that solder can flow into the passageway **32** when the solder ring **34** is heated.

First, the plug **28** with the solder ring **34** thereon is placed into the opening **18** at the end of the tube **10.** The surface **18** has an axial length equal to the height of the plug **26** so as to provide a smooth end cap surface in the finished product. The tube **10** with the cap and solder ring in place, is then positioned, with its lowermost end **12** dipped into a suitable cold solution **36.** The working fluid is then injected into the heat pipe assembly and freezes at the bottom of the heat pipe assembly. The portion of the tube **10** above the cold fluid **36** is placed within a vacuum chamber **38** which is connected up, through a conduit **40,** to a vacuum pump or other means of evacuating chamber **38.** A suitable induction coil **42** is placed around the vacuum chamber **38** adjacent the solder ring **34** on top of the cap **26.**

Initially, the tube **10** is placed into the cold solution **36** prior to the evacuation of the vacuum chamber **38.** The cold solution **36** brings the working fluid below its triple point, i.e., freezing point of the working fluid at low pressure. This causes the solidification of the working fluid. Then, the vacuum chamber **38** is exhausted and the pressure within the tube **10** is also reduced to the pressure in the vacuum chamber **38** by reason of the through passage **32** and the plug **26.**

This allows all of the gases within the plug **10** to be evacuated. However, since the working fluid **24** is below its triple point, there should be little or no loss of working fluid. After evacuation of the tube **10,** the induction coil **42** is energized, causing the solder ring **34** to be heated. The solder then flows, around the clearance between upper portion **30** and inner surface **18** of the tube and, further, the solder flows axially into through passage **32** closing the same. Then, when the induction coil is removed, the seal is formed between the plug **26** and the surface **18.** Further, the plug **26** has its through passage **32** sealed by reason of the flow of the solder therein. This results in the finished product shown in FIG. **1.** That is, the finished heat tube shown in FIG. **1** has a closed flat surface end **44** formed by the flat end of reduced diameter portion **30** and the solder **46** which has flowed into the clearance between the reduced diameter portion **30** and the inner surface **18** and the tube **10.** Additionally, the passageway **32** of the plug **26** has been sealed by the solder **46** flowing therein. This gives a flat surface in the end of the heat pipe **10.** If desired, this flat surface can be sanded, grinded, or otherwise polished to provide a smooth end surface.

It should be noted that the heat pipe **10,** in its finished product, has identical end walls, with the wall **44** being, in outer appearance, similar to the end wall **12.** This has been achieved without loss of the working fluid during the manufacturing process.

Although this invention has been described with respect to its preferred embodiments, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of the invention be limited, not by the specific disclosure herein, only by the appended claims.

What is claimed is:

1. A method of manufacture comprising the steps of:

a. providing a heat conductive hollow member have an open end;

b. placing a working fluid in said hollow member;

c. placing a plug in said open end with a passageway being formed to provide communication between the inside and outside of said hollow member;

d. freezing the portion of the hollow member supporting the working fluid to a temperature below the triple point of the working fluid;

e. thereafter evacuating the hollow member through said passageway; and

f. subsequently heat sealing the plug to the open end of the hollow member while closing said passageway.

2. The method of manufacture of claim **1** wherein said step of providing the heat conductive hollow member having an open end includes providing a heat conductive hollow member having a capillary section along the inner surface thereof.

3. The method of manufacture of claim **2** wherein said step of placing a plug in said open end includes placing a plug having an axial passageway therethrough.

4. The method of manufacture of claim **1** wherein said step of heat sealing the plug to the open end of the hollow member includes placing a fusable metal on said plug and thence heating the same to allow said fusable metal to flow into said passageway and to seal said plug to the open end of the hollow member.

5. The method manufacture of claim **4** wherein said step of placing a plug in said open end of the hollow member includes providing a plug which forms a clearance space between the plug and the hollow member, said step of heat sealing the plug includes heating the fusable metal to fill in the clearance space between the plug and the open end of the hollow member.

6. The method of manufacture of claim **5** wherein said heat sealing step includes inductively heating the fusable metal after evacuating the chamber.

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