United States Patent

[11] **3,604,503**

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[54] **HEAT PIPES**
1 Claim, 5 Drawing Figs.

[52] **U.S. Cl.** **165/96,** 62/514, 165/32, 165/105
[51] **Int. Cl.** **F28f 27/00,** F28d 15/00
[50] **Field of Search** 165/105, 32, 96; 62/514

[56] **References Cited**

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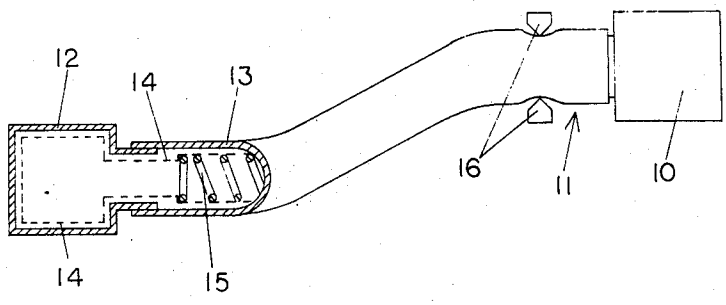
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ABSTRACT: An improved heat pipe having an evaporator and a condenser connected together by a flexible heat transfer tube lined with a wick, with a clamping means connected to the outer circumference of the flexible heat transfer pipe for reducing the circumference thereof to thereby restrict the transfer of vaporized heat transfer fluid from the evaporator to the condenser.



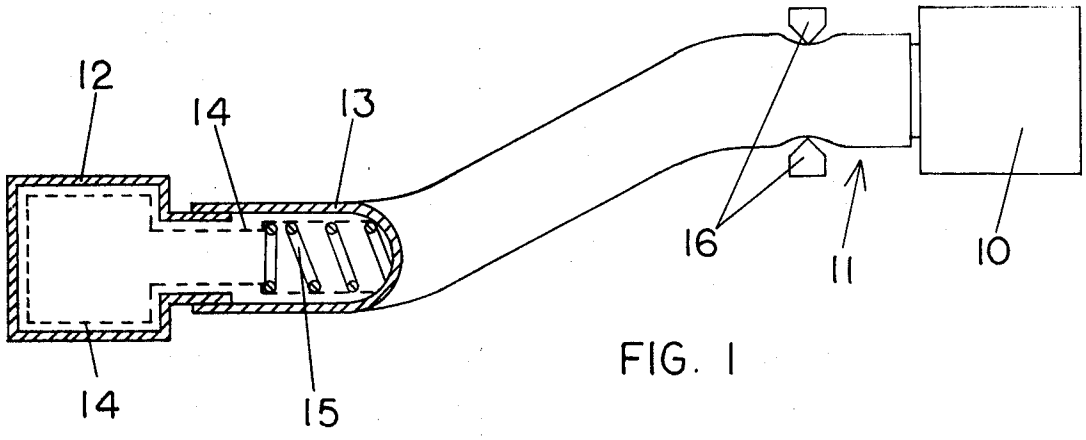


FIG. 1

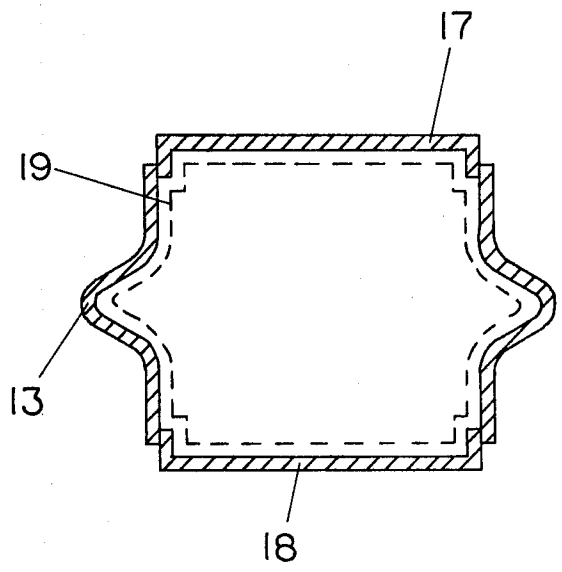


FIG. 2

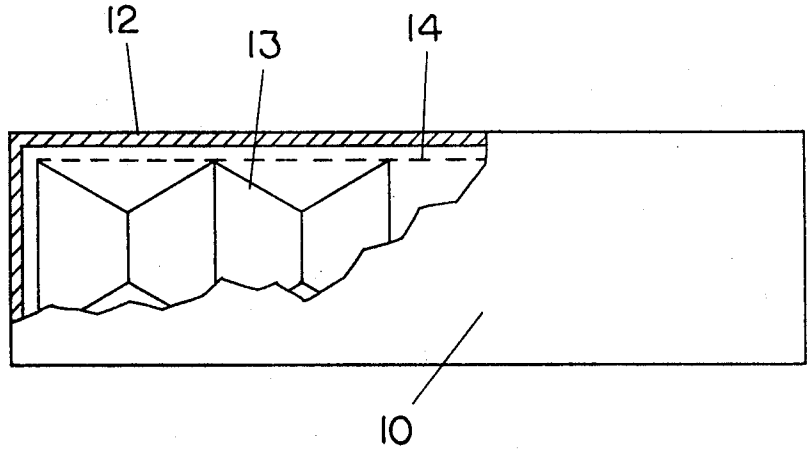


FIG. 3

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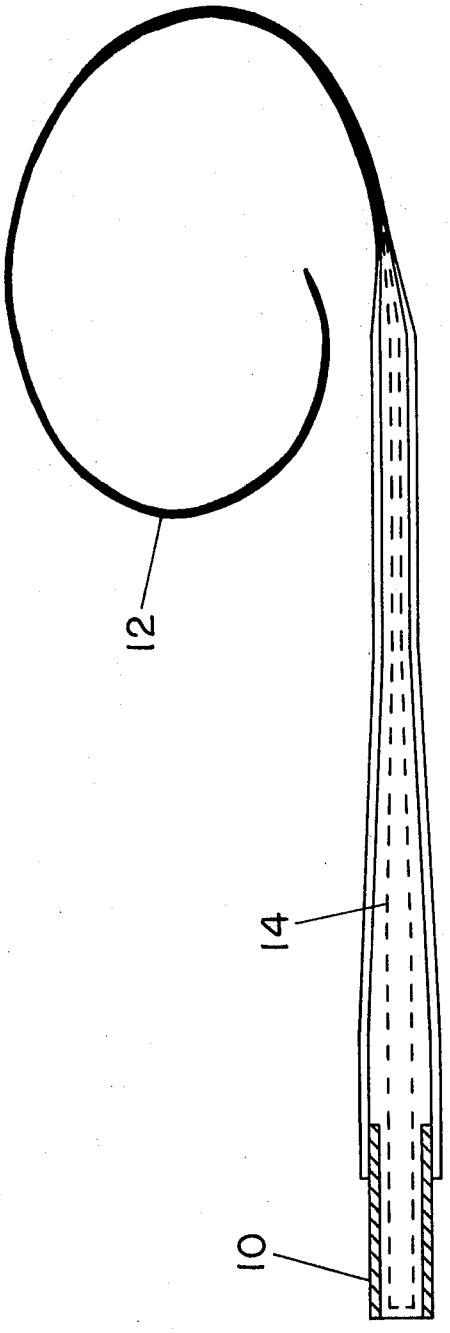


FIG. 4

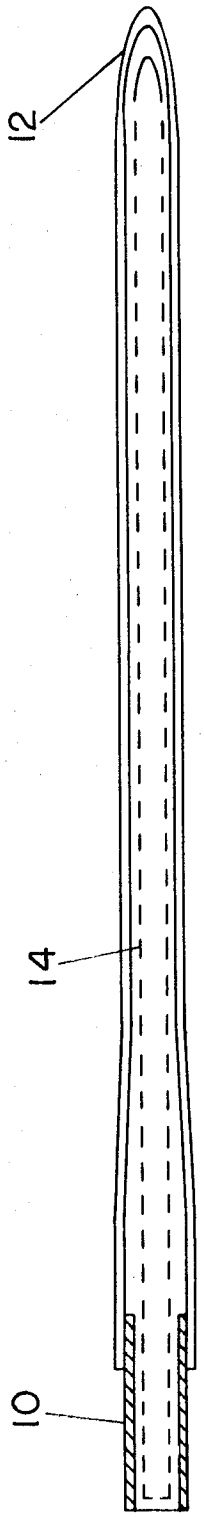


FIG. 5

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HEAT PIPES

This invention relates to improvements in heat pipes. In particular, it relates to new and novel means for transferring vaporized heat exchange fluid from a heat input source or evaporator to a heat sink or condenser and returning the condensed fluid to the evaporator. The invention relates in general to an improved, flexible conveying means between the evaporator and the condenser for the transfer of the heat exchange fluid between the evaporator and the condenser.

Heat pipes are well known in the art. The patent to Grover, U.S. Pat. No. 3,299,759, in particular, discloses the concept of the use of a heat pipe for a transfer of heat from one point to another.

Experience has shown that existing heat pipes are not suitable in applications where heat must be transferred along nonlinear paths or where either the evaporator or the condenser is subjected to vibration, or where it is necessary to electrically insulate the evaporator from the condenser, while providing high, thermal conductivity input and output areas.

Moreover, it has been found that chemical reaction with the working fluid and leakage in the transfer tube interferes with the operation of the heat pipe. This interference becomes particularly significant in small heat pipes with a small amount of working fluid. Thus, it is desirable to provide a transfer tube of material that is chemically inert and of a low porosity. One such material is "Teflon TF RESIN."

In addition, a definite need has arisen in the art for an improved heat pipe capable of providing temperature control and power flattening.

When used in this application, the term "thermal power flattening" refers to the ability to maintain constant output heat flux or heat transfer rate per unit area for large variations in the rate of heat input. Temperature control refers to the ability to maintain nearly constant temperature for large variations in heat transfer rate through the heat pipe.

It is therefore an object of this invention to provide an improved heat pipe having a flexible fluid transfer tube between the evaporator and condenser which tube is chemically inert to the working fluid and of a low porosity.

Another object of this invention is to provide an improved heat pipe having a flexible fluid transfer tube between the evaporator and the condenser which electrically insulates the evaporator from the condenser and provides a high thermal conductance path between the two.

It is another object of the present invention to provide an improved heat pipe which is adapted for use in applications requiring relative motion between the evaporator and the condenser sections, and for use in applications wherein a limited amount of space is available for installation.

It is a further object of this invention to provide a heat pipe which can conduit the working fluid along a nonlinear path between evaporator and condenser.

It is the further object of this invention to provide an improved heat pipe with a flexible transfer tube between evaporator and condenser which can generate a mechanical force which is a function of the heat absorbed by the evaporator for use in applications such as temperature control and thermal power flattening.

It is a further object of this invention to provide a heat pipe which can produce a constant output heat flux for a wide range of heat input fluxes.

The objects of this invention are achieved by interposing between the evaporator and condenser sections of the heat pipe a flexible fluid transfer tube having a low porosity and being chemically inert to the working fluid so that the fluid is transferred in its vapor state from the evaporator to the condenser and returned in liquid state with a minimum of interference during the passage. The transfer tube is made of a material having a high electrical resistance and a low thermal conductance to electrically insulate the evaporator from the condenser and allow a minimum of heat loss through the walls of the transfer tube. The fluid transfer tube is flexible, allowing for relative movement between the evaporator and the condenser either laterally or axially.

Other objects and advantages of this invention will be better understood by reference to the drawings and their accompanying specification wherein:

FIG. 1 is a partial cutaway view of one embodiment of the invention.

FIG. 2 is a cutaway view of a second embodiment of the invention used as a thermal force transducer, as well as providing flexible heat transport, temperature control, and thermal power flattening.

FIG. 3 is a partial cutaway view of a third embodiment of the invention used for temperature control and for thermal power flattening.

FIGS. 4 and 5 are cross section views of a fourth embodiment of the invention used in applications where limited space is available.

Referring now to FIG. 1, it will be seen that the improved heat pipe which comprises this invention consists of a sealed reservoir or evaporator **10** of high thermal conductivity, a flexible fluid transfer tube **11** and a heat output reservoir or condenser **12**. Evaporator **10** and condenser **12** are well known in the art and their manner and type of construction is also well known. For efficient operation of the heat pipe, the evaporator and the condenser must be made of a material of high thermal conductivity for rapid heat exchange. Flexible fluid transfer tube **11** consists of a flexible pipe **13** which is lined internally with a flexible wick **14** held in place by a spring or other retaining means **15**. Flexible wick **14** extends continuously from evaporator **10** through flexible fluid transfer tube **11** into condenser **12**. A suitable working fluid is provided in the device in a manner well known in the art. Thus, when heat is applied to evaporator **10**, the fluid in wick **14** is evaporated to a vapor state and travels through flexible fluid transfer tube **11** into condenser **12**. The relatively lower temperature of the condenser causes condensation of the vapor to the liquid state and the resultant removal of heat. The liquid is absorbed into wick **14** and transferred back to evaporator **10** by capillary action in the manner well known in the art. The overall heat transfer process approaches constant temperature as a limiting case.

It is a well-known principal of thermodynamics that a constriction in a vapor flow passage will cause what is known as a "throttling" effect. This effect is manifest by a drop in temperature in the direction of the vapor flow and is accomplished by use of a valve or orifice in the vapor flow passage. In order to achieve this effect and enhance the condensation of the vapor as it passes though flexible fluid transfer tube **11**, a clamp or other squeezing device **16** is provided on the tube. By controlling the internal diameter of fluid transfer tube **11**, the total amount of heat flow through and the temperature drop of the vapor as it passes through the tube can be controlled.

Spring support **15** retains wick **14** against the inner wall of flexible pipe **13** and thus provides support for the pipe while at the same time not interfering with its flexibility.

Flexible pipe **13** is made of a material having both low thermal conductivity and high electrical resistance. Thus, in addition to its normal features, the heat pipe has low thermal loss and low electrical conductance between evaporator **10** and condenser **12**. In addition, flexible pipe **13** is made of a material having a low porosity and being chemically inert to the working fluid. "TEFLON" is one such material.

The particular embodiment of the invention shown in FIG. 1 is adaptable for uses wherein relative movement between the evaporator **10** and condenser **12** is necessary or desirable. Moreover, the flexible tube having a high thermal resistance allows for maximum heat transfer between evaporator **10** and condenser **12** over nonlinear paths or in other applications where it is necessary or desirable that the evaporator be displaced from the condenser.

In the modifications shown in FIG. 2, flexible pipe 13 is initially compressed or "accordian" shaped. A wick 19 lines the inner walls of the entire heat pipe to provide the liquid-vapor heat transfer process as has been previously described. The flexible pipe 13 is initially compressed as shown when no heat transfer is taking place. Condensation and vaporization of the heat transfer fluid within wick 19 causes expansion and contraction of the flexible pipe 13 in a "bellows" effect and thus provides a relative movement and force between the evaporator 17 and condenser 18 which is a function of the amount of heat input to the heat pipe. The modification shown in FIG. 2 also exhibits the characteristics of the heat pipe shown in FIG. 1.

This particular modification has many uses in the field of temperature and pressure control. The efficient transfer of heat between evaporator 17 and condenser 18 renders the device extremely accurate for use in such control systems as that of a space satellite. In the particular modification shown in FIG. 2, the flexible tube or bellows 13 is initially collapsed as shown and as heat input is increased, it expands as a function of the increase in temperature, thus acting as a force generating thermometer.

At FIG. 3, a third modification of the invention is shown wherein flexible member 13 is in the form of an internal bellows and the heat pipe itself is a sealed tube having an evaporator 10 and walls 12 which provide the condenser or heat rejection function. Wick 14 lines the interior walls of the pipe and provides the liquid-vapor heat transfer as previously described. As heat is put into the evaporator 10, it causes expansion of vapor from wick 14 increasing the vapor pressure which in turn causes movement of flexible pipe 13 as a function of the temperature and the amount of heat supplied. The movement of flexible pipe 13 changes the surface area of condenser 12 which is exposed to the vapor. The variation in the condenser area results in a constant amount of heat being rejected to the sink to thus provides thermal power flattening and temperature control.

Another modification of the invention for accomplishing thermal power flattening and temperature control is shown in FIGS. 4 and 5. This particular modification is useful in many applications where a limited amount of space is available for housing the heat pipe when in an inoperative position as shown in FIG. 4. The evaporator 10 is placed at the heat source while the condenser 12 is initially formed in coil to minimize the space it occupies. The expansion of the vaporized heat transfer fluid into condenser 12 causes condenser 12 to uncoil, thus exposing a greater surface area to the air or other cooling medium so that is as heat is added to evaporator 10, a greater transfer occurs due to the larger surface area exposed to the cooling medium. The condensed heat transfer fluid is returned to evaporator 10 by the capillary action of wick 14. Thermal power flattening and temperature control are thus achieved.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A heat pipe having an evaporator, a condenser, a heat exchange fluid and a transfer means for transferring the heat exchange fluid between the evaporator and the condenser, wherein the improvement comprises:

said transfer means consists of a flexible pipe connecting the evaporator to the condenser and a flexible wick lining the inside wall of said flexible pipe and extending into said evaporator and said flexible pipe and extending into said evaporator and said condenser respectively, whereby said evaporator and said condenser may move relative to each other, and a heat exchange fluid is transferred between the evaporator and the condenser,

clamp means operably connected to the outer circumference of said flexible pipe for reducing the circumference thereof to thereby restrict the transfer of vaporized heat transfer fluid from the evaporator to the condenser.