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HEAT PIPE WITH CONTROL

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Fig. 1.

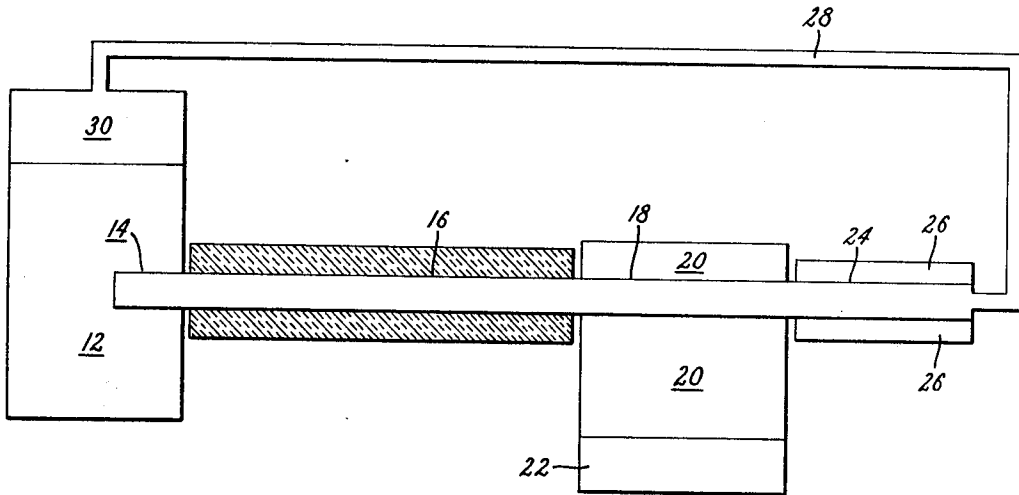
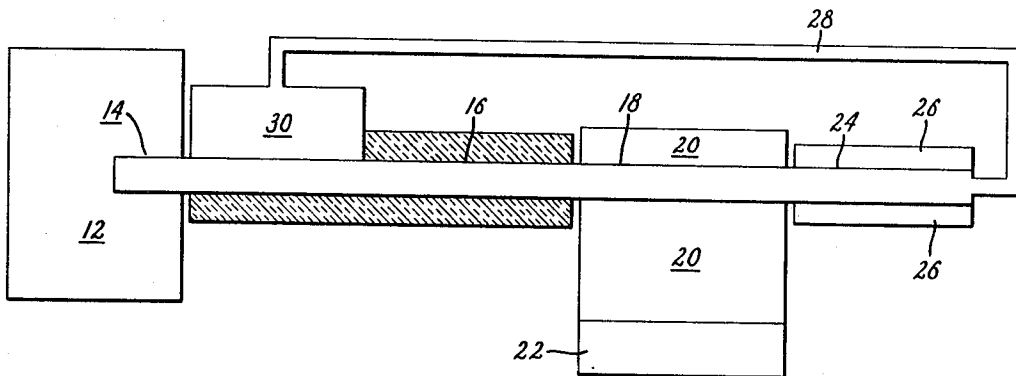


Fig. 2.



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HEAT PIPE WITH CONTROL

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1 Claim

ABSTRACT OF THE DISCLOSURE

Heat is conveyed from a nominally constant-output heat source to a heat utilization device by a heat pipe employing a transfer medium whose vapor pressure varies rapidly with temperature change. In order to maintain the operating temperature approximately constant with changes in consumption by the utilization device (or in the event of variation in the supposedly constant source output) an inert gas reservoir is connected to the end of the heat pipe remote from the source. The reservoir temperature is maintained approximately constant in order to keep the pressure of the inert gas approximately constant by placing it in close thermal communication with the heat pipe whose temperature it tends to regulate.

REFERENCES

"Structures of Very High Thermal Conductance," G. M. Grover, T. P. Cotter, G. F. Erickson, *Journal of Applied Physics*, vol. 35, No. 6, June 1964, pp. 1990-1991, "The Heat Pipe," K. Thomas Feldman, Jr., Glen H. Whiting, *Mechanical Engineering*, February 1967, pp. 30-33.

SPECIFICATION

This invention pertains to devices for the transfer of heat by the flow of a vaporized condensable fluid.

Certain heat sources, such as isotope heat generators, produce an output of heat power which varies very slowly with time as compared with variations in power requirements, is not adjusted to match current requirements but is left effectively free-running, and consequently is most conveniently utilized by a suitable thermal conductor capable of removing the heat so produced at a temperature convenient for utilization and compatible with maintaining the physical integrity of the source. A known device suitable for this purpose is the heat pipe, which is described in the cited references (which are included herein by reference), and consists usually of a closed structure containing a heat transfer material which is capable of existence as a liquid at the desired temperature, and has at that temperature a vapor pressure which is substantial but low enough to be withstood by the container. The liquid is vaporized at the heat source and the resultant vapor flows by its own pressure to the cooler portions of the structure, where it is condensed, yielding its latent heat. This procedure would ordinarily simply result in transfer of all the liquid from the hot to the cooler portions of the structure, and the process would stop. However, the walls of the structure are covered with a porous wick structure which is wet by the condensed vapor, now liquid, and conveys the liquid back to the hot region, thus establishing a continuous circulation. This process is most simply practiced in the absence of any gas other than the vapor of the liquid. However, in order to operate at moderate pressures and desirably high temperatures, it is often necessary to employ liquids which it is difficult to produce and maintain free of other gases. For example, a common heat pipe is one in which the structure is a tube of stainless steel lined with a wick of stainless steel mesh and the fluid is molten sodium metal. Sodium readily forms hydrides, so that to obtain sodium vapor free of traces of hydrogen is very

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difficult. However, a moderate amount of foreign non-reactive gas is not very harmful, since the continued flow of sodium vapor from the hot to the cool region tends to drive the foreign gas to the end of the pipe away from the heat source. Its pressure is, of course, that of the vapor.

It is apparent that the operating temperature of the heat pipe will be whatever is required to produce a sufficient flow of vapor to transmit the heat being passed through the pipe. If a constant heat input is provided, and the thermal impedance to removal of that amount of heat from the cool part of the pipe is increased, the operating temperature of the pipe will increase until the temperature at the cool part is sufficient to cause flow of the constant amount of heat through the increased impedance. This may be undesirable. It has been taught in the prior art to restrict such temperature increase by limiting the increase in vapor pressure in the heat pipe by providing a reservoir of foreign gas connected to an addendum to the cool end of the pipe. Under normal operating conditions, the addendum is occupied chiefly by the foreign gas, and remains comparatively cool. If, however, the removal of heat at the cool end of the pipe becomes insufficient at the normal operating temperature to remove all the heat being put in at the hot end, the foreign gas is compressed only slightly (because of the comparatively large volume of the reservoir) and the vapor begins to condense in the addendum, from which the excess heat may flow into the surrounding without a marked increase in the pressure and temperature of the vapor. This device, while commendable, has the defect that the pressure in the gas reservoir is markedly a function of temperature, and may vary widely with the ambient temperature. My invention comprises placing the gas reservoir in good thermal contact with the most nearly constant temperature part of the system.

This has two advantages, when applied to a nominally constant output heat source. So long as the discarding of heat from the addendum of the heat pipe at the desired operating temperature is sufficient to maintain the source at the desired operating temperature, the gas pressure in the reservoir will remain approximately constant. If, however, use of the full area of the addendum is insufficient (with the removal at the regular cool part) to discard all the heat being produced, so that the temperature of the source begins to rise, the pressure in the gas reservoir will rise also, permitting the heat pipe to operate at a somewhat higher temperature and so to increase the heat flow at the normal cool part and also at the addendum. This may be achieved by placing the foreign gas reservoir either directly in good thermal contact with the heat source itself (which may be inconvenient from a design standpoint) or, which analysis shows to be slightly superior, in good direct thermal contact with the portion of the heat pipe immediately adjacent to the heat source, and thus still, albeit indirectly, in good thermal contact with the heat source.

Thus I achieve the desirable result of stabilizing the operating temperature of the heat pipe system for normal variations in operating conditions and at the same time of making the system somewhat self-stabilizing under abnormal conditions outside of the normal range of variations.

For the better explanation and understanding of my invention, I have provided figures of drawing in which

FIG. 1 represents schematically a system according to my invention in which the foreign gas reservoir is located in thermal contact with the heat source itself, and

FIG. 2 represents schematically a system according to my invention in which the foreign gas reservoir is located in thermal contact with a part of the heat pipe immediately adjacent to the heat source.

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Referring to FIG. 1, there is represented a heat source 12 from which there extends a heat pipe 14, which has an insulated portion 16 extending immediately from heat source 12 to a condensing section 18 which is in contact with a utilization device 20, which accepts heat from part 18 and rejects it, at a lower temperature, to a radiator 22. Beyond condensing section 18 lies addendum 24 of the heat pipe which is provided with a radiator 26; and the end of addendum 24 is connected by a tube 28 to foreign gas reservoir 30, which is represented in good thermal contact with heat source 12.

FIG. 2 is identical with FIG. 1, except that foreign gas reservoir 30 is represented as being in good thermal contact with insulated portion 16 of heat pipe 14, and thus also in good thermal contact with heat source 12.

In a particular embodiment of my invention, preferable for many purposes, the heat pipe is a tube of 0.65 inch inside diameter and wall thickness of .0465 inch, charged with 60 grams of metallic sodium lined with wicking of stainless steel. The foreign gas may be argon at a pressure of 51.6 torr, the volume of the foreign gas reservoir being approximately 30 cu. in. This is for operation at a nominal temperature of 650 degrees C.

The heat source 12 may be an isotope heat source; and the utilization device 20 may be a thermoelectric pile or any other suitable heat converter.

In normal operation, utilization device 20 absorbs heat from part 18 of the heat pipe 14, converts it to electrical energy, and rejects the heat at reduced temperature through radiator 22. Any excess of heat is dissipated along a part of addendum 24 and thence by radiator 26, the remainder of addendum 24 being filled with gas from reservoir 30 at a pressure determined by the temperature of that reservoir, which will be determined by the temperature of the heat source 12 for the embodiment of FIG. 1, or by the nearly identical temperature of insulated portion 16 of heat pipe 14.

If abnormal conditions should cause the vapor to fill the entire addendum 24 without dissipating all the output of source 12 at the desired temperature, the temperature of heat source 12 will rise and increase the temperature of foreign gas reservoir 30, either by direct contact or through section 16 of pipe 14, and the vapor pressure and the temperature in heat pipe 14 will increase, increasing the dissipation of heat at least at addendum 24, tending to stabilize the system even under the abnormal condition.

The mass of inert gas required is determined by the usual gas law $PV=MRT$, where P is the vapor pressure of the working substance at the desired operating temperature T, V is the volume of the system less the volume normally occupied by the vaporized working substance, M is the mass of gas required, R is the usual gas constant.

While the lack of simple analytic expressions for various thermal functions renders a simple general quantitative analysis of the operation of my invention difficult, it is possible to give a simple formula for determining the volume of reservoir required to provide a given temperature variation for a given change in operating conditions. It should be observed that, while the gas in the reservoir is maintained at substantially the heat pipe operating temperature, the gas in the pipe itself, since it serves to push back the vapors which convey heat, will be at a somewhat lower temperature. It is usually a sufficiently good approximation to determine for one set of operating conditions the ratio of the absolute temperature of the gas in the pipe to the absolute temperature of the gas in the reservoir, and to assume that this ratio K

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remains constant as the temperature of the gas in the reservoir varies. From the known heat transfer characteristics of the heat pipe, it is possible to determine the volume of the pipe which must be occupied by the inert gas under the two different operating conditions. The reservoir temperature and pressure will necessarily be the same as those of the vaporizable working substance, and will thus be determinable from the vapor-pressure-temperature curve for the working substance. The volume of the reservoir required to provide the given operating temperatures will be:

Volume of reservoir

$$= \frac{\frac{P(II) \text{ vol. pipe (II)}}{K \text{ temp. res. (II)}} - \frac{P(I) \text{ vol. pipe (I)}}{K \text{ temp. res. (I)}}}{\frac{P(I)}{\text{Temp. res. (I)}} - \frac{P(II)}{\text{Temp. res. (II)}}}$$

where the abbreviations have the following meanings:

P(I) and P(II) are, respectively, pressure at first and second sets of conditions

Vol. pipe (I) and vol. pipe (II) are the volume of inert gas in the heat pipe under each of the indicated sets of operating conditions (I) or (II)

Temp. res. (I) and temp. res. (II) are the absolute temperature of the reservoir under each of the indicated sets of operating conditions (I) or (II).

K has been defined in the preceding.

All pressures must be in the same units; all temperatures must be in the same units; all volumes must be in the same units; but it will be observed that the dimensions of the right-hand side of the equation are of the form

Pressure x Volume/Temperature - Pressure/Temperature

so that the pressure and temperature units cancel out. Thus there is no need for consistency among the different kinds of units; pressure in pounds per square inch, temperature in absolute Reaumur, and volumes in cubic millimeters will still yield the required volume in cubic millimeters.

What is claimed is:

1. In a heat pipe system comprising:

a heat source;

a heat pipe in thermal contact with the heat source, comprising:

a condensing section in thermal contact with a utilization device

an addendum for dissipating heat not absorbed by the said utilization device;

a reservoir of foreign gas connected to the terminal end of the said addendum;

the improvement wherein said reservoir of foreign gas is in good thermal contact with the said heat source.

References Cited

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MEYER PERLIN, Primary Examiner

A. W. DAVIS, Assistant Examiner

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