

[54] **RADIOISOTOPE FUELED HEAT TRANSFER SYSTEM**[75] Inventors: **Frederick J. Sparber, Belen; Glen H. Whiting, Albuquerque, both of N. Mex.**[73] Assignee: **The United States of America as represented by the United States Atomic Energy Commission, Washington, D.C.**[22] Filed: **June 5, 1968**[21] Appl. No.: **735,957**[52] U.S. Cl. **176/39, 60/203, 136/202, 165/105**[51] Int. Cl. **F28d 15/00, G21d 9/00**[58] Field of Search **176/39; 165/105; 60/203; 310/4; 136/202**[56] **References Cited****UNITED STATES PATENTS**

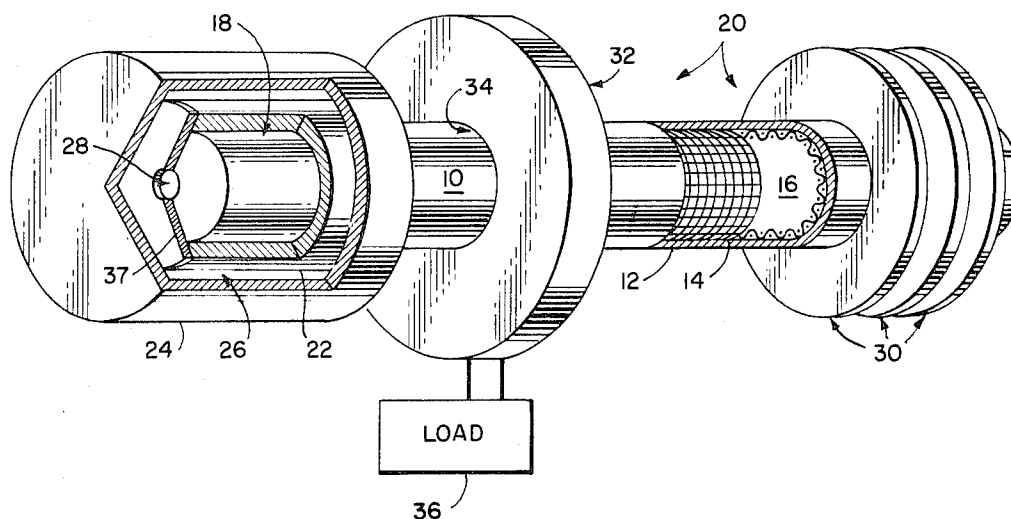
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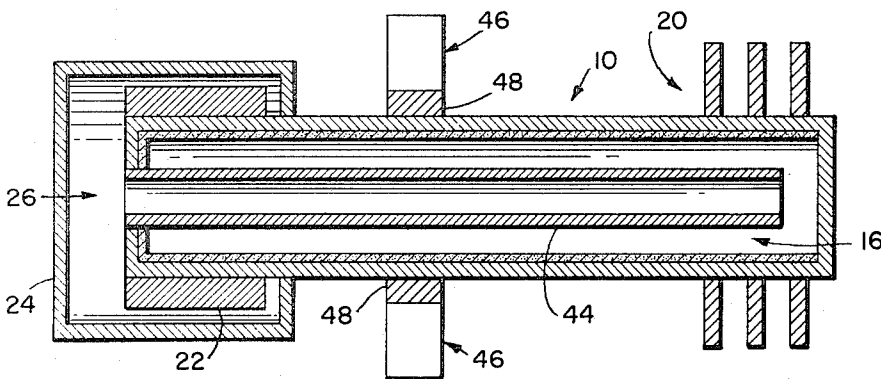
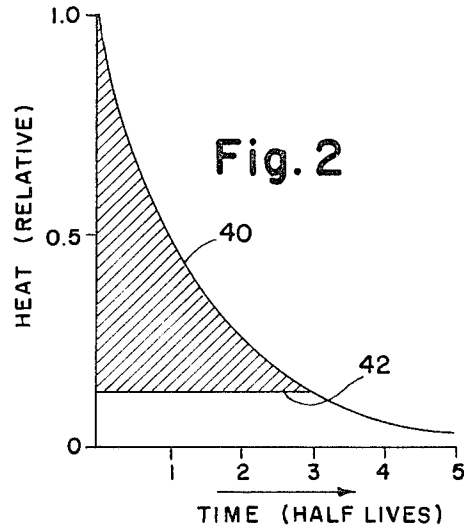
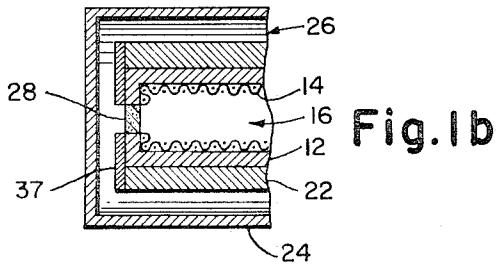
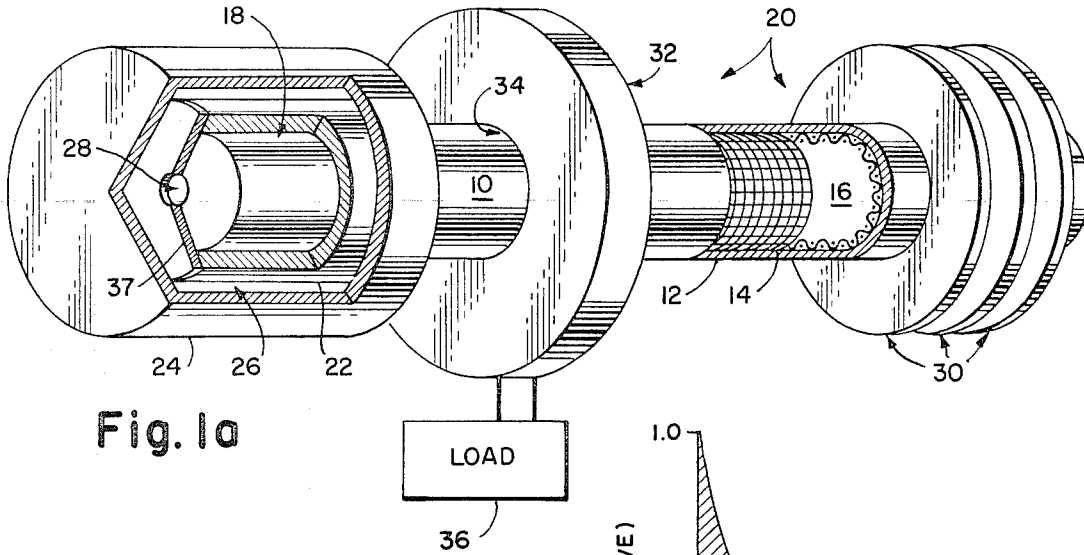
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[57] **ABSTRACT**

A heat transfer system for supplying a constant temperature to a heat utilization device including a heat transfer pipe having the utilization device mounted intermediate an alpha emitting radioisotope fuel for vaporizing the working fluid of the heat pipe and a heat exchanger for dissipating excess heat from the condenser portion of the heat pipe, means for retaining helium generated by the radioisotope fuel and a passageway for transporting the helium to the interior of the heat pipe to maintain constant the internal pressure and vaporization temperature of the working fluid within the heat pipe as the rate of heat dissipation from the radioisotope decreases.

10 Claims, 4 Drawing Figures



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RADIOISOTOPE FUELED HEAT TRANSFER SYSTEM

BACKGROUND OF THE INVENTION

There are many applications in the laboratory, space systems, the military and industry for heat sources or heat transfer systems which may efficiently and reliably provide or dissipate a constant quantity of thermal energy over long periods of time. Such applications include precision measurement of thermal characteristics of materials and devices, controlled cooling of various powered devices such as electric motors or electron tubes and the energizing of thermal conversion devices such as thermoelectric or thermionic electrical generators. Heat pipes, that is a heat transfer device which utilizes the evaporation, condensation, and surface tension characteristics of a working fluid within a closed container lined with a suitable porous wick, have been effectively used with conventional heat sources in these various applications. By selection of the proper working fluid and container materials and using a constant temperature heat source, heat pipes may be designed to operate at constant temperatures from the cryogenic region up to 2,200°C, limited in the high temperature region by materials technology. Conventional heat sources such as gas burners and induction or resistance furnaces may provide the desired constant temperature and constant heat inputs to the evaporator section of the heat pipe. However, such heat sources require bulky or relatively heavy supplies of energy or fuel if an extended period of operation is desired.

Where a relatively long life heat source is desired and where a premium is placed on size and weight such as in space applications or remote and inaccessible areas, it has been proposed that the relatively light weight and compact radioisotope type heat source be used to power a heat pipe. Radioisotope heat sources have a number of inherent drawbacks or limitations for applications of this type. Since radioisotopes decay exponentially, the heat generated by a radioisotope and available for the heat pipe also decays exponentially. The rate of exponential decay is dependent on the half life of the particular radioisotope material used. High energy content radioisotopes with short half lives exhibit a faster decay rate. Heat pipes using short half life, high energy content radioisotope heat sources will thus, during the first few half life periods, experience a wide range of decaying heat input with correspondingly lowering of operating temperatures. It would be advantageous in many applications of radioisotope fueled heat pipe to use these short life, high energy content radioisotopes due to the savings in weight and size.

Further, some of the more desirable radioisotopes, such as polonium 210 and plutonium 238, emit alpha particles during the decaying process which may accumulate within the fuel container and eventually rupture the container.

SUMMARY OF INVENTION

In view of the limitations of the prior art as noted above, it is an object of this invention to provide a radioisotope fueled heat transfer system having a constant temperature heat transfer surface which may convey heat to utilization device.

It is a further object of this invention to automatically provide constant pressure within a heat pipe having an exponentially decreasing heat input.

Various other objects and advantages will appear from the following description of one embodiment of the invention, and the most novel features will be particularly pointed out hereinafter in connection with the appended claims.

The invention comprises a heat pipe, means for holding an alpha emitting radioisotope fuel adjacent thereto for supplying heat to said heat pipe, means for retaining helium atoms generated by said fuel within said heat pipe.

DESCRIPTION OF DRAWINGS

The present invention is illustrated in the accompanying drawings wherein:

FIG. 1a is a perspective, partially cutaway view of a heat transfer system incorporating features of the present invention;

FIG. 1b is a fragmentary cross-sectional view of a portion of the device shown in FIG. 1a;

FIG. 2 is a graph heat input and heat output vs. time for the device shown in FIGS. 1a and b; and

FIG. 3 is a cross-sectional view of another embodiment of this invention.

DETAILED DESCRIPTION

The heat transfer system shown in FIGS. 1a and b include a heat pipe 10 having a closed outer container or shell 12, a porous wick or capillary means 14 saturated with a suitable condensible working fluid and a central vapor passage or channel 16. In this embodiment, outer shell 12 is shown in the form of a tubular conduit or pipe. Outer shell 12 may take any convenient cross section, e.g., constant or gradually increasing or decreasing, and width in either a straight or bent configuration depending on the particular application of the system. The wick is shown as a wire screen mesh but may be of any porous shape or material which will provide capillary movement of the working fluid, such as woven cloth, fibrous glass, porous metal, porous ceramic tubes or narrow grooves cut lengthwise in the interior wall or surface of shell 12. The condensible working fluid may be water, acetone, glycerine, ammonia, molten salts, cesium, sodium, potassium, lithium or silver depending on the desired operating temperature and conditions of the heat pipe. By way of example, typical operating temperatures for water may be from about 80° to 145°C, for sodium from about 600° to 750°C for lithium from about 1,100° to 1,350°C. The shell 12 and wick 14 may be made of any suitable material compatible with the operating conditions of the heat pipe and the particular working fluid used.

A heat pipe utilizes a reflux condensing or boiling condensing thermal system together with capillary action to vaporize the working fluid in the high temperature zone or evaporator section 18 and condense the vapor in the low temperature zone or condenser section 20 of the heat pipe to drive or force the vaporized working fluid from the high temperature zone to the low temperature zone through channel 16 and return the condensed working fluid to zone 18 through wick 14. Initially, the temperature along the entire length of the heat pipe is nearly isothermal with a temperature gradient generally of only a few degrees at the boiling-condensing temperature of the working fluid at the

working pressure. Zones 18 and 20 may be of any convenient length depending on the desired heat flux density.

An alpha emitting, radioisotope fuel 22 is mounted or held adjacent heat pipe 10 along and in thermal contact with the walls adjacent to the high temperature zone 18. Fuel 22 is disposed within a conduit or enclosure 24 and separated therefrom by an annular chamber 26 for collecting alpha particle emitted from the fuel and the resulting helium atoms. Enclosure 24 may provide or include any necessary thermal insulation and radiation shielding. A passageway may be provided directly or through a suitable filter 28 to channel 16 of heat pipe 10, for the selective, one way passage of helium atoms resulting from the alpha particles emitted from fuel 22. There may be applications where it would be desirable to place fuel 22 within channel 16 of the heat pipe adjacent wick 14 to permit the direct transfer of alpha particles and resulting helium to channel 16.

The distal or far extremity or portion of the low temperature zone 20 may be coupled to some suitable heat sink or heat exchanger apparatus either directly through the walls of outer shell 12 or through radiator fins 30 so as to dissipate excess heat to some medium such as the atmosphere or space. A conventional utilization device 32, such as thermionic or thermoelectric converters, a steam boiler or other thermal energy converter, may be mounted with good thermal contact along a constant temperature heat transfer surface or portion 34 on heat pipe 10 intermediate the heat dissipating portion and fuel 22. Utilization device 32 in turn, may be connected by electrical or mechanical means to a suitable load 36.

Radioisotope fuel 22 may be any alpha emitting radioisotopic material, e.g., polonium 210, plutonium 238, curium 242, or the like. The particular radioisotope used may depend on the particular application of the heat transfer device taking into consideration the energy content, half life, biological hazard and cost of the material as well as the volume and weight of material needed to provide the required heat for a prescribed period of operation. The radioisotope may be used in its pure or metal form or as a ceramic or other compound. For instance, for 2 KW of heat, polonium 210 in its metal form would require about 1.65cc of material while curium 242 in its ceramic oxide form would require about 2.27cc of material. The fuel 22 may be formed, as shown, in a solid or porous tubular configuration or as stacked rings or other similar form with or without additional porous members to aid release of alpha particles which may become trapped in the fuel. Such trapped particles could cause fuel swelling and possible fuel rupture and in time adversely affect heat transfer to heat pipe 10. The fuel may be suitably held in place by pressure fitting over the heat pipe or by a mounting ring or bracket 37 or clad within a structural member (not shown).

Filter 28 may be a porous frit or plug made of any suitable high strength material, such as a ceramic or a refractory metal cermet, and may be formed by conventional hot pressing techniques to attain a porosity which will permit alpha particles or helium atoms generated by the fuel to pass through the cermet, while blocking the higher atomic weight vapors and gases in channel 16 of heat pipe 10. Thus, as the alpha particles and helium atoms accumulate within chamber 26, the pressure therein will increase to the point where it ap-

proaches and exceeds the pressure within the heat pipe and permit passage of the alpha particles and helium atoms into the heat pipe. It may be desirable under certain operating conditions, particularly with very short half life radioisotopes, to precharge chamber 26 to some initial pressure with a noncondensable, gas or vapor so that the alpha particles emitted by the fuel or the resulting helium, may pass through filter 28 at an earlier stage of operation.

As shown in FIG. 2 by curve 40, the heat generated by a radioisotope decreases exponentially with time. The rate of decrease, that is the time scale of the abscissa, will depend on the half life of the fuel while the scale of heat generated along the ordinate will depend on the quantity of fuel. Assuming that it is desired that the heat transfer surface 34 (i.e., the conversion zone of the low temperature zone of heat pipe 10) be maintained at a constant temperature for three half lives of fuel 22, the heat transmitted to utilization device 32 will follow curve 42. Thus, radiator 30 must have sufficient surface area to dissipate the excess heat generated by fuel 22 as indicated by the shaded area between curves 40 and 42. It is apparent that as the heat transfer system operates, the quantity of excess heat decreases and a smaller amount of radiator heat exchange surface is needed. Since the internal pressure-temperature relationship of a heat pipe is defined by the formula;

$$PV = n k t$$

where

P = pressure in heat pipe

V = volume of heat pipe

n = number of molecules of vapor

k = Boltzmann molecular gas constant, and

t = temperature of vapor.

As the heat generated by the fuel decreases, the number of vaporized molecules n and therefore the boiling pressure P and temperature t will decrease.

However, with the present invention, as the radioisotope fuel decays, alpha particles are emitted at the same rate as the heat input decreases along curve 40 of FIG. 2. These alpha particles or helium atoms resulting therefrom pass through filter 28 and, by diffusion pump action between the working fluid vapor and helium in channel 16, are swept to the extreme far end of low temperature zone 20 in the heat pipe. As the alpha particles build up in channel 16 of heat pipe 10, the particles displace a portion of the working fluid vapors, effectively decreasing the volume of channel 16 and the area of its heat dissipating portion as well as the heat exchange surface of radiator 30 by cutting out successive fins thereof. The displacement of working fluid vapors maintains both the pressure P and temperature, t , constant in the remaining active portion of the heat pipe. The heat transfer surface 34 of heat pipe 10 adjacent utilization device 32 may thus be maintained at a constant temperature until such time as the effective active length of heat pipe 10 (i.e., the working fluid vapor-helium atoms interface) reaches surface 34. The time period of constant temperature at heat transfer surface 34 may be determined by proper selection of heat exchange surface areas in radiator 30, length of radiator 30 or number of fins thereof, radioisotope to be employed, cross section of channel 16, and position of utilization device 32 along heat transfer surface 34, preferably adjacent fuel 22 for the longest period of operation.

In the embodiment of the invention shown in FIG. 3, the alpha particles emitted by fuel 22 and collected in chamber 26 of conduit 24 or the resulting helium atoms are transmitted directly to the far or extreme end of low temperature zone 20 of heat pipe 10 by a hollow, uninter-
 rupted tube or conduit 44 extending from chamber 26 along the longitudinal axis and a substantial portion of the length of channel 16, as shown. As fuel 22 decays, the helium resulting from alpha particles pass through tube 44 displacing working fluid vapor in chan-
 nel 16 and decreasing the effective active volume of heat pipe 10 and the length of the excess power rejection zone of the low temperature zone of heat pipe 10 in the same manner as that described above for FIGS. 1 a and 1 b.

The utilization device in this embodiment is shown as a pair of thermionic tubes or diodes 46 mounted on a thermal conductive ring 48.

The present invention utilizes the alpha particles emitted by a radioisotope fueled heat pipe to decrease the effective volume of the heat pipe and maintain the internal pressure and the temperature of a heat transfer surface of the heat pipe constant over any desired number of half lives of the radioisotope. The constant temperature heat transfer surface may be used to supply heat to any desired thermal energy conversion or utilization device with suitable heat conduction members or materials positioned contiguous with the heat transfer surfaces and the utilization device.

It will be understood that various changes in the details, materials and arrangements of the parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principles and scope of the invention as expressed in the appended claims.

What is claimed is:

1. A heat transfer system for use with an alpha emitting radioisotope fuel for supplying a substantially constant temperature to a heat transfer surface adjacent a heat utilization device comprising a heat transfer pipe having a high temperature zone and a low temperature zone, said low temperature zone including a heat dissi-

pating portion and a heat transfer surface intermediate said high temperature zone and the heat dissipating portion, a condensable working fluid disposed within said pipe, capillary means disposed along the inner surface of said pipe between said high temperature and low temperature zones for transporting condensed working fluid from said low temperature zone to said high temperature zone; means adjacent said heat pipe at said high temperature zone for holding an alpha emitting radioisotope fuel for vaporizing said working fluid; and means for retaining helium generated by said fuel within said pipe for maintaining said heat transfer surface at a constant temperature as radioisotope fuel decays.

2. The system of claim 1 having a radioisotope fuel selected from the group consisting of polonium 210, plutonium 238 and curium 242.

3. The system of claim 1 wherein said fuel is of generally annular configuration disposed about a portion of said heat pipe.

4. The system of claim 3 wherein said retaining means includes an enclosure disposed about said fuel and separated therefrom by a helium collection chamber.

5. The system of claim 1 wherein said system includes means for transmitting said helium from said retaining means to the interior of said pipe.

6. The system of claim 5 wherein said transmitting means is a passageway interconnecting said retaining means and the low temperature zone of said heat pipe.

7. The system of claim 6 wherein said passageway is disposed centrally of said heat pipe along its longitudinal axis.

8. The system of claim 5 wherein said transmitting means is a filter.

9. The system of claim 1 having fins projecting from said heat dissipating portion of said pipe for dissipating excess heat generated by said fuel.

10. The system of claim 1 wherein said utilization device is mounted on said heat transfer surface adjacent said holding means.

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