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[54] **HEAT PIPE HAVING IMPROVED DIELECTRIC STRENGTH**
8 Claims, 10 Drawing Figs.

[52] U.S. Cl..... **165/105,**
 165/32; 174/15; 313/12, 313/44; 317/234

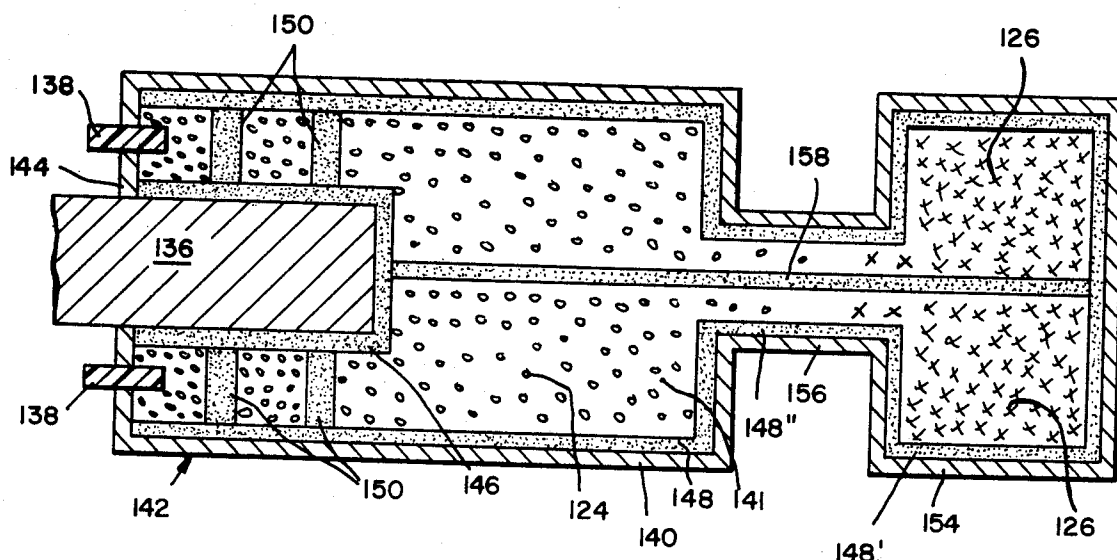
[51] Int. Cl..... **F28d 15/00,**
 H01j 7/24

[50] Field of Search..... **165/105;**
 317/234; 174/15; 313/12, 44; 62/514

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ABSTRACT: The disclosed heat pipe includes a hermetically sealed housing having two portions electrically insulated from one another and maintained at differing electrical potentials. Contained within the housing is a volatile working fluid, a capillary wick and an inert gas having relatively high dielectric strength. Sufficient inert gas is contained within the housing to maintain a predetermined breakdown voltage at the lowest temperature of operation of the heat pipe.



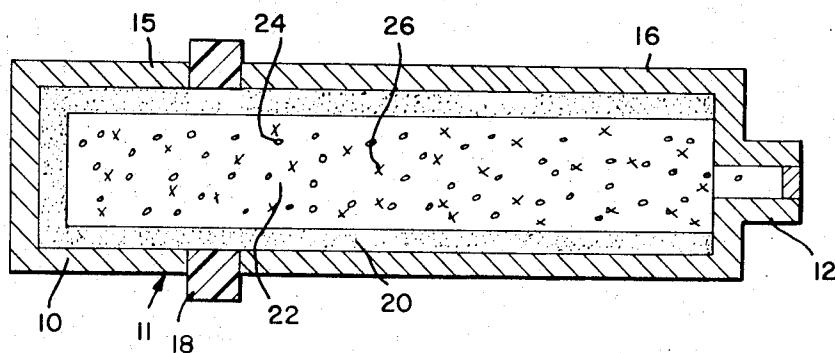


Fig. 1a.

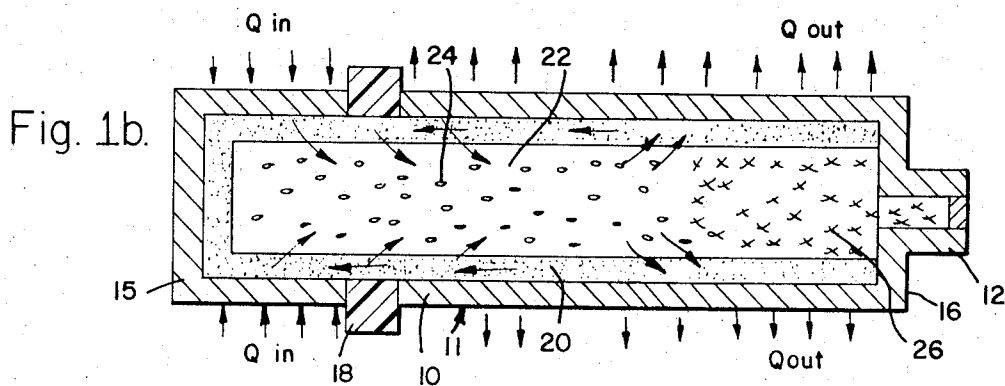


Fig. 1b.

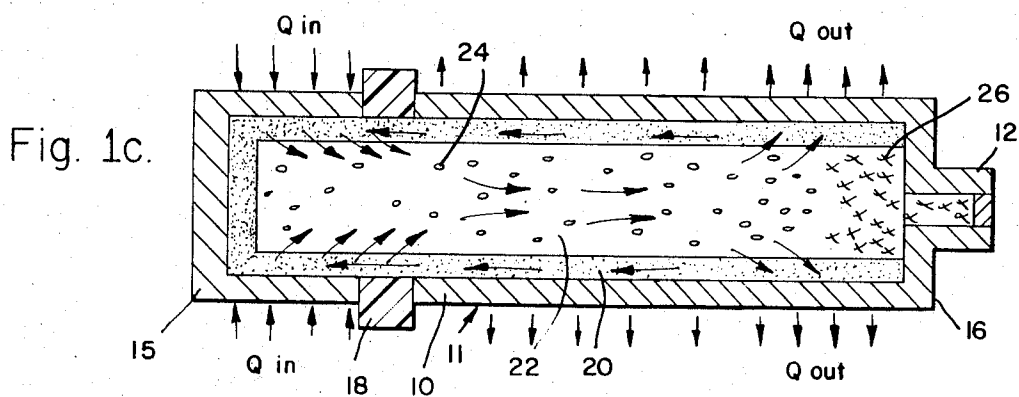


Fig. 1c.

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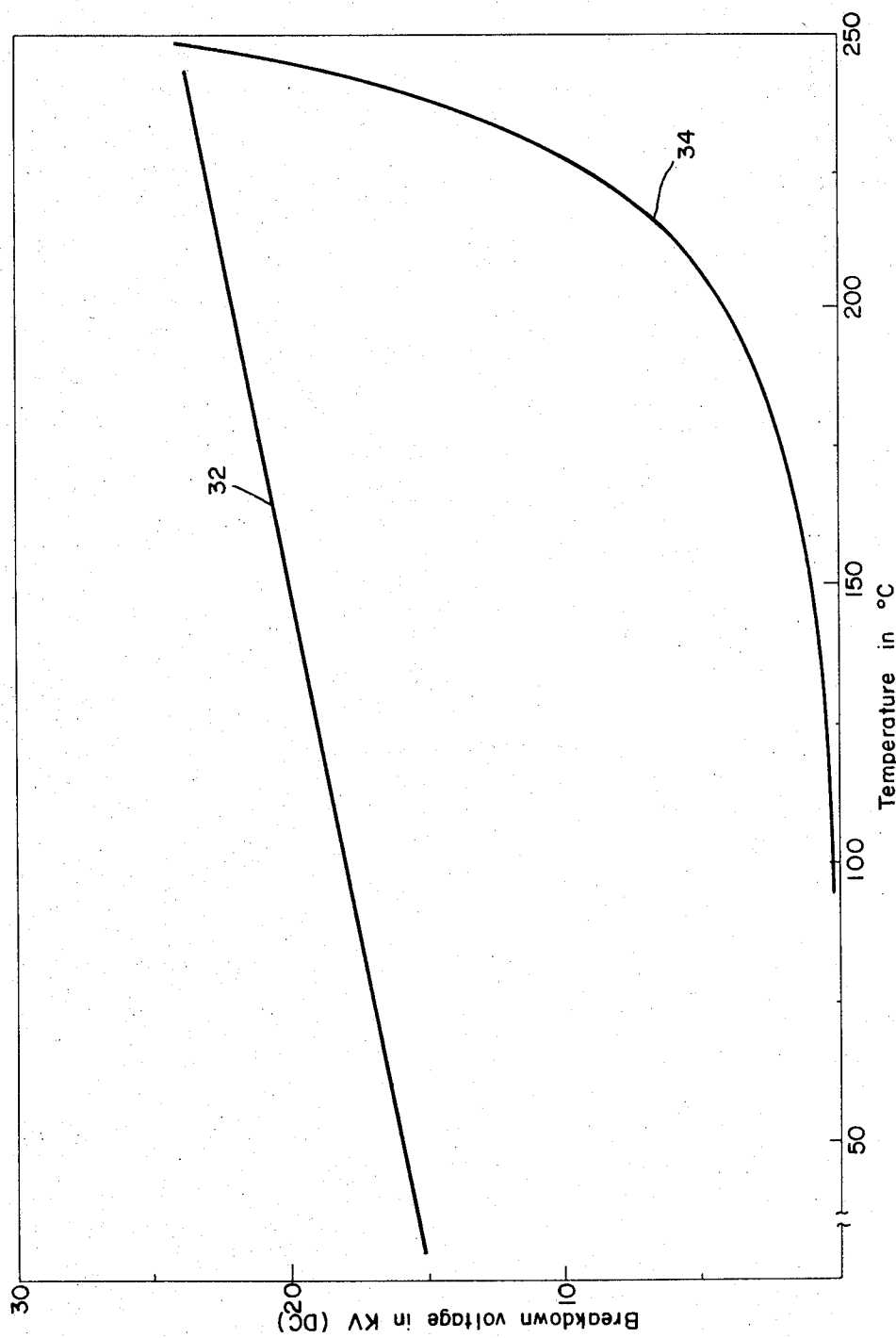


Fig. 2

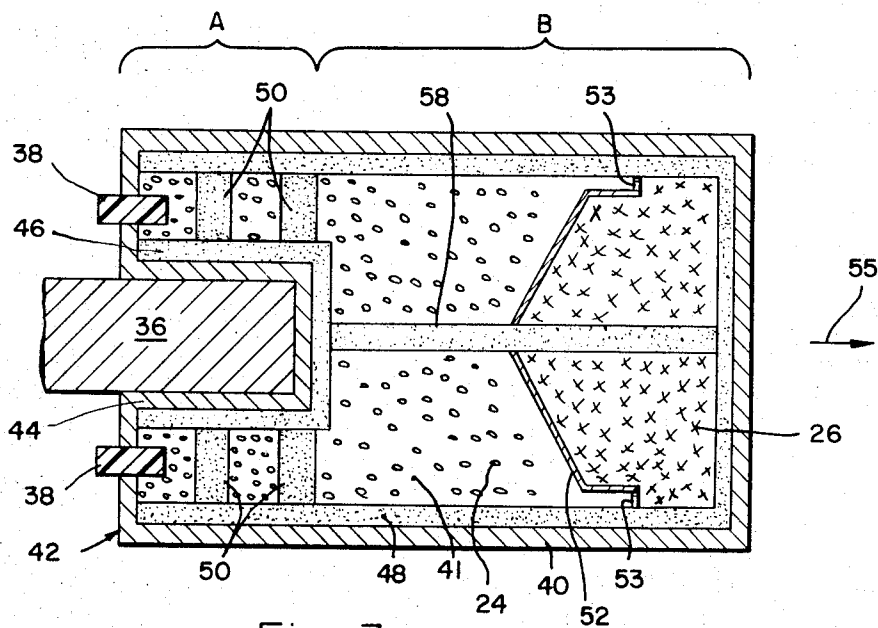


Fig. 3.

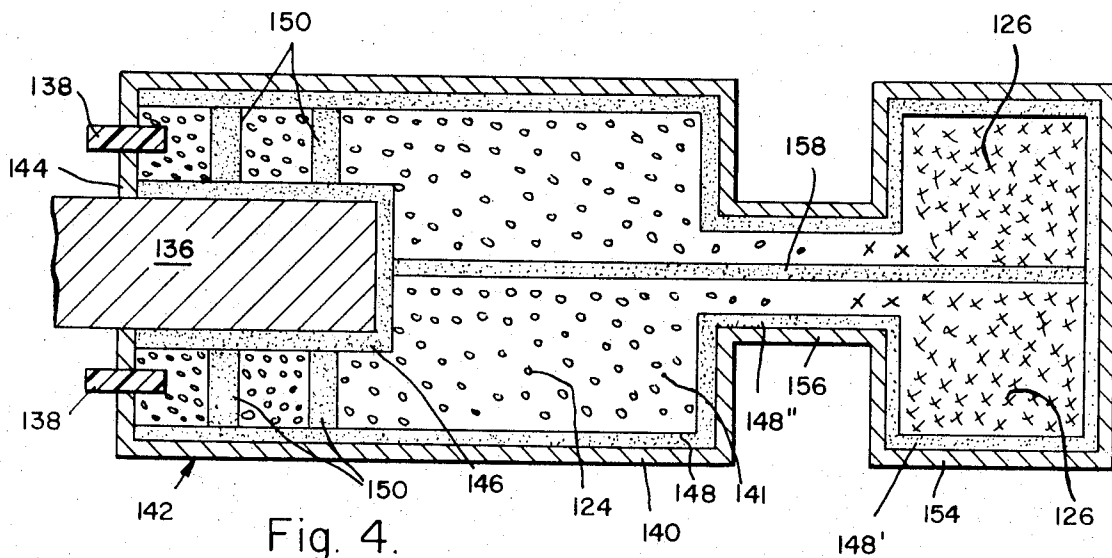
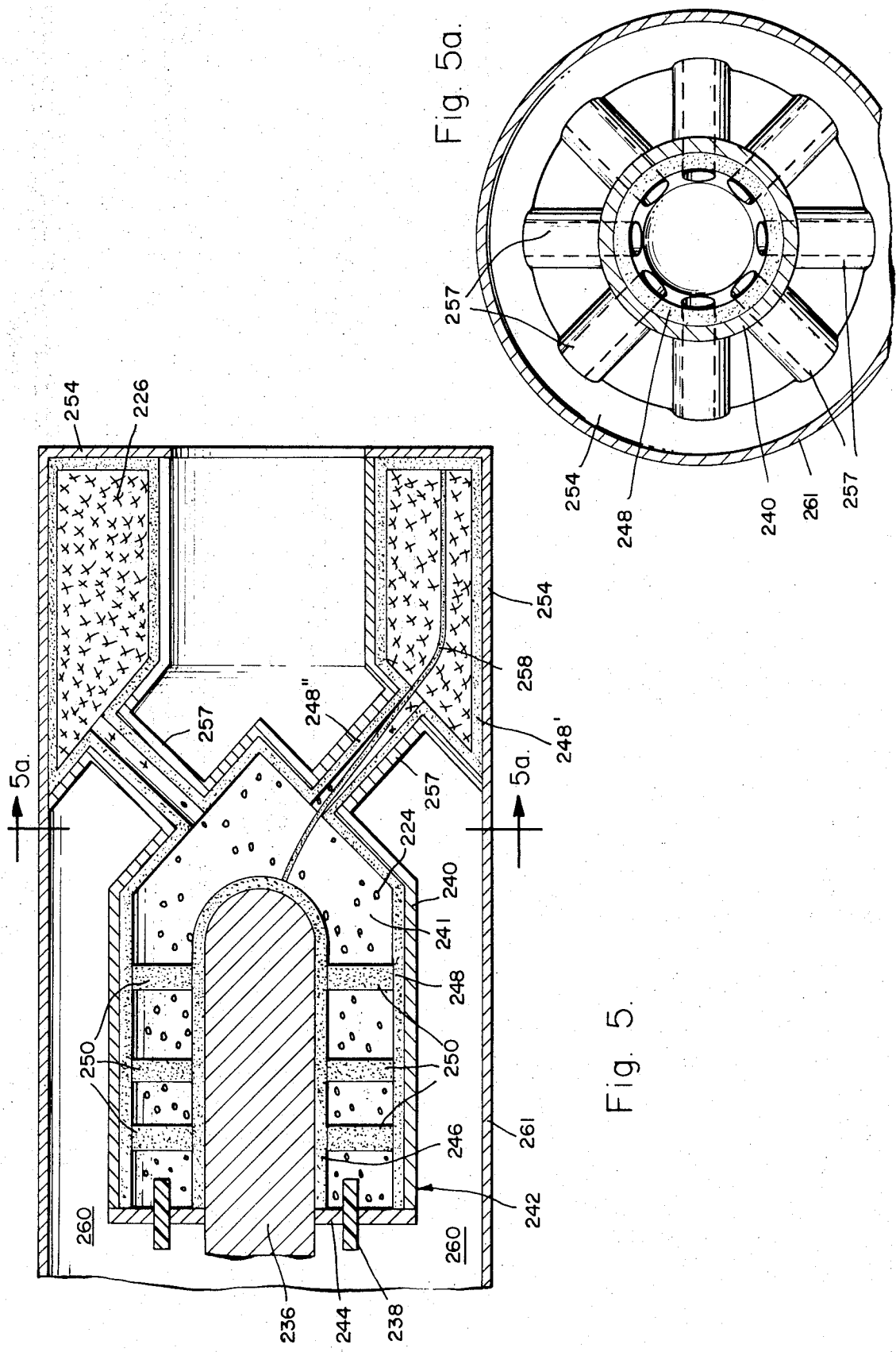


Fig. 4.



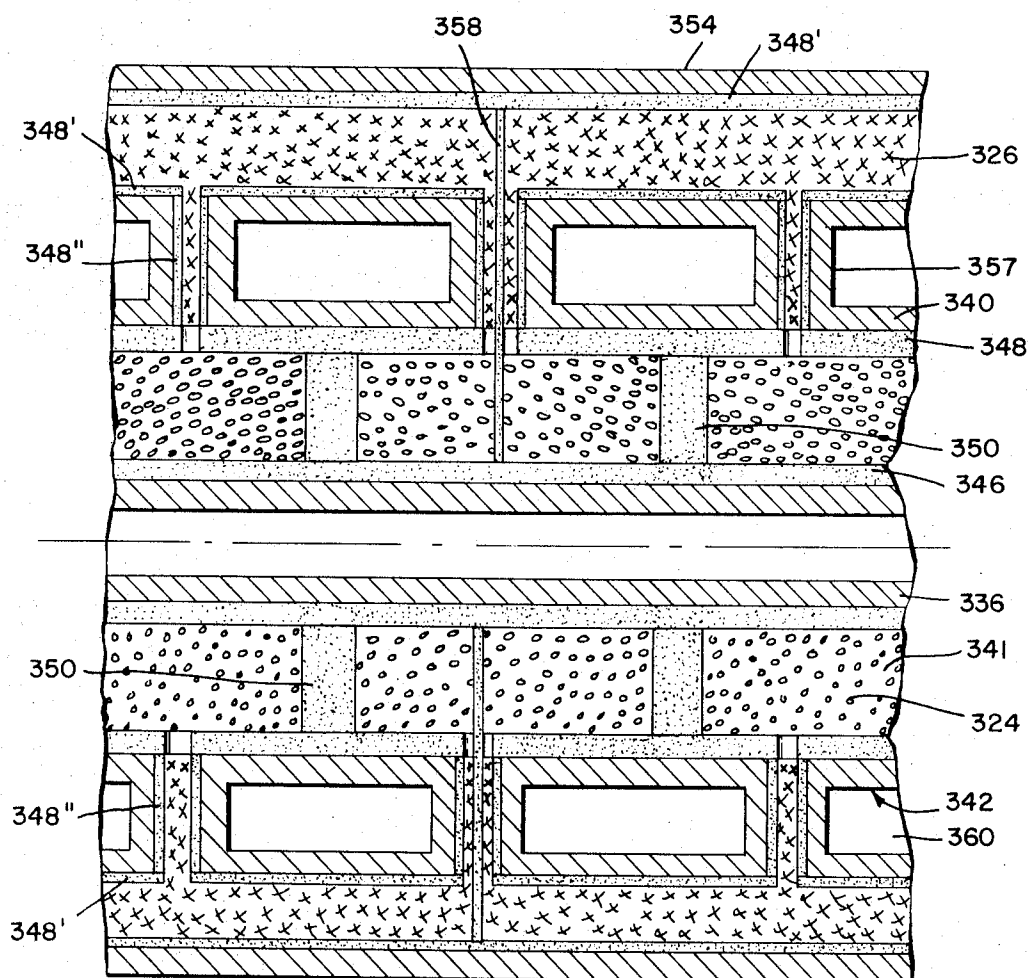


Fig. 6.

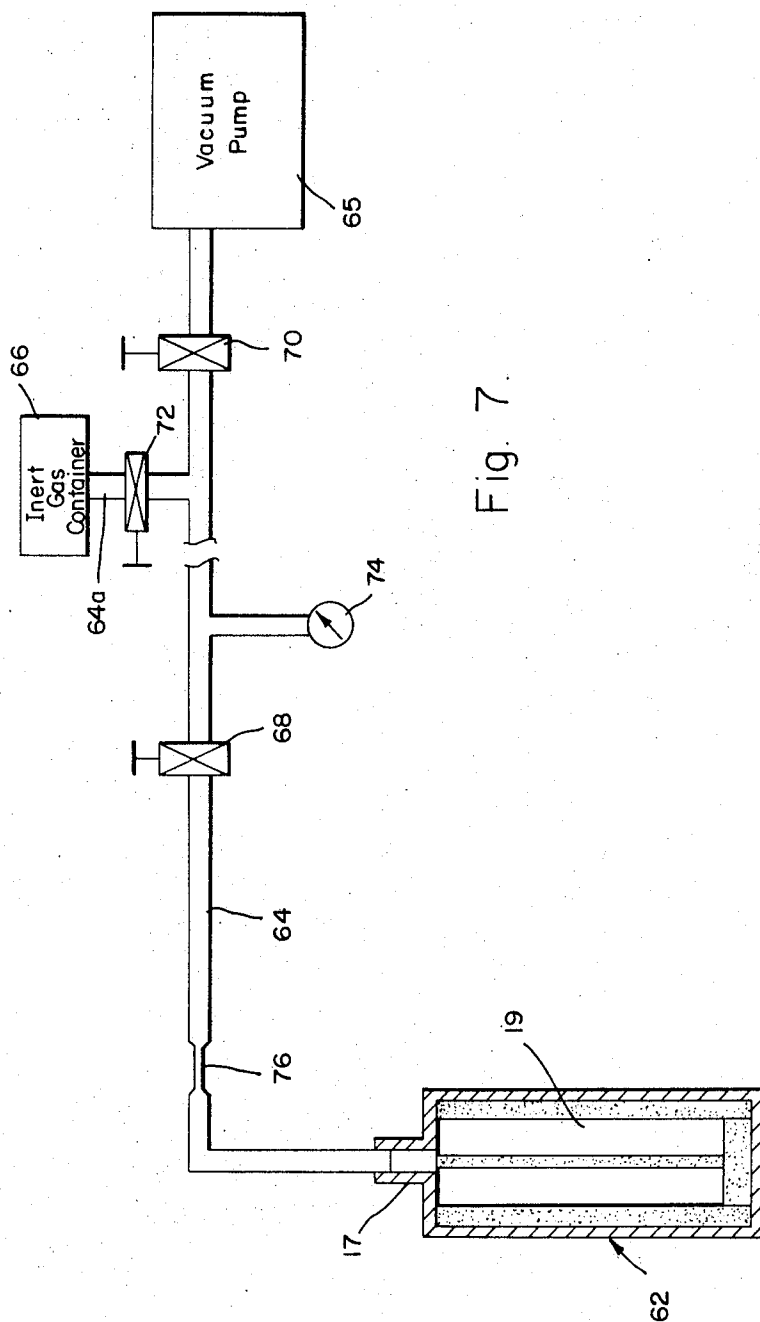


Fig. 7.

HEAT PIPE HAVING IMPROVED DIELECTRIC STRENGTH

This invention relates to heat pipes, and more particularly relates to a heat pipe having a high dielectric strength so as to maintain a predetermined breakdown voltage at low temperature operating ranges.

Heat pipes are often used to transfer thermal energy from a first region to a second region by means of heat exchange so as to "cool" the first region, for example. This energy exchange may be made through any medium that conducts heat. One effective way to achieve this energy exchange is to employ a suitable fluid that assimilates energy at the first region when the fluid vaporizes; then, after traveling in vapor form to the second region, releases the energy there by condensation. Return of the fluid in its liquid form to the first region may be accomplished by means of gray or capillary action, for example.

It is often desirable to transfer energy by heat exchange from a surface maintained at one electrical potential to a surface at a substantially different electrical potential. Since heat pipe fluid is normally contained within a hermetically sealed chamber, when the temperature inside of the chamber is reduced, the pressure of the fluid vapor inside of the chamber is also reduced; thus the dielectric strength (the maximum potential gradient a material can withstand without rupture) of the fluid vapor is decreased. Prior art heat pipe cooling systems have employed bellow or similar devices to maintain the fluid vapor at a constant pressure in order to maintain the desired dielectric strength of the fluid vapor at low temperatures. Alternatively, heaters have been used to heat the fluid vapor so as to increase its pressure prior to the operation of the heat pipe. For applications where available space is minimal and where reliability of operation must be extremely high (such as the cooling of electronic equipment contained within a space satellite), such heat pipe arrangements not practical.

Accordingly it is an object of the present invention to provide a heat pipe having improved dielectric strength so as to maintain a predetermined high breakdown voltage at low temperatures.

It is a still further object of the present invention to provide a high dielectric strength heat pipe that is simple and economical to manufacture.

It is yet another object of the present invention to provide a high dielectric strength heat pipe that occupies minimal space, that is light in weight, and is reliable in operation.

In accordance with the foregoing objects, a heat pipe according to the invention includes a hermetically sealed housing having two portions that are electrically insulated from each other. A capillary wick is disposed along the inner surface of the sealed housing. Contained within the housing and within at least a portion of the wick is a volatile working fluid. Also contained within the housing is preselected quantity of a substantially chemically inert gas having a dielectric strength greater than that of the working fluid when in the vapor state at a predetermined operating temperature.

Additional objects, advantages and characteristic features of the present invention will become more readily apparent from the following detailed description of preferred embodiments of the invention when considered in conjunction with the accompanying drawings in which:

FIGS. 1a, 1b, and 1c are longitudinal sectional views illustrating the construction and operation of a heat pipe according to an embodiment of the invention;

FIG. 2 is a graph showing the breakdown voltage as a function of temperature for two exemplary operative fluids for a heat pipe according to the invention;

FIGS. 3 and 4 are longitudinal sectional views illustrating heat pipes according to further embodiments of the invention;

FIG. 5 is a longitudinal sectional view illustrating a heat pipe according to still further embodiment of the invention;

FIG. 5a is a cross-sectional view taken along line 5a-5a of FIG. 5;

FIG. 6 is a longitudinal sectional view illustrating a heat pipe according to a still further embodiment of the invention; and

FIG. 7 is a schematic diagram illustrating a method of manufacturing a heat pipe according to the invention.

Referring to FIG. 1a with greater particularity, a heat pipe according to the invention, designated generally by the numeral 11, includes a housing 10. Housing 10 may be essentially cylindrical in shape, for example, and may have first and second elongated electrically conductive portions 15 and 16 separated by a ring 18 of electrically insulative material so that portions 15 and 16 may be maintained at substantially different electrical potentials. One end of housing 10 is provided with a vacuum stem 12, which when sealed off allows heat pipe 11 to become hermetically sealed. A capillary wick 20, which may be the form of several strips or a solid sheet, for example, is disposed along the inner surface of housing 10. The wick 20 may be of a material (such as nylon, paper, glass fiber, silicon dioxide, porous ceramics, ceramic-metal fiber components, or combinations of the foregoing, for example) having sufficient electrically insulating properties to withstand any practical potential difference between housing portions 15 and 16. Wick 20 may be force fit into housing 10, or riveted, sintered or soldered thereto, for example.

Wick 20 is saturated with an appropriate working fluid that vaporizes in vapor space 22 enclosed by housing 10. Contained within vapor space 22 is not only the working fluid vapor (represented in FIG. 1 by circles 24) but also a predetermined quantity of inert gas (represented in FIG. 1 by x's 26). This inert gas is essential in maintaining a predetermined breakdown voltage between housing portions 15 and 16 at the lower operating temperatures of the heat pipe. Therefore, the inert gas 26 has dielectric strength and a boiling point higher than those of the working fluid vapor at the aforementioned lower operating temperatures. The amount of working fluid in the heat pipe 11 should be, as nearly as possible, equal to, if not in excess of, the void wick volume (i.e., the amount of fluid which the wick will hold when saturated) of wick 20 since too little fluid will prohibit efficient energy exchange by heat transfer.

One of several factors to consider in selecting an appropriate working fluid is the dielectric strength of the fluid when in either vapor or liquid states and the desired temperature range of operation of the heat pipe. Other factors desirable in a working fluid are a high latent heat of vaporization for maximum energy transfer ability, low viscosity for reduced internal fluid friction, and high surface tension and good wetting ability of the wick material for a high capillary force. A nonexclusive list of possible working fluids with their appropriate temperature ranges is given below:

Working fluid	Approximate dielectric strength at atmospheric pressure and room temperature (Approx. 25° C.)	Approximate useful temperature range, °C.
Dowtherm A.....	500 volts/mil.....	150-350
CP-63.....	Not available.....	150-350
CP-9.....	do.....	150-350
FC43.....	560 volts/mil.....	120-220
Dowcorning 200.....	250 volts/mil.....	100-200
Freon 13.....	Not available.....	20-75
Freon 12.....	do.....	-28-38

The above working fluids are readily available commercially and are manufactured by companies such as the Dow Chemical Company, Minnesota Mining and Manufacturing Co., E. I. Du Pont de Nemours, and the Monsanto Co. It should be understood that the above list is only exemplary as to suitable working fluids, dielectric strengths and temperatures for a heat pipe according to the invention.

The structure and composition of the capillary wick 20 determines, to a large extent, the efficiency of the heat pipe 11. As illustrated in FIG. 1, wick 20 may take the form of a

cylindrical shell closed at one end and attached to the adjacent inner surfaces of housing 10; alternatively, wick 20 may consist of a plurality of wick strips extending longitudinally along the inner surfaces of housing 10 from portion 15 to portion 16. Channels, screens, cloths or sintered structures made of the aforementioned wick materials or combinations thereof, for example, may be used for the wick configuration.

Wick thickness is also an important design consideration. An excessively thick wick will impede the flow of heat transversely through the wick; on the other hand if the wick is too thin, the capillary flow of the condensed working fluid will be impeded. Furthermore, the length of wick 20 should be minimized in order to reduce pressure drop in the condensed working fluid. The desired length of the wick is a function of the wick pore size and the type of working fluid used. For example, for a wick made of silicon dioxide and with Dowtherm A being used as the working fluid, when the working fluid is flowing in the wick against the force of gravity (i.e., the heat pipe is being operated in a vertical attitude) the wick length may be approximately 6 inches and the wick thickness approximately one-eighth of an inch.

The breakdown voltage between housing portions 15 and 16 (i.e., the voltage at which portions 15 and 16 are no longer electrically insulated from one another) is dependent on the dielectric strength of the fluid in vapor space 22, the distance between the surfaces over which breakdown may occur, and the shape of the surfaces over which breakdown occurs (assuming wick 20 has a higher dielectric strength than the fluid in space 22). Disregarding the shape of portions 15 and 16, by increasing the width of insulating ring 18 and thereby the distance between portions 15 and 16, the breakdown voltage for a given pressure is increased. Therefore, it is advantageous to make ring 18 as wide as is possible.

The gas 26 used in a heat pipe according to the invention should be sufficiently chemically inert so that it will not interfere with the operation of the heat pipe. The more chemically inert the gas, the longer the operational life of the heat pipe. Another criteria in selecting an appropriate inert gas is its dielectric strength at the lowest temperature range of operation of the heat pipe. The dielectric strength of the inert gas over this temperature range should be greater than the dielectric strength of the working fluid vapor over the same temperature range. It is also necessary that the inert gas have a boiling point lower than that of the working fluid so as to minimize interference with the heat transfer by the working fluid. In addition, the inert gas should be substantially insoluble in the working fluid. Typical examples of appropriate inert gases to be used in conjunction with the aforementioned exemplary working fluids N_2 , SF_6 , C_3F_8 , C_4F_8 , C_4F_{10} , and C_2F_6 .

The exact amount of inert gas to be used in heat pipe 11 depends on the particular gas and working fluid used as well as on the breakdown voltage at a desired temperature. For example, assume that SF_6 gas is used as the inert gas, Dowtherm A is used as the working fluid, and that a breakdown voltage of not less than 15k volts is desired for a 0.200 inch spacing between portions 15 and 16 at their point of closest proximity over an operating temperature from room temperature (25° C. approximately) to about 250° C. The breakdown voltage of Dowtherm A vapor at room temperature and at pressures near atmospheric pressure is substantially below the aforementioned breakdown voltage of 15k volts. However, the breakdown voltage of a mixture of Dowtherm A and SF_6 gas at the same temperature and at a pressure of 300 mm. Hg. is approximately 15K volts. In order to maintain the breakdown voltage of the heat pipe above 15K volts at all temperatures of operation, sufficient SF_6 gas must be introduced into the heat pipe housing 10 so that the total internal vapor pressure at the lowest operating temperature of the heat pipe is 300 mm. Hg.

Typical heat pipe vapor cavity breakdown voltage vs. temperature characteristics are illustrated in FIG. 2. Curve 32 shows the characteristic for a heat pipe employing a mixture of Dowtherm A and SF_6 gas (at 300 mm. Hg. pressure at room temperature); curve 34 shows the characteristic for Dowtherm A alone.

The operation of a heat pipe according to the invention will now be explained with reference to FIGS. 1a, 1b and 1c. FIG. 1a represents the heat pipe at ambient temperature with an amount of inert gas 26, as discussed above, intermixed with vaporized working fluid 24. As heat is applied to portion 15 (FIG. 1b), working fluid in adjacent regions of the wick 20 is evaporated. Working fluid vapor 24 then travels toward portion 16, since portion 16 is at a lower temperature than portion 15. As the working fluid vapor travels from higher temperature portion 15 toward the lower temperature portion 16, the kinetic energy of the working fluid vapor "pushes" the inert gas toward portion 16. At or in the vicinity of portion 16, the working fluid vapor condenses, thereby transferring heat through wick 20 and housing 10. The condensed working fluid is then, by capillary force, drawn back through wick 20 toward portion 15 where it is once again evaporated. When the heat pipe is operating at maximum heat transferring capacity (FIG. 1c), the kinetic energy of the working fluid vapor "pushes" the inert gas to the end of the heat pipe adjacent vacuum stem 12. The amount of space occupied by the inert gas is proportional to the kinetic energy of the working fluid vapor. Minimal interference with the movement of the heat transferring working fluid vapor by the inert gas is thereby achieved. Only a small portion of the effective length of the heat pipe is thus "sacrificed" for heat transfer purposes, while orders of magnitude increases in the dielectric strength of the heat pipe can be achieved at low operating temperatures.

The exact structure of a heat pipe according to the invention may be modified so as to be especially suitable for a particular heat transfer operation.

FIG. 3 illustrates a cross section of a heat pipe according to the invention which may be used to remove heat from a substantially cylindrical member 36, which may be the collector of a traveling-wave tube, for example, and which is maintained at a desired electrical potential. Electrically insulating ring 38 insulates heat input portion 44 of a heat pipe housing 42 from a heat output portion 40 of housing 42. Heat input portion 44 is in contact with the member 36 to be cooled, and thus resides at the same electrical potential as the member 36, while the heat output portion 40 resides at a substantially different electrical potential, for example, ground. Heat pipe housing 42 encloses a hermetically sealed vapor cavity 41. A fluid evaporating wick 46 is disposed substantially along the surface of housing portion 44 facing into vapor cavity 41, while a fluid condensing wick 48 is disposed substantially along the surface of housing portion 40 facing into vapor cavity 41. Alternatively, housing portion 44 may be partially eliminated, and wick 46 disposed in contact with the outer surface of member 36. A plurality of electrically insulating spoke wicks 50 connect wicks 46 and 48 to facilitate the return of working fluid evaporated from wick 46 and condensed in wick 48 to wick 46 by means of capillary action. Wicks 50 may be spokes, wedges or annular members, for example, the particular shape of the wicks 50 not being critical.

The heat pipe of FIG. 3 functions in a manner similar to that of FIGS. 1a, 1b and 1c. The kinetic energy of working fluid vapor molecules traveling from the vicinity of member 36 toward housing portion 40 is generally sufficient to maintain the inert gas away from the major heat transfer region during operation of the heat pipe if the working fluid-inert gas interface area is relatively small. For larger interface areas, however, an interface shield 52 may be inserted into the heat pipe vapor cavity 41 to enhance the separation between the two fluids. Shield 52 minimizes the interface area by allowing inert gas-working fluid contact only along gas passageways 53.

It is often desirable to operate a heat pipe at various attitudes in relation to the direction of a force field, such as gravity, for example. Since the heat pipe operates by capillary force, the effect of gravity may impede the capillary action within the condensing portion of the wick. For the heat pipe of FIG. 3, if an electrically insulative siphon wick 58 is employed as shown, the heat pipe may be operated substantially independently of a force field such as gravity, assuming the force field exists in a direction illustrated by arrow 55.

For steady state heat pipe operation, the following equation approximates the factors which affect the flow of working fluid within the wicks: $\Delta P_c = \Delta P_v + \Delta P_1 + \Delta P_g$ (1) where ΔP_c is the capillary driving pressure, ΔP_v is the pressure drop along wick 48 caused by the vapor flow, ΔP_1 is the pressure drop due to the working fluid liquid flow, and ΔP_g is the pressure drop along wick 48 due to gravity. The capillary driving pressure within wick 48 must be sufficient to support the column of fluid within it, otherwise the fluid will flow out of wick 48 into vapor space 41. Wicks 46 and 50 and the portion of wick 48 within region A act as a U-tube, and consequently a siphon effect overcomes the pressure drop due to gravity. If a quantum of fluid condenses in wick 48 in region B, a siphon U-tube effect will be created by means of wick 48 and siphon wick 58. Therefore, the heat pipe may be operated substantially free from the effect of gravity.

Since vapor space 41 contains a dielectric material (the working fluid and the inert gas), when a potential difference exists between housing portions 40 and 44, a capacitance effect results. The amount of capacitance depends largely on the distance between portions 44 and 40, the greater the distance, the less the capacitance. If a limited amount of power is available to charge the resultant capacitor, as may be the case in a space satellite, the distance between portions 40 and 44 should be maximized.

FIG. 4 illustrates a modification of the heat pipe shown in FIG. 3; the reference numerals designating corresponding parts in these two embodiments are the same, except that for FIG. 4 the prefix numeral 1 is employed. In the heat pipe illustrated in FIG. 4, shield 52 is eliminated and as a functional substitute therefor an inert gas holding section, or chamber, 154 is connected to vapor cavity 141 by means of a throat section 156 and a siphon wick 158. The inner surfaces of holding section 154 and of throat section 156 may be lined with extensions 148' and 148'' respectively of wick 148. Holding section 154 is used to substantially remove the inert gas from the heat transfer areas while the heat pipe is operating; hence the inert gas temperature more closely approximates the ambient temperature.

The operation of the heat pipe illustrated in FIG. 4 is substantially the same as that of the heat pipe illustrated in FIG. 1. In steady state operation of the heat pipe, the working fluid vapor "pushes" the inert gas into section 154 through throat 156 where it may be more easily held at a temperature lower than the temperature in cavity 141. Lining the inner surfaces of section 154 and throat 156 with extensions 148' and 148'' of wick 148 facilitates the return of condensed working fluid to wick 146. Wick 158, evaporating wick 146, condensing wick 148 and spoke wicks 150 function to provide a siphon-like capillary path to substantially eliminate the effect of gravity on the operation of the heat pipe as discussed above.

FIGS. 5 and 5a illustrate a modification of the heat pipe shown in FIG. 4. The last two reference numeral digits designating corresponding parts in these two embodiments are the same; however, for the FIG. 5-5a embodiment the numeral 2 rather than 1 is used as the first reference numeral digit. The heat pipe illustrated in FIGS. 5 and 5a operates in essentially the same manner as that of FIG. 4 but differs from the embodiment of FIG. 4 in that member 236 to be cooled has a substantially dome-shaped end and that inert gas section, or chamber, 254 is annularly disposed around the longitudinal axis of the heat pipe and extends both radially outwardly of and longitudinally beyond housing 242. Housing portion 261 extends longitudinally from the outer wall of holding section 254 toward member 236 and is spaced from and annularly disposed about housing 242 so as to form a cooling channel 260 for allowing a suitable coolant such as air, for example, to absorb heat from the outer surfaces of housing 242. A plurality of housing throat sections 257 extending into channel 260 connect holding section 254 with vapor cavity 241.

In order to allow working fluid that condenses in section 254 to return to wick 246, either a siphon wick 258 may be used to connect wick 248 with wick 246, or the inner surfaces of throat sections 257 may be lined with extension 241'' of

wick 248. When a greater working fluid capillary flow capacity is desired both arrangements may be employed simultaneously. Since member 236 may extend a substantial distance into vapor cavity 241, the length of cavity 241 may be extended to accommodate the additional length, and additional spoke wicks 250 may be employed to ensure uniform distribution of working fluid over evaporating wick 246.

FIG. 6 illustrates a modification of the heat pipe of FIG. 5. The last two reference numeral digits designating corresponding parts in these two embodiments are the same, however, for the FIG. 6 embodiment the numeral 3 rather than 2, is used as the first reference numeral digit. The embodiment illustrated in FIG. 6 differs from that illustrated in FIG. 5 principally in that member 336 is an elongated shaft or tube whose surface requires heat removal and that inert gas holding section, or chamber, 354 is substantially longitudinally coextensive with heat pipe housing 342. As with the embodiment of FIG. 5, holding section 354 is annularly disposed around heat pipe housing 342 and spaced therefrom so as to form a cooling channel 360 between the inner surface of section 354 and the outer surfaces of housing 342. A plurality of radially disposed throats 357 extend into channel 360 and connect vapor cavity 341 and gas holding section 354.

Heat pipes according to the invention may be used to remove heat from a variety of electronic devices. For example, the embodiments of the invention illustrated in FIGS. 3, 4 and 5-5a could be used to cool the collector or the electron gun portions of a traveling-wave tube. The embodiment illustrated in FIG. 6 may be used to cool the wave-electron beam interaction section of a traveling-wave tube, for example.

Referring to FIG. 7, in order to manufacture a heat pipe according to the present invention, a heat pipe assembly 62 (which for purpose of explanation is illustrated as the heat pipe 11 of FIG. 1) is attached by stem 17 to one end of a pipe 64. The other end of pipe 64 communicates with a vacuum pump 65 and via an auxiliary pipe 64a with an inert gas container 66. A first valve 68 is used to hermetically isolate the inert gas container 66 and pump 65 from the heat pipe assembly 62. A second valve 70 is employed to hermetically isolate the pump 65 from container 66 and heat pipe assembly 62. A third valve 72 hermetically isolates inert gas container 66 from pump 65 and assembly 62. A pressure gauge 74 is connected to the interior of the pipe 64 between the valves 68, 70 and 72.

In manufacturing a heat pipe according to the invention, the proper amount of working fluid is first inserted into the heat pipe assembly 62. Next, unwanted fluids are removed from the heat pipe. This removal may be accomplished by vacuum pumping the vapor cavity 19 of assembly 62 by means of pump 65. Escape of working fluid from assembly 62 during vacuum pumping may be minimized by means of a heated venturi section 76 of pipe 64. When venturi section 76 is heated to a higher temperature than assembly 62, escaping working fluid is returned to the assembly 62. During the vacuum pumping operation valves 68 and 70 are open while valve 72 is closed.

The next step in manufacturing the heat pipe is to eliminate from pipe 64 any substances that might later adversely affect the operation of the heat pipe. This may be accomplished by releasing inert gas into pipe 64 (by opening valve 72), and then allowing pump 65 to clear the pipe 64 of the inert gas and any accompanying impurities (valve 70 open, valve 72 closed). The impurity removal operation (during which time valve 68 remains closed) may have to be repeated several times in order to eliminate substantially all impurities.

Finally, an amount of inert gas sufficient to maintain the heat pipe at a desired breakdown voltage is inserted into assembly 62. Assembly 62 is cooled to the heat pipe's minimum operating temperature, and inert gas is allowed to enter the heat pipe (valve 70 is closed while valves 68 and 72 are opened) until the desired gas pressure (determined as discussed above) is attained. When the gas pressure within the heat pipe reaches the desired value, as indicated on gauge 74,

valve 68 is closed, and assembly 62 is hermetically sealed at stem 17.

Although the present invention has been shown and described with reference to particular embodiments, nevertheless, various changes and modifications obvious to a person skilled in the art to which the invention pertains are deemed to lie within the spirit, scope and contemplation of the invention.

I claim:

1. A heat pipe comprising:

a hermetically sealed housing having a heat input portion and a heat output portion and an electrically insulating portion disposed between said input and said output portions;

first capillary wick means disposed within said housing substantially along a surface of said heat input portion, second capillary wick means disposed within said housing substantially along a surface of said heat output portion, electrically insulating wick means connecting said first and second wick means;

a volatile working fluid contained within said housing and within at least portions of said wick means;

a substantially chemically inert gas contained with said housing and having a dielectric strength greater than the dielectric strength of said fluid when in the vapor state at a predetermined operating temperature, said gas also having a boiling point below that of said fluid; and

means for enhancing separation of said fluid in the vapor state and said gas when heat is being transferred from said heat input portion to said heat output portion by means of said fluid.

2. A heat pipe according to claim 1 wherein said fluid is selected from the group consisting of Dowtherm A, FC43, Dowcorning 200, Freon 13, and Freon 12; and said inert gas is selected from the group consisting of N_2 , SF_6 , C_3F_8 , C_4F_8 , 8, C_4F_{10} and C_2F_6 .

3. A heat pipe according to claim 1 wherein the volatile working fluid contained within said housing is sufficient to substantially saturate each said wick means, and the quantity of said inert gas disposed within said housing is sufficient to maintain electrical insulation between said heat output portions at said operating temperature.

4. A heat pipe according to claim 1 wherein the last named means is an interface shield disposed within said output portion of said housing.

5. A heat pipe according to claim 1 wherein the last named means includes a chamber spaced from but operatively coupled to said heat output portion such that said gas may pass from said housing into said chamber, whereby during the operation of said heat pipe said inert gas substantially resides in said chamber and said working fluid substantially resides in said housing.

6. A heat pipe comprising:

a hermetically sealed housing of substantially tubular shape having a heat input portion and a heat output portion and an electrically insulating portion disposed between said input and said output portions;

first capillary wick means disposed within said housing substantially along a surface of said heat input portion, second capillary wick means disposed within said housing substantially along a surface of said heat output portion, electrically insulating wick means connecting said first and second wick means;

a volatile working fluid contained within said housing and within at least portions of said wick means;

a substantially chemically inert gas contained with said housing and having a dielectric strength greater than the dielectric strength of said fluid when in the vapor state at a predetermined operating temperature, said gas also having a boiling point below that of said fluid;

a chamber annularly disposed around the longitudinal axis of said housing and extending both radially outwardly of and longitudinally beyond said housing;

wall means spaced from the outer surface of said housing for forming in conjunction therewith a cooling channel for allowing the removal of heat from said housing; and throat means extending into said channel for providing a passageway for the flow of inert gas and working fluid between said housing and said chamber.

7. A heat pipe comprising:

a hermetically sealed housing of a substantially tubular shape having a heat input portion and a heat output portion and an electrically insulating portion disposed between said input and said output portions;

first capillary wick means disposed within said housing substantially along a surface of said heat input portion, second capillary wick means disposed within said housing substantially along a surface of said heat output portion, first electrically insulating wick means connecting said first and second wick means;

a volatile working fluid contained within said housing and within at least portions of said wick means;

a substantially chemically inert gas contained with said housing and having a dielectric strength greater than the dielectric strength of said fluid when in the vapor state at a predetermined operating temperature, said gas also having a boiling point below that of said fluid;

a chamber annularly disposed around the longitudinal axis of said housing and extending both radially outwardly of and longitudinally beyond said housing;

wall means spaced from the outer surface of said housing for forming in conjunction therewith a cooling channel for allowing the removal of heat from said housing;

a plurality of throats extending into said channel for providing passageways for the flow of inert gas and working fluid between said housing and said chamber;

third capillary wick means disposed within said chamber and said throats, substantially along a surface of said chamber and of said throats, said third capillary wick means being connected to said second capillary wick means; and

second electrically insulating wick means connecting said first and said third capillary wick means.

8. A heat pipe comprising:

a hermetically sealed housing of substantially tubular shape having a heat input portion and a heat output portion and an electrically insulating portion disposed between said input and said output portions;

first capillary wick means disposed within said housing substantially along a surface of said heat input portion, second capillary wick means disposed within said housing substantially along a surface of said heat output portion, first electrically insulating wick means connecting said first and second wick means;

a volatile working fluid contained within said housing and within at least portions of said wick means;

a substantially chemically inert gas contained with said housing and having a dielectric strength greater than the dielectric strength of said fluid when in the vapor state at a predetermined operating temperature, said gas also having a boiling point below that of said fluid;

a chamber annularly disposed around and substantially longitudinally coextensive with said housing, said chamber and said housing forming a cooling channel for allowing the removal of heat from said housing;

a plurality of throats extending radially outwardly from said housing and into said channel for providing a passageway for the flow of inert gas and working fluid between said housing and said chamber;

third capillary wick means disposed within said chamber and said throats substantially along a surface of said chamber and of said throats, said third capillary wick means being connected to said second capillary wick means; and

second electrically insulating wick means connecting said first and said third capillary wick means.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,563,309

Dated February 16, 1971

Inventor(s) Algerd Basiulis

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

- Col. 1, line 17, "gray" should be --gravity--.
line 37, after "arrangements" insert --are--.
- Col. 2, line 16, after "be" insert --in--.
- Col. 3, line 50, after "fluids" insert --are:--.
line 58, after "temperature" (first occurrence) insert --range--.
- Col. 4, line 14, "hat" should be --heat--.
line 68, delete "Since the heat pipe" (first occurrence).
- Col. 5, line 75, " 241" " should be --248"--.
- Col. 7, line 36, after "C₄F₈" delete "8".
line 37, "C₄F₁₀O" should be --C₄F₁₀--.
line 42, after "heat" insert --⁴input and said heat--.

Signed and sealed this 26th day of October 1971.

EAL)
test:

WARD M. FLETCHER, JR.
Testing Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents