

United States Patent

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[54] UNILATERAL HEAT TRANSFER APPARATUS 6 Claims, 3 Drawing Figs.

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165/80, 165/105
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[50] Field of Search 165/105,
80, 32

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ABSTRACT: Unilateral heat transfer apparatus comprises an evacuated heat transfer chamber wherein the evaporator surface is covered with a suitable capillary structure. Heat added to the evaporator vaporizes a working fluid and the vapors move to a condenser where they give up their heat of vaporization and condense. The condensate is returned by gravity to the capillary structure. The device conducts heat readily in one direction but has a high resistance to heat flow in the opposite direction.

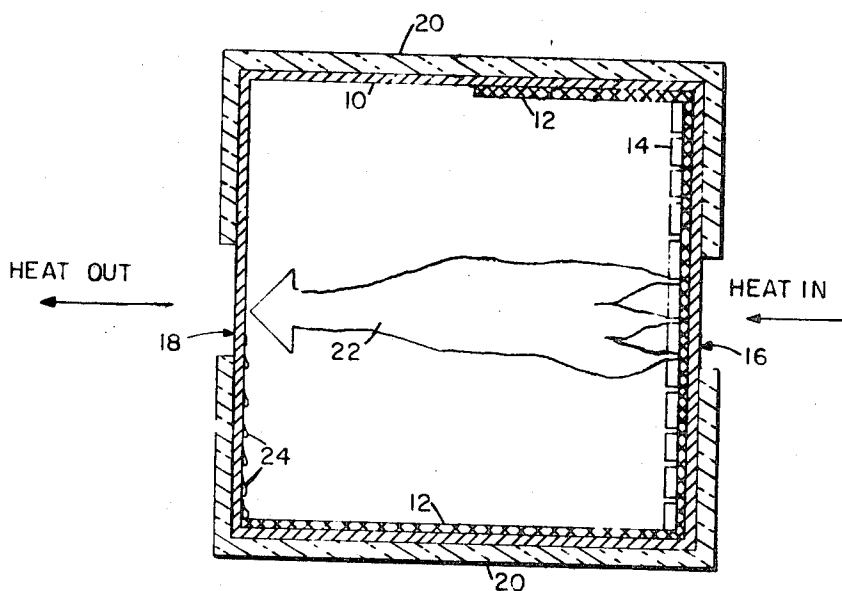


FIG. 1

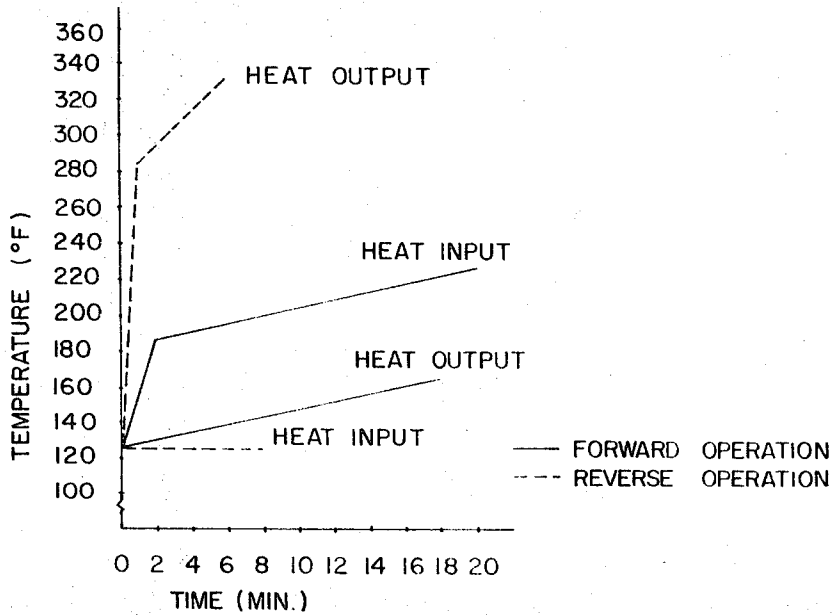
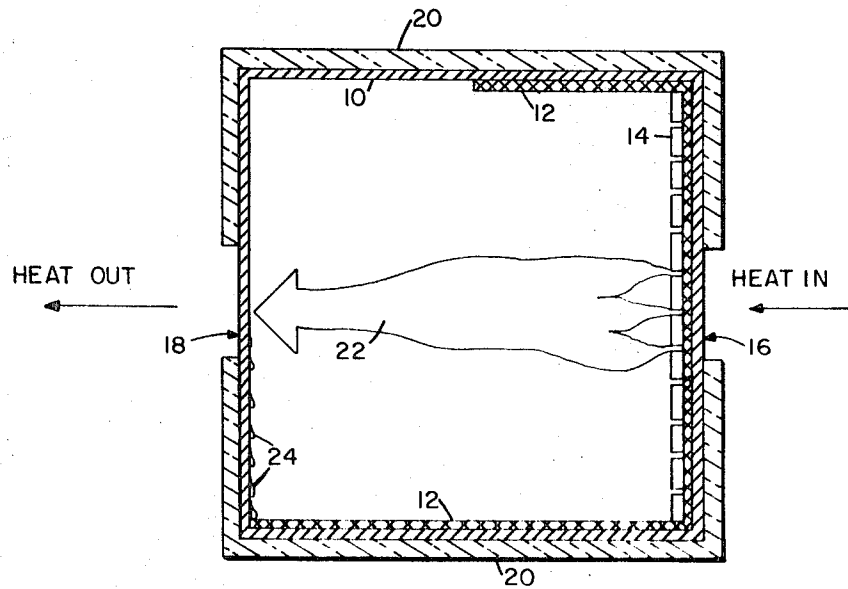


FIG. 2

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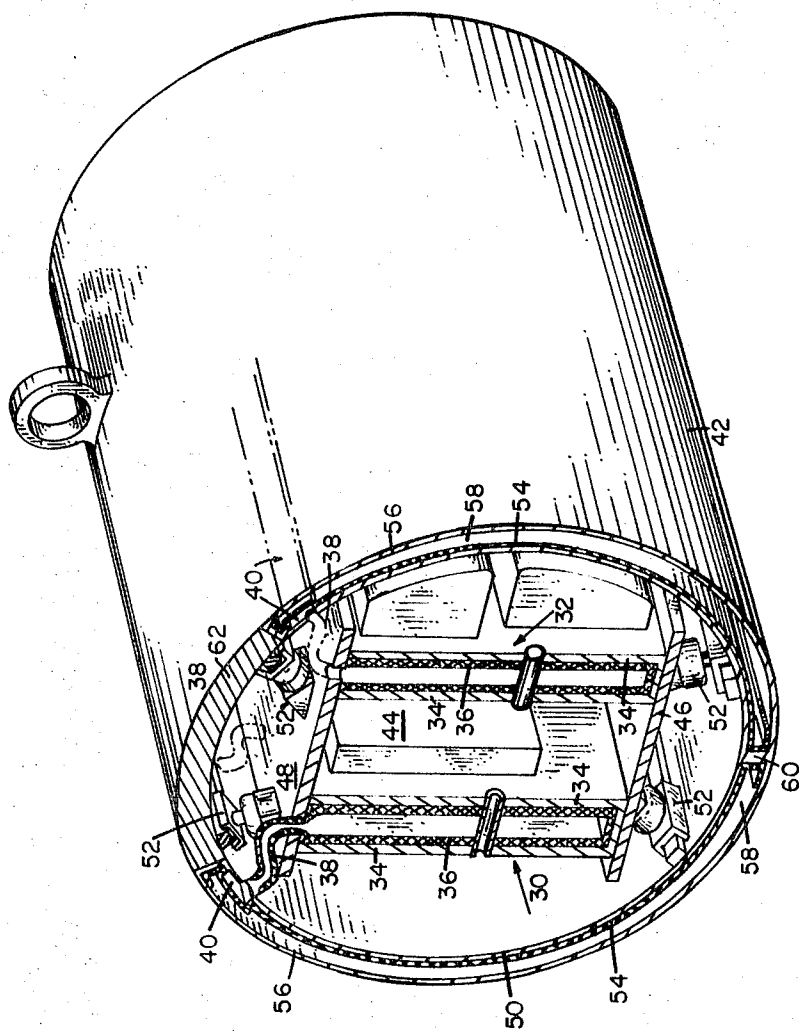


FIG. 3

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UNILATERAL HEAT TRANSFER APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to the field of heat transfer systems and more particularly to a directional heat pipe.

2. Description of the Prior Art

The heat pipe is a bilateral heat transfer device, relatively independent of gravity, which is capable of transferring large quantities of heat with a very small temperature difference between the heat source and heat sink. In its essence the heat pipe comprises a closed, evacuated chamber having its inside walls lined with a capillary structure, generally a wick, saturated with a volatile fluid. The fluid is evaporated from the wick in an evaporator section at one end of the heat pipe and condenses back to the liquid state in the condenser section at the opposite end. Capillary action is the force which causes the condensed working fluid to return to the evaporator section to complete the transfer cycle. A heat pipe is generally connected between a source of given heat flux and an infinite heat sink at a given temperature. This arrangement has proven quite satisfactory in many applications where the heat sink temperature is naturally lower than that of the heat source or where such a temperature differential may be readily maintained by artificial means. There are, however, a number of potential applications for the heat pipe wherein the bilateral heat transfer character of the heat pipe is clearly undesirable. One specific example of this drawback is encountered in cooling the electronic equipment of high-speed aircraft. At high Mach numbers aircraft skin surfaces are aerodynamically heated and operate to pump heat back into the system that is to be cooled by the heat pipe.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to provide a new and novel unilateral heat transfer system.

It is another object of the present invention to provide apparatus of the above-described character using heat pipe principles.

It is an additional object of the present invention to provide apparatus of the above-described character which is gravity dependent in its operation.

These and other objectives of the present invention are achieved by providing an evacuated tube having its interior surfaces with the exception of the heat output or condenser section covered with a wicking material. Heat added to the evaporator produces vaporization of a volatile liquid from the wick and the vapors travel from the evaporator to a condenser under a slight pressure gradient. The removal of the latent heat of vaporization at the condenser causes the vapor to condense and the condensate returns by gravity to the region of the wick whereby it is returned to the evaporator to complete the cycle. Since there is no wicking material disposed adjacent the heat output end of the device, a heat source near the output does not reverse the operation of the invention and flow of heat back into the object to be cooled is inhibited.

The foregoing as well as other objects, features and advantages of the present invention will become more apparent from the following detailed description taken in conjunction with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional illustration of a unilateral heat pipe in accordance with the present invention.

FIG. 2 is a graph illustrating the relative forward and reverse heat conductivity of the apparatus of FIG. 1.

FIG. 3 is a three-dimensional cross section view of an embodiment of the present invention adapted to cooling avionics equipment.

DESCRIPTION OF PREFERRED EMBODIMENTS

Turning now to FIG. 1 the present invention is schematically illustrated in its fundamental form. A closed evacuated container 10 has a capillary structure in the form of a wick 12 disposed on the inside surface of the evaporator or heat input end. A perforated metal plate 14 operates to hold the wick 12 in place yet allow evaporation of a volatile liquid. With the exception of the heat input and output surfaces 16 and 18 respectively the remainder of the apparatus may be covered with a layer 20 of insulating material to confine the transfer of heat to these areas. In the majority of applications this insulation is not required and is not necessary for proper operation.

When heat is applied to the heat input surface 16 the liquid in the wick 12 is vaporized and the vapors 22 travel toward the cooler heat output surface 18 under a slight pressure gradient. The removal of heat at the heat output surface 18 causes the vapor to condense and the condensate 24 returns by gravity to the wick 12 which provides a path via which the condensed working fluid returns to the heat input or evaporator by capillary action.

It will be seen, however, that if the heat output surface 18 is of a higher temperature than the input surface 16 the apparatus of the present invention offers a high resistance to heat flow. Since vapor is a poor thermal conductor any heat transfer in the reverse direction from heat output 18 to input 16 takes place very slowly. The marked difference in the forward and reverse heat transfer characteristics of the present invention is graphically illustrated in FIG. 2. These data were taken by the applicant during the testing of the actual apparatus of the invention as shown in FIG. 1. The solid lines shown in FIG. 2 represents the surface temperatures of the heat input and output surfaces 16 and 18 as a function of time for operation of the invention in the forward direction. The temperature difference between the heat input and output surfaces was found to be approximately 60°. The heat output surface was at saturation temperature while the input is relatively higher, since to boil the working fluid temperatures higher than saturation are required. A large portion of the temperature difference, however, may be eliminated by providing improved contact between the capillary structure and container such as by using grooves cut in the interior container walls as the capillary structure. The dashed lines shown in FIG. 2 illustrate the high resistance provided by the present invention to reverse heat flow. The heat output surface 18 was heated to slightly under the melting point of the solder bonding a test thermocouple (not shown) to the surface and the heat input surface 16 exhibited a negligible temperature rise.

FIG. 3 is a three-dimensional view with portions cut away of an embodiment of the present invention which is particularly well adapted to provide cooling of avionics apparatus on high-speed aircraft. This embodiment may comprise two compound heat transfer systems. The first system, two of which, 30 and 32, are illustrated, includes a closed rigid evaporator container 34 having its inside surfaces covered with a wick 36. A plurality of flexible wick sections 38 are connected to wick-lined heat sink channels 40 which are disposed longitudinally in but isolated by a vapor space 58 from the surface of a double-walled container 42 or aircraft skin in which the electronics 44 to be cooled are carried. The heat transfer systems 30 and 32 are mounted between plates 46 and 48 which are in turn secured to the inner wall 50 of the double-wall container 42 by a series of brackets 52. The outer surface of the inner wall 50 is covered with a suitable wicking material 54 and separated from the outer wall 56 of container 42 by a vapor space 58 and thus comprises the second or outer heat transfer system.

In operation at airspeeds when the temperature of the outer wall 56 is lower than the operating temperature of the electronic components 44 heat is extracted from the components at their base which vaporizes a volatile working fluid (not shown) from the wick 32 of the first or inner heat transfer system. The vapors travel under slight pressure through the

flexible sections 38 into the heat sink channels 40. The vapors give up their heat of vaporization in the heat sink channels, condense and return by gravity to the flexible wick sections 38 where gravity flow is augmented by capillary flow back to the evaporator container 34. Movement of the vapors from the flexible wicking sections 38 to the heat sink channels 40 produces evaporation of working fluid from the upper portions of wick 54. This vapor moves across the vapor space 58 and condenses on the inner surface of the outer wall 56 of the double-walled container 42. Heat is thus liberated to the exterior environment, the condensate flows by gravity to the bottom of the vapor space 58 and is returned to the evaporation area through wick 54 by capillary action. In an alternative embodiment the flexible wicking sections may simply be contiguous with the wick 54. In such an arrangement the vapors would pass through the flexible sections 38 into the vapor space 58 and condense on the inner surface of the outer wall 56.

When airspeed increases to the point that the temperature of the outer wall 56 exceeds that of the electronic components 44 the outer heat transfer system acts as a thermal diode. Since very little liquid is available at the inner surface of the outer wall 56 any heat in order to reach the inside wall 50 of the container 42 must be transferred through the vapor space by conduction and convection. As discussed above with reference to FIGS. 1 and 2 this results in a much slower rise in the temperature of the internal electronics. The solid portions 60 and 62 of the container 42 are obviously necessary to the structural integrity of the apparatus in an airborne environment, however, their heat transfer properties are negligible when compared to the efficient unilateral cooling provided by the double-walled thermal diode construction of the remainder of the container.

It will thus be seen that the applicant has provided a new and improved unilateral heat transfer system based upon heat pipe principles. The apparatus of the invention conducts heat efficiently in one direction but offers a high resistance to heat flow in the opposite direction. Since certain changes in the above-described construction will become apparent to those skilled in the art it is intended that all matter contained in the foregoing description or shown in the appended drawings shall

be interpreted as illustrative and not in a limiting sense.

Having described what is new and novel and desired to secure by Letters Patent, what is claimed is:

1. Unilateral heat transfer apparatus comprising
 - a closed evaporative heat transfer chamber having an evaporator portion and a condenser portion,
 - a volatile working fluid disposed within said chamber, and
 - a capillary structure disposed on the interior surfaces of said chamber exclusive of said condenser portion thereof and extending from said evaporator portion to a point beneath said condenser portion,
 whereby said working fluid condensing at said condenser portion flows by gravity to said capillary structure and heat applied to said evaporator portion is conducted by evaporative heat transfer to said condenser portion and heat applied to said condenser portion is substantially prevented from transfer to said evaporator portion.
2. Apparatus as recited in claim 1 wherein said capillary structure is a wick disposed in heat transfer relation with said chamber.
3. Apparatus as recited in claim 1 wherein said capillary structure comprises a plurality of grooves integrally formed in the walls of said chamber.
4. Apparatus as recited in claim 1 further including means for mounting electronic components in heat transfer relation with the evaporator portion of said chamber.
5. Apparatus as recited in claim 4 wherein said evaporator portion of said chamber comprises a wick-lined rigid chamber and a flexible wick-lined segment forming a continuous chamber therewith, said condenser portion comprises a double-walled container having a vapor space between said walls, having a wick disposed on the outer surface of the inner wall, and having the outer surface of the outer wall thereof in heat transfer relation with a heat sink, and said components are mounted on the exterior of said rigid chamber.
6. Apparatus as recited in claim 5 wherein said vapor space is contiguous with said evaporator chamber.

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