

[72] Inventors William J. Levedahl;
Sidney Frank, both of Baltimore, Md.
[21] Appl. No. 772,954
[22] Filed Nov. 4, 1968
[45] Patented Aug. 31, 1971
[73] Assignee Isotopes, Inc.
Westwood, N.J.

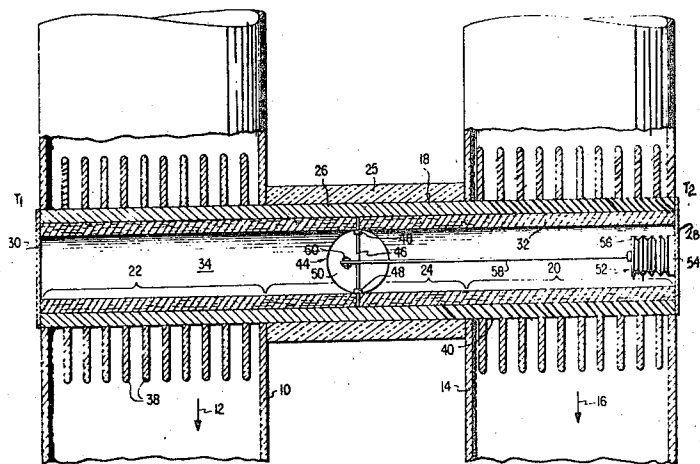
[54] VALVED HEAT PIPE
4 Claims, 1 Drawing Fig.

[52] U.S. Cl. 237/9,
237/12.3 R, 165/32, 165/105
[51] Int. Cl. B60h 1/02
[50] Field of Search 237/9, 12.3;
165/32, 105

References Cited			
UNITED STATES PATENTS			
Re.18,110	6/1931	Vernet	237/12.3 W
1,143,380	6/1915	Gibson	326/93 A UX
2,255,543	9/1941	Fisher	236/34
2,529,915	11/1950	Chausson	165/105 X
3,399,717	9/1968	Cline	165/105 X
3,402,761	9/1968	Swet	165/105 X
3,414,050	12/1968	Anand	165/105 X
3,489,203	1/1970	Fischell	165/105 X

Primary Examiner—Edward J. Michael
Attorney—Fleit, Gipple & Jacobson

ABSTRACT: A selectively operated mechanical valve within the vapor phase passage of a heat pipe to control the isothermal transfer of thermal energy..



VALVED HEAT PIPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of heat pipes for transporting thermal energy in an essentially isothermal manner from a heat source to a heat sink, and more particularly, to a heat pipe which may be selectively operated depending upon the temperature of either the heat source at the evaporator section of the heat pipe or the heat sink at the condenser section.

2. Description of the Prior Art

Heat pipes have recently come into vogue and comprise in their simplest form a closed container, normally metallic, employing on the inner surface a capillary structure which is essentially saturated with the liquid phase of a working fluid. The heat pipe transfers heat, almost isothermally from one point on the external surface to any other point by a vaporization-condensation cycle. The majority of heat pipes fabricated to date are tubular and use screen or formed grooves as the capillary structure, which extends the length of the heat pipe inner wall. A condensed liquid moves, by capillary action, from the condenser surface to the evaporator surface while the vapor phase of the working fluid passes in the opposite direction through a central void region.

Thus, the vapor phase passes unimpeded through the central void region while the condensed liquid phase passes through the capillary wick or along spaced capillary grooves. In general therefore, the concept of a heat pipe involves a closed container which transports thermal energy by means of latent heat of vaporization and in which condensate is returned from the heat sink to the heat source by capillary forces. Thus, the heat pipe is more effective than a solid conductor as well as being lighter in weight and therefore quite useful in many applications. It also has advantages over a pumped liquid system as it eliminates the moving apparatus of a pump and has no electrical or mechanical power input requirements. Since it does not require gravity for its operation, it is particularly well suited to heat transport applications in space.

Automatic control of a rather sophisticated nature has been suggested for controlling waste heat dissipation by incorporating within the heat pipe, in a preferred form, a noncondensable gas which selectively controls the amount of heat rejecting surface available at the condenser portion or end of the heat pipe. In this respect, as the temperature increases, the noncondensable gas shrinks in volume with respect to the vaporized working fluid, thereby increasing the amount of heat rejection surface at the condenser end of the heat pipe.

SUMMARY OF THE INVENTION

This invention employs a butterfly valve in the vapor space which may be selectively moved to open, to partially open, or to completely closed position to thus inhibit the flow of vapor and materially reduce the transfer of thermal energy. Preferably, a bellows-type thermal motor is mechanically coupled to the butterfly valve and is positioned at either the condenser or evaporator end of the heat pipe to automatically open or close the valve depending upon the temperature in the vicinity of the bellows motor. The butterfly valve is preferably positioned within the vapor passage of an adiabatic heat transport section intermediate of the condenser and evaporator ends of the heat pipe. Alternatively, the bellows motor may have operatively coupled thereto, an electrical resistance heater which is energized by an exterior control signal to selectively actuate the valve. A bimetallic thermal motor may be substituted for the bellows motor, or a magnetic actuator of either the permanent magnet or electromagnetic type may be employed to operate the butterfly valve. This itself, may be formed of a magnetic material.

The valved heat pipe may be advantageously employed for the transport of heat from the exhaust gases of an automobile engine to the engine coolant within the automobile heat

exchanger or to the vehicle occupant compartment circulated air to quickly raise the compartment temperature during engine warmup. When the coolant temperature rises to a prescribed value, the valve automatically closes terminating the auxiliary source of thermal energy for the vehicle heating system.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE is a sectional view of a simplified automotive heating system employing the improved valve heat pipe of the present invention.

BRIEF DESCRIPTION OF THE INVENTION

The automotive system in which the present invention is supplied, is shown in simplified manner to include two primary components, the exhaust manifold 10 in the form of a cylindrical tube which carries the exhaust gas for instance in the direction of arrow 12, while the vehicle further includes an air duct 14 normally positioned behind the engine, at the front end of the vehicle passenger compartment, through which air is circulated as indicated by arrow 16 as a result of vehicle movement or under the positive force of an air-circulating fan or blower (not shown). The present invention is directed to a valved heat pipe indicated generally at 18 which has a condenser end 20 positioned within the air duct 14 and an evaporator end 22 positioned within the exhaust manifold. In conventional heat pipe fashion, a heat transport portion 24 couples the evaporator and condenser ends and is surrounded by thermal insulation 25 to form an essentially adiabatic section or portion of the heat pipe. The heat pipe consists essentially of a metallic container, tubular in form and is provided with condenser end wall 28 and evaporator end wall 30 forming a closed metallic container. Along the inner surface and in contact therewith is a cylindrical capillary structure in the form of a wick 32 which extends the length of the heat pipe from condenser end 20 to evaporator end 22. Thus, there is left a central void region 34 through which passes the vapor phase of a working fluid carried by the heat pipe with the liquid phase moving in the opposite direction through the capillary wick 32. The working fluid comprises a vaporizable liquid (not shown) with the vapor and liquid phases in equilibrium and the liquid phase of the fluid saturating the wick. The heat pipe constitutes a high thermal conductance device and may be therefore used to deliver thermal energy from the evaporator end 22 positioned within the exhaust manifold 10 to the condenser end 20 positioned within the vehicle compartment circulating air duct 14. There is very little concomitant drop in temperature with temperature T_1 at the evaporator or heat source end of the heat pipe being slightly higher than T_2 at the condenser or heat sink end. It is noted that the exterior surface 36 of the heat pipe evaporator section 22 carries a plurality of spaced, radially directed fins 38 to facilitate transfer of heat from the exhaust gases to the heat pipe evaporator section. In like fashion, the external surface 40 of the condenser section 20 is also provided with a plurality of spaced, radially extending fins 42 which facilitate transfer of heat to the circulating air within the air duct 14.

The present invention is directed to the use of a butterfly valve 44 or the like, mounted within the adiabatic heat transport section 18 of the heat pipe for selectively and variably impeding the movement of vapor phase working fluid from the evaporator section 22 to the condenser section 20 of the heat pipe. In this respect, a mounting pin 46 extends transversely of the heat pipe container tube 62. The pin 46 is fixed to the interior casing wall and carries a pair of spaced bearings 48, with the bearings being coupled to circular valve disc 50 thus allowing the valve disc 50 to pivot about the axis of pin 46. The valve disc 50 is pivoted from a fully or partially closed position to the fully open position shown in the present embodiment by a bellows-type heat motor 52 positioned within the condenser section 20 of the heat pipe. In this respect, the left-hand end 54 of the bellows is fixed to wall 28 while the right-hand end

56 is mechanically coupled to the valve disc 50 by shaft 58. To facilitate pivoting of valve disc 50, the shaft 58 is pivotally connected at 60 to the valve disc 50 at a point offset from the pivot axis of the valve disc 50. The valve 44, depending upon its position, limits the flow rate of vapor phase working fluid from the evaporator section 22 to the condenser section 20 and therefore limits the rate of thermal energy transport from the heat source to the heat sink. The valve 44, in order to block the flow of vapor as completely as possible when closed, is located in the adiabatic or insulated section 18 of the heat pipe as shown, where the heat pipe has a well-defined insulated heat transport section. If there is no heat transport section, the valve is preferably located at the interface between the evaporator and condenser. The stationary pin or shaft 46, on which the valve rotates, pierces the wick and may be welded to the container tube 26, or may be spring loaded against the inner surface of the wick.

In the embodiment shown, during engine warmup, with the engine coolant or compartment air being relatively cold, thermal energy is readily transported from the hot exhaust manifold gases at the evaporator end to the condenser end of the heat pipe. Thus, the heat pipe functions in a normal manner with the valve being fully open as shown and delivering heat from the source to the sink at a designed rate. If the temperature of the heat sink or condenser end 20 of the heat pipe increases to a prescribed value, the temperature at which the fluid in the heat pipe is operating will reach a corresponding value, such that its associated vapor pressure will be sufficient to compress the bellows 52. In this way, the valve will begin to close and decrease the transport of thermal energy to the heat sink. If the heat sink temperature continues to rise, the bellows will be compressed still further until the valve is fully closed. At this point, the transfer of heat from the evaporator end 22 to the condenser end 20 will consist solely of conduction in the tube wall 26 and the wick 32 (if the wick is metallic). When the valve 44 is closed, the temperature of the fluid from the evaporator side of the valve rises and approaches the source temperature. Any pressure buildup which may begin, relieves itself by blowing around the valve and through the porous wick, displacing any liquid which may not yet have vaporized. Ultimately, there is no liquid at the evaporator end 22 and only superheated vapor. At the condenser end 20 there is a liquid pool with some local refluxing occurring on the condenser side of the valve to accommodate conducted heat from the evaporator end. The entire pipe is at a single equilibrium pressure determined by the temperature at the condenser end.

The selection of the vaporizable working fluid depends upon the temperature range in which it is desired to operate the heat pipe. Since this range lies between the triple and critical points of water, water is a possible choice as a working fluid. Tapwater may be employed, although tapwater could include gases which would act as noncondensables within the heat pipe 18, and may also include minerals which would clog the wick or other capillary transport means.

As mentioned previously, the temperature T at the condenser end is always slightly less than the temperature T_1 at the evaporator end 22. Therefore, T_2 may be at 150° F. with the thermal drop across that end of the heat pipe such that the temperature within the vehicle compartment is being brought to perhaps 70° F. With temperature T_1 also at essentially 150° F., the exhaust may be 800° F. The vapor pressure throughout the heat pipe is the same and would be that value corresponding to 150° F.

It is important to note that the vapor pressure remains the same throughout the heat pipe regardless of the position of the valve and further, the bellows could be modified insofar as the linkage arrangement is concerned so that the valve is normally closed at low temperature and opens as temperature increases.

This invention provides an effective on-off control with the valve only having to move a slight distance from fully open to partially closed position to produce a pressure drop which

could defeat the flow of heat from evaporator to condenser. Further, the bellows or other thermal operator motor could be positioned within the evaporator end of the heat pipe rather than the condenser end with the same type of linkage connection to the pivotable butterfly valve. While the condenser is shown as positioned within an air duct, it likewise could be positioned within a water coolant passage with the water going directly to the vehicle passenger compartment heat exchanger. For this arrangement the temperature to which the liquid coolant could safely rise would be the controlling value. For instance, if water were used as the automobile engine coolant, when its temperature approached the heat pipe temperature 212° F. T_2 would be somewhat higher, say 300° F., and the vapor pressure corresponding to T_2 would be such as to compress the bellows, close the valve, and stop the delivery of heat from the exhaust gas. Of course, the coolant temperature circulating through the vehicle heat exchanger would be much higher than the actual air passing through the air duct and being circulated throughout the passenger compartment. Thus, while the water temperature may approach 212° F., the air temperature within the air duct must be maintained at a much lower value. With regard to the evaporator end 22 of the heat pipe, it may be positioned within the exhaust manifold 10 or it could be placed within the exhaust pipe, the muffler, or in fact within a formed recess within the engine block. It is preferable that the evaporator section of the heat pipe be positioned as close as possible to the area where heat is produced in the engine, such as in proximity to the engine cylinders.

Instead of a bellows-type thermal motor acting to control the position of the pivotable butterfly valve 44, a substitute thermal motor such as a bimetallic strip type motor may be employed, or in fact, the butterfly valve disc 50 may be formed of magnetic material and actuated externally by the use of an applied permanent magnet or electromagnetic field. For instance, an electromagnetic coil may be wrapped about the heat pipe adiabatic section 24 and together with a spring on the valve itself may be employed to maintain the valve in either open or closed position; whereupon energization of the electromagnetic coil would result in pivoting of the valve to a position at right angles to that offered by the spring bias. In such a case, the electromagnetic coil could be actuated through the use of a thermocouple which provides the electrical energy in response to temperature increase. In the latter case, the only moving part is the valve with the valve being in a sealed, clean, high purity environment at all times.

From the above, it can be seen that the valved heat pipe offers a great number of applications and may be either internally actuated or externally actuated to shut off on decreasing sink temperature or increasing sink temperature. Further, the externally electrically actuated unit may be controlled to shut off, or open in response to a temperature signal from the heat source as well as the heat sink or any other external temperatures or from any outside applied control signal, temperature initiated or not. Further, the valve, rather than being located at the interface between the condenser and evaporator sections or preferably in the adiabatic heat transport section, may be located at some position in either the evaporator or condenser sections if partial operation of either section is desired.

While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A fast-acting automobile heating system for an automobile including an engine, an exhaust manifold and a duct for delivering air to the passenger compartment, said system comprising; a heat pipe having an evaporator section positioned within the exhaust manifold and a condenser section within the air duct, a normally open valve carried by said heat pipe within the heat pipe vapor passage, and thermal motor means carried by said heat pipe vapor passage, and thermal motor means carried by said heat pipe for closing said normally open

5

valve in response to increase in temperature of the heat pipe working fluid, said heat pipe being tubular in configuration, said inner surface of said tubular heat pipe including capillary transport means, said normally open valve comprising a butterfly-type valve disc having a diameter on the order of the inner diameter of said capillary transport structure.

2. The automobile heating system as claimed in claim 1 wherein said thermal motor comprises a sealed bellows motor carried by said condenser section of said heat pipe and operatively coupled to said butterfly-type valve disc.

6

3. The automobile heating system as claimed in claim 2 wherein said valve member is positioned within said thermal energy transport section of said heat pipe, said heat transport section carries adiabatic insulation means and said evaporator and condenser sections include external fins carried by said heat pipe and extending respectively within said air duct and said exhaust manifold.

4. The automobile heating system as claimed in claim 1 wherein said vaporizable working fluid comprises water.

15

20

25

30

35

40

45

50

55

60

65

70

75