NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

N78-17336

MAY 18 1979

REPLY TO ATTN OF: GP

TO: NST-44
~~KSK~~/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	: 3,777,811
Government or Corporate Employee	: TRW, Inc. Redondo Beach, CA.
Supplementary Corporate Source (if applicable)	:
NASA Patent Case No.	: ARC-10,198-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES [✓] NO [ ]

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Henderson

Bonnie L. Henderson

Enclosure

(NASA-Case-ARC-10198) HEAT PIPE WITH DUAL WORKING FLUIDS Patent (NASA) 6 p CSCL 20D N78-17336

Unclas
00/34 05398

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,777,811 Dated December 11, 1973

Inventor(s) Arnold P. Shlosinger

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

On the cover page, change the inventor's name from "Shcosinger" to --Shlosinger-- in both occurrences.

Insert the following within the first paragraph of the specification:

--The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).--

Signed and sealed this 23rd day of April 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

W-1046
ARC-10,198-1

United States Patent [19]

Shcosinger

[11] **3,777,811**

[45] **Dec. 11, 1973**

[54] **HEAT PIPE WITH DUAL WORKING FLUIDS**

[75] Inventor: Arnold P. Shlesinger, Los Angeles, Calif.

[73] Assignee: TRW Inc., Redondo Beach, Calif.

[22] Filed: June 1, 1970

[21] Appl. No.: 42,088

[52] U.S. Cl. 165/105, 165/134
[51] Int. Cl. F28d 15/00
[58] Field of Search 165/105, 134, 107

[56] **References Cited**

UNITED STATES PATENTS

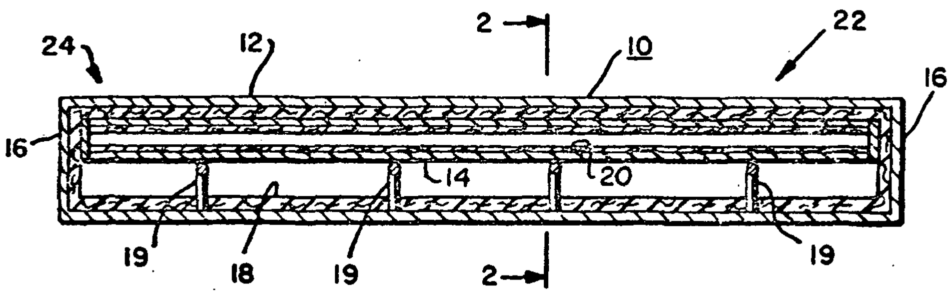
2,372,502	3/1945	Lehane et al.	165/154 X
3,554,183	1/1971	Grover et al.	165/105 X
3,618,660	11/1971	Busse	165/105 X
3,535,562	10/1970	Byrd	310/4
3,429,122	2/1969	Pravda et al.	60/39.51 R
3,450,195	6/1969	Schnacke	165/105 X
3,532,158	10/1970	Hiebert	165/105 X

Primary Examiner—Albert W. Davis, Jr.
Attorney—Daniel T. Anderson, Jerry A. Dinardo and Donald R. Nyhagen

[57] **ABSTRACT**

In a heat pipe containing a main working fluid that normally freezes under low heat loads, an auxiliary working fluid is provided that, although being less efficient than the main working fluid, nevertheless remains liquid at low heat loads when the main working fluid freezes, so as to sustain heat pipe action.

10 Claims, 4 Drawing Figures



PATENTED DEC 11 1973 3,777,811

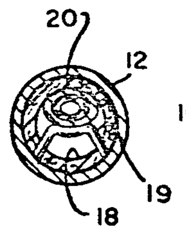


Fig. 2

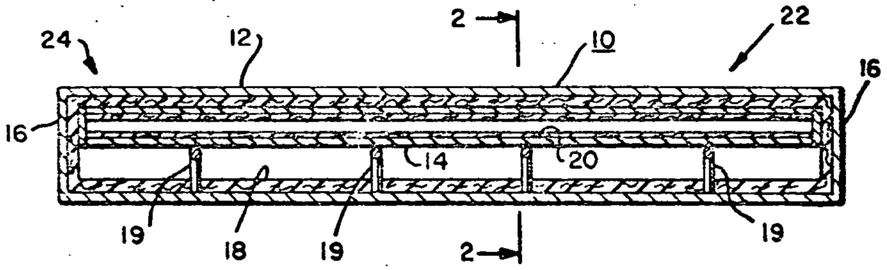


Fig. 1

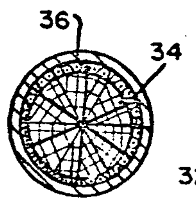


Fig. 4

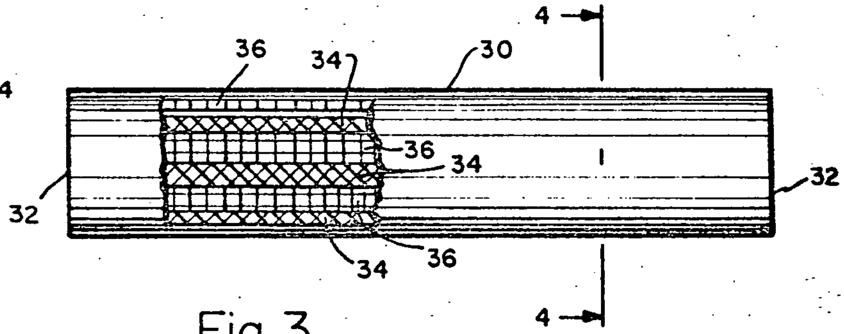


Fig. 3

Arnold P. Shlosinger
INVENTOR

BY Jerry A. Dinardo

AGENT

HEAT PIPE WITH DUAL WORKING FLUIDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to heat pipes generally and more particularly to heat pipes that will continue to function under low heat load conditions.

2. Description of the Prior Art

Heat pipes or heat pipe-type devices can be defined as devices employing closed evaporating-condensing cycles for transporting heat from a locale of heat generation to a locale of heat rejection and using a capillary structure or wick for return of the condensate. Such devices consist of a closed container which may be of any shape or geometry. They often have the shape of a pipe or tube, closed on both ends, and the term "heat pipe" was derived from such devices. The term "heat pipe" is, however, in the present specification and claims used in a more general sense to refer to devices of any type of geometry that are designed to function as described.

In such a device, air or other noncondensible gases are removed from the internal cavity of the container. All interior surfaces are lined with a capillary structure, such as a wick. The wick is soaked with a fluid which will be in the liquid phase at the normal working temperature of the device. The free space of the cavity then contains only the vapor of the fluid, at a pressure corresponding to the saturation pressure of the working fluid at the temperature of the device. If, at any location, heat is added to the container, the resulting temperature rise will increase the vapor pressure of the working fluid and evaporation of liquid will take place. The vapor formed, being at a higher pressure, will flow towards the colder regions of the container cavity and will condense on the cooler surfaces of the wick on the inside of the container wall. Capillary effects will cause the liquid condensate to return to the areas of heat addition. Because the heat of evaporation is absorbed by the phase change from liquid to vapor and released when condensation of the vapor takes place, large amounts of heat can be transported, with very small temperature gradients, from areas of heat addition to areas of heat removal. The foregoing is well-known and heat pipes have been recognized for several years as very effective heat transport devices. They will transport large amounts of heat with small temperature gradients independent of gravity effects, which makes these devices suitable for applications in space.

The requirements for desirable working fluids for heat pipe devices include properties such as high surface tension which will enhance capillary pumping, high heat of vaporization, and a freezing point of the working fluid above the lowest temperature which may occur at the cold areas of the device. It is this last requirement that has severely limited the application of heat pipe-type devices to heat transport in space. Unfortunately, the known more efficient working fluids include the liquid metals and water, which have high freezing points, whereas the lower freezing point fluids such as ammonia, the alcohols, the Freons and cryogenic fluids are less effective and less desirable. Solidification of the working fluid at the cold areas of a heat pipe stops operation of the heat pipe. When freezing occurs in a heat pipe, the vapor pressure in the cold area drops. This results in evaporation of the working fluid in the warmer areas and flow of the vapor to the cold areas. As a result of this process, all the working fluid moves to the areas of the heat pipe which are below the solidification point of the working fluid, and the wick in the warmer areas will be completely deprived of liquid and dry out. Increase of heat flow into the warm areas of the device does not then result in effective transfer of heat to the colder areas. No working fluid in the liquid state is available for evaporation and transport of heat by vapor flow to the colder areas. Theoretical and experimental investigations have shown that once a heat pipe is frozen at its cold areas, only conductive heat transfer in the container wall is available to restart the heat pipe. Very large temperature differences between the warm and cold areas of frozen heat pipes have been observed.

SUMMARY OF THE INVENTION

The principal object of the invention is to overcome the foregoing drawbacks. In accordance with the invention, an efficient working fluid is used as the main heat pipe working fluid at high heat transfer loads. When heat transfer loads diminish to the point where the fluid in the colder areas of the heat pipe solidifies, a low freezing point auxiliary working fluid is available to transfer heat to the cold areas of the heat pipe. Because the large heat flow rates are taken care of by an efficient, although high freezing point working fluid, a low freezing point auxiliary fluid can be used, even if its heat transport capability is relatively poor. Heat flow at a low rate will be maintained. When heat transfer loads increase, the auxiliary working fluid provides enough heat flow to initiate melting of the solidified main working fluid. The main working fluid, after it has been liquified, then returns by capillary action to the warmer areas of the heat pipe where it evaporates and transports additional amounts of heat to the cold areas, further helping in the melting of the working fluid in the cold areas. Thereby, a heat pipe in which the main working fluid has become solid during a period of low heat load is able to start again when heat loads increase.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a longitudinal sectional view of a dual section heat pipe employing two different freezing point working fluids according to the invention;

FIG. 2 is a section taken along line 2—2 of FIG. 1;

FIG. 3 is a side elevational view partly in section of another form of heat pipe employing a two part wick structure and two different freezing point working fluids according to the invention; and

FIG. 4 is a section taken along line 4—4 of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, there is illustrated a dual section heat pipe 10, there being a main, larger, outer section 12 enclosing an auxiliary, smaller, inner section 14. The outer section 12 has a larger cross-section than the inner section 14, but both sections 12 and 14 have the same length. Although the two sections 12 and 14 of the heat pipe 10 are illustrated as each having a circular cross-section, they may be rectangular, square, or of other operable geometry. The heat pipe 10 is hermetically sealed at its ends, as by plates 16, so that the interior of the outer section 12 is isolated from the interior of the inner section 14.

The interior surface of the outer section 12 is lined with capillary material, or a wick 18. Quartz fiber, metal screens, or other woven or sintered materials may be used for the wick 18. The wick 18 may be joined to the surface by means including bonding, soldering, spot welding, or spring tension of the wick material.

The outer surface of the inner section 14 is over its entire length in thermal and physical contact with the wick 18 and is preferably joined thereto. The inner section 14 may likewise be made of copper and may be joined to the wick 18 by means of longitudinally spaced spring wire supports 19 or similar means. Similarly, the interior surface of the inner section is lined with a wick 20, such as quartz fiber, metal screens, or other woven or sintered material joined thereto by means of bonding, soldering, spot welding or spring tension of the wick material.

It is preferable that a substantial outer surface area of the inner section 14 be in contact with the wick 18 of the outer section 12 so as to provide good thermal coupling therebetween. Thus, where the outer section 12 is circular in cross-section, the inner section 14 has preferably a flattened or oval cross-section to afford contact along a wide circular arc of the wick 18. However, other geometrical configurations may be used, provided there is sufficient area of thermal contact between the two sections 12 and 14.

Both sections 12 and 14 are evacuated of all noncondensible gases. Both wicks 18 and 20 are saturated with working fluid. However, two different working fluids are used. The working fluid used in the outer section 12 is chosen for its high efficiency as a thermal transport medium and will be referred to as the main working fluid. Usually, such a working fluid has too high a freezing point to operate properly under the low temperature and low heat load requirements that are met in outer space, for example. Water and some of the liquid metals, such as potassium and lithium, have desirable heat transport qualities that make them suitable for the working fluid in the outer section 12, which serves as the main heat pipe operating section under normal temperature and heat load conditions.

The working fluid in the inner section 14 is selected principally for its low freezing point and secondarily for its heat transport qualities and will therefore be referred to as the auxiliary working fluid. Methyl alcohol, for example, has a freezing point 144°F below that of water at the vapor pressures encountered in a heat pipe and would be suitable for use in the inner section 14. Freon or ammonia would also be suitable.

To illustrate the operation of the heat pipe 10, it is assumed that the environment at the cold end of the heat pipe 10, shown generally at 22, is below the freezing point of the main working fluid in the outer section 12. It is further assumed that under high heat loads, the main working fluid is maintained liquid by the heat transferred to the cold end 22 from the warm end, shown generally at 24, where thermal input energy is applied. The transfer of heat occurs by heat pipe action involving vaporization of the working fluid, transfer of the vapor from the warm end 24 to the cold end 22, condensation of vapor and transfer of heat to the cold end 22, and return of the condensed fluid to the warm end 24 by capillary action.

After a period of such operation, assume that the heat load or input at the warm end 24 diminishes to a point where the cold end 22 of the heat pipe 10 drops in temperature below the solidification point of the main working fluid, and as a result of working fluid freezing at the cold end 22, the wick 18 at the warm end 24 dries out. The lower freezing point working fluid in the inner section 14 is still in the liquid state, even if the main working fluid solidifies. When an increase of heat flow into the warm end 24 of the heat pipe 10 occurs, the heat will cause the auxiliary working fluid in the inner section 14 to vaporize and transport its heat of vaporization to the cold areas of the inner section 14 at the cold end 22. The heat at the cold end of the inner section is transmitted through the wall of the inner section 14 to the wick 18 of the outer section directly in contact therewith and to the solidified main working fluid, thereby melting the latter. As the main working fluid melts and returns to liquid form, it wets the wick 18 and redistributes itself throughout the wick 18. Now that the main working fluid has reestablished its liquid form throughout the wick 18, the main outer section 12 of the heat pipe 10 regains control of heat pipe action.

In a modified version of the heat pipe system above described, advantage is taken of the selective wettability of certain capillary materials or wicks towards different fluids. Capillary action is, of course, dependent on the wettability of the material of the wick by the specific working fluid. The modification described below is based on the realization that many materials are wetted by one liquid but not by others. For example, metallic copper is easily wetted by methyl alcohol but not by water, whereas oxidized copper is easily wetted by both methyl alcohol and water.

Referring now to FIGS. 3 and 4, a main and an auxiliary heat pipe share a common outer closed envelope 30 closed at both ends by plates 32. The interior surfaces of the envelope 30 and plates 32 are lined with alternating strips of two different wick materials 34 and 36 selected for their different wettability properties. The main wick material 34 is constituted by wider strips on the cylindrical surface of the envelope 30. The auxiliary wick material 36 is constituted by narrower strips on the cylindrical surface of the envelope 30. The end plates 32 may be covered with alternate wide and narrow wedges of the main and auxiliary wick material 34 and 36, respectively. Alternatively, the end plates 32 may be covered with the main wick material 34. The main wick material 34 may be oxidized copper mesh, whereas the auxiliary wick material 36 may be copper mesh.

Two different working fluids are provided within the envelope 30. One of the working fluids, such as water, constitutes the main working fluid and readily wets the oxidized copper or main wick material 34 but is repelled by the copper or auxiliary wick material 36. The other working fluid, such as methyl alcohol, constitutes the auxiliary working fluid and readily wets the copper or auxiliary wick material 36.

The combination of main working fluid and main wick material 34 within the envelope 30 can be considered as constituting a main heat pipe, whereas the combination of auxiliary working fluid and auxiliary wick material 36 within the same envelope 30 can be considered as constituting an auxiliary heat pipe.

During normal operation under high heat loads, both working fluids will be in liquid state and function as heat transport media. In condensing from vapor form, the liquid water droplets of the main working fluid are repelled by the auxiliary wick material 36 and will soak only the main wick material 34. The condensing methyl alcohol vapors will soak the auxiliary wick material 36 and may mix in part with the water in the main wick material 34.

In a low temperature environment under reduced heat load conditions, the water will freeze in the main wick material 34, leaving the auxiliary wick material 36 soaked with liquid methyl alcohol. The auxiliary heat pipe will continue to function after the main heat pipe has stopped functioning. Thus, when the heat load increases again, the auxiliary fluid will transport heat to the cold areas, thawing out the frozen water until it all returns to liquid form again. When the water is entirely liquid again, it restores heat pipe action in the main heat pipe which now functions with greater efficiency than the auxiliary heat pipe.

The principal advantage of the invention is that it will permit the application of heat pipe-type devices in situations where, as a result of varying heat flows or of variations in the external environment at the "cold" or "heat rejection" areas of the heat pipe, freeze-up occurs in a working fluid which has a high efficiency for heat transport. In such a device, the large heat loads will be transferred by the main working fluid which has been selected for maximum heat transport capability. When the heat input into the device is reduced and less heat is transferred to the cold areas, the cold areas will drop below the solidification temperature of the main working fluid. Circulation of the main working fluid will cease for the reasons described above. The auxiliary working fluid will then carry the reduced heat transfer loads. Should the heat load now be increased, the auxiliary fluid will provide the needed heat transfer to the cold end of the device to start thawing or melting of the solidified main working fluid and start the process going again. The range of applications of heat pipes and heat pipe-type devices is thereby vastly increased.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A heat pipe structure, comprising:
- a. means forming a first heat pipe wall area of given longitudinal extent;
- b. means forming a second heat pipe wall area joining said first heat pipe wall area substantially along their entire longitudinal extent;
- c. first capillary means covering said first heat pipe wall area;
- d. second capillary means covering said second heat pipe wall area;
- e. said first and second capillary means being in thermal exchange relationship with each other and with said first and second heat pipe wall areas along their entire longitudinal extent;
- f. a first working fluid arranged for transport through said first capillary means but not through said second capillary means;
- g. a second working fluid arranged for transport through said second capillary means;
- h. said first working fluid having a freezing point above the lowest expected operating temperature of said heat pipe structure; and
- i. said second working fluid having a freezing point below the lowest expected operating temperature of said heat pipe structure whereby, during periods when said heat pipe structure is subjected to said lowest operating temperature to cause solidification of said first working fluid with consequent interruption therein of thermal transport action, said second working fluid will remain sufficiently fluid to continue functioning as a thermal transport medium.

2. The invention according to claim 1, wherein said first heat pipe wall area forms a first enclosure means, and said second heat pipe wall area forms a second enclosure means.

3. The invention according to claim 2, and further including means supporting said second enclosure means eccentrically within said first enclosure means.

4. The invention according to claim 2, wherein said first enclosure means comprises a first tube, the interior surface of which is covered with said first capillary means;

said second enclosure means comprises a second tube, the interior surface of which is covered with said second capillary means;

and means joining the exterior surface of said second tube in thermal contact with said first capillary means along contiguous arcuate portions thereof.

5. The invention according to claim 4, wherein said joining means comprises longitudinally spaced support members spring pressed between said first and second tubes along surface portions thereof that are opposite said contiguous arcuate portions where said second tube and said first capillary means are held in thermal contact thereby.

6. The invention according to claim 4, wherein said second working fluid has a freezing point substantially below that of water.

7. The invention according to claim 1, wherein said first and second heat pipe wall areas join to form a single enclosure means, and said first and second capillary means comprise sets of alternating strips covering the interior surface of said enclosure means.

8. The invention according to claim 7, wherein one set of said alternating strips is fabricated of a material that is readily wetted by said second working fluid but that repels said first working fluid;

and wherein the other set of said alternating strips is fabricated of a material that is readily wetted by said first working fluid.

9. The invention according to claim 8, wherein one set of said alternating strips is fabricated of copper and the other set is fabricated of oxidized copper.

10. The invention according to claim 9, wherein said first working fluid consists of water and said second working fluid consists of methyl alcohol.

* * * * *