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METHOD OF MAKING A VAPOR DEVICE
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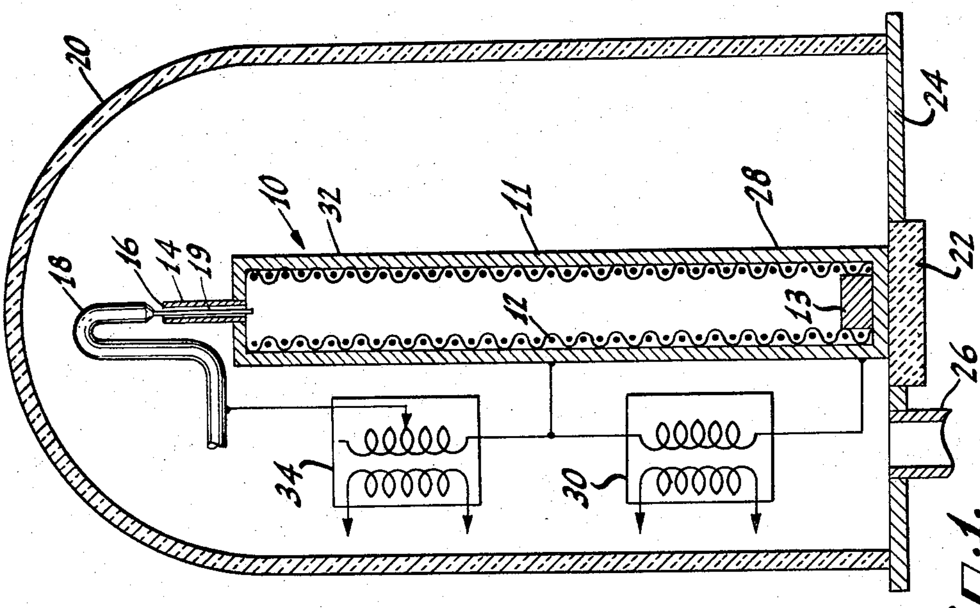

Fig. 1.

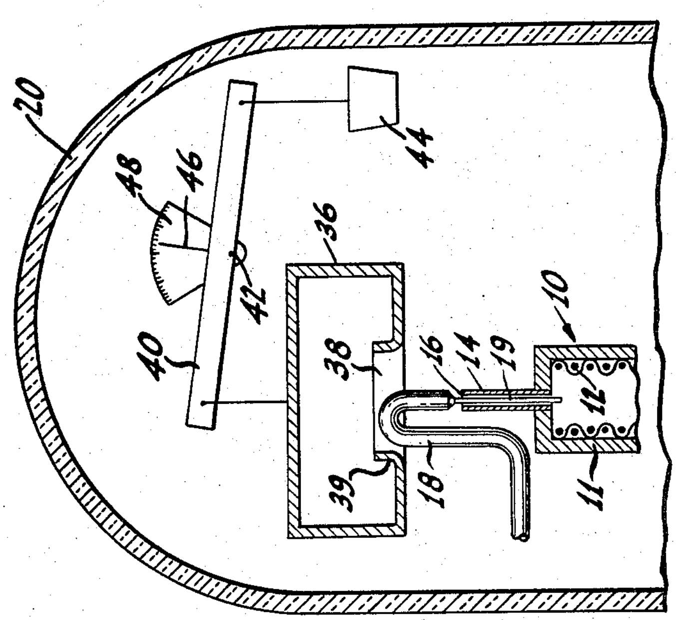

Fig. 2.

Inventor:
WILLIAM B. HALL
L. A. Larsen
Attorney

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METHOD OF MAKING A VAPOR DEVICE

William B. Hall, Lancaster, Pa., assignor to Radio Corporation of America, a corporation of Delaware

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My invention relates to a method of making a vapor device and particularly to a method of evacuating and sealing such devices.

One type of vapor device is a heat pipe which is used to convey heat from a heat source such as a fossil fuel flame, to a heat utilization or dissipation zone. A heat pipe usually comprises a tubular structure having a capillary lining and a vaporizable heat transfer or working medium therein. The vaporizable working medium is selected to have a vaporization temperature at least as high as the operating temperature of the heat pipe. When such operating temperature is about 1400° C., lithium may be used as the working medium.

For most efficient operation of the heat pipe it is desirable that the envelope of the heat pipe as well as the working medium be evacuated of substantially all undesirable foreign gases. Gases within the envelope of the device adversely affect efficiency by collecting in regions where they form insulating barriers to the vapor transport of heat. When such gas collecting regions are formed adjacent to the envelope wall at the heat input zone, the heat input to the heat pipe from the heat source is reduced. When the gases collect on the envelope wall at the heat utilization or dissipation zone, the heat output of the pipe is lessened.

When a heat pipe is designed for operating at a relatively high temperature of about 1400° C., for example, it is desirable for maximum gas evacuation that the heat pipe envelope as well as the working medium be heated to a temperature that is higher than the operating temperature during the evacuating step, and that the envelope be sealed before the temperature is lowered. In this way, evolution of gases from the envelope walls and from the working medium that would normally take place during operation, is avoided and longer high efficiency operation of the heat pipe is assured. It is also desirable to compensate for loss of working medium during the outgassing and evacuating step.

After the device envelope has been evacuated of undesired gases, it is desirable to seal the envelope while at the aforementioned higher temperature and while connected to an exhaust system.

Accordingly, it is an object of the invention to outgas the walls of the envelope of a vapor device as well as the working medium therein, at a temperature at least as high as the intended operating temperature of the device while preserving an amount of working medium in the device required for efficient operation of the device.

Another object is to hermetically seal the device envelope in a convenient manner after gases therein, including gases evolved during the outgassing step, have been evacuated.

In carrying out a preferred embodiment of my novel method, a device, e.g., a heat pipe with a working medium therein is heated at least to its intended temperature of operation. This temperature serves to outgas the heat pipe envelope and the working medium therein. While at such temperature, the heat pipe envelope is evacuated to a reduced pressure which may be about 10^{-6} torr. The evacuation is preferably effected through an elongated passageway terminating in an orifice in one end of the heat pipe envelope. A wire or rod of such diameter as to nearly close the orifice may be positioned in the passageway. To prevent condensation of the working medium in the region of the orifice, the passageway walls as well as the wire, are heated to a temperature higher than the temperature of operation of the device. The length of the passageway helps to control the flow of working medium therethrough as a consequence of frictional losses therein.

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During the outgassing operation, some loss of the working medium is unavoidable. I have provided a preferred way for determining the magnitude of the relatively small amount of working medium lost during the outgassing and evacuating step. I initially provide an excess amount of the working medium in the heat pipe and when this amount has been lost I seal the envelope so that an optimum quantity of working medium remains in the heat pipe after the evacuating and sealing steps have been completed.

Further objects and features of my novel method will become apparent as the present description continues.

In the drawing, to which reference is now made for an illustrative example of my novel method:

FIG. 1 is a sectional view of a heat pipe associated with apparatus for outgassing, evacuating and hermetically closing the envelope thereof; and

FIG. 2 is a fragmentary sectional view, partly schematic, of means for determining the amount of working medium lost during a practice of my method.

In practicing my novel method, as shown in FIG. 1, a heat pipe **10** having an envelope **11** and a capillary lining **12** is provided with a desired quantity of working medium **13** such as lithium. The wall of envelope **11** has a thickness of about 0.030 inch in one example. At one end of the envelope **11** is a reduced area extension or nipple **14** defining an elongated passageway terminating in an orifice **16**. The envelope **11** and the nipple **14** may be made of a refractory metal such as molybdenum. The capillary lining **12** may be made of a molybdenum wire mesh having capillary openings.

A wire or rod **18** has a thinned-down portion **19** extending into the orifice **16**. The wire portion **19** has a cross sectional area for nearly closing the orifice **16**. The wire **18** including portion **19** is made of a metal having a higher melting point temperature than the walls of the orifice **16**. Where the passageway walls are made of molybdenum having a melting point temperature of 2620° C. the wire **18** may be made of tungsten having a melting point temperature of 3370° C. In this way the wire **18** prevents collapse of the nipple when the walls thereof are heated to a sealing temperature.

In one example, the portion **19** of wire **18** has a diameter of about 0.060 inch while orifice **16** has a diameter of about 0.062 inch. This provides an 0.001 inch annular space around the wire portion **19**. The wall thickness of the nipple is about 0.04 inch and its length is about 0.5 mil. This wall thickness is significant in that it is sufficiently small to avoid the formation of an undesirably large heat sink in the nipple and provides desired resistance for heating by I^2R losses. Heat retaining capacity of the nipple heat sink is increased with increase in the mass of the nipple **14**. If the heat sink is large enough it may draw heat away from the inner surface region of the orifice to such a degree that the wire portion **19** will melt before the inner surface region melts. Such melting of the wire **19** is objectionable in that it may not result in the formation of a desired closing meniscus.

In practicing my method, the heat pipe **10** is supported within a bell jar **20** where the heating of the heat pipe **10** is accomplished by electric current losses therein. The heat pipe may be supported on an insulating disc **22**, made of ceramic for example and hermetically sealed to a base **24** upon which the bell jar **20** rests and to which it is hermetically sealed. The bell jar **20** is evacuated to a pressure of about 10^{-6} torr through an exhaust tubulation **26**.

The heat pipe 10 has a heat input region 28 which may be heated electrically by I^2R losses as by a transformer 30 connected to a suitable electrical power supply, not shown. The heat input region 28 may be heated to the operating temperature, i.e., about 1400° C. by a power input thereto of 2500 amperes at 1 volt, for example. Preferably, during a practice of my method, the heat input region is heated to a temperature higher than the operating temperature of the device, to assure desired release of substantially all gases from the wall 10 of the device, the capillary lining 12 and the working medium 13. Such higher temperature may be about 1600° C., requiring a power input of 2950 amperes at 1.75 volts.

The heat pipe also has a heat utilization or dissipation zone 32 which is heated by the condensation therein of the working fluid. This zone of the heat pipe includes the nipple 14, heated by the electrical current from a variable transformer 34 connected to a suitable power supply, not shown. The nipple 14 is heated to a temperature higher than the temperature to which the heat input zone 28 is heated. Such higher temperature may be about 2000° C. and is produced by a power input to the heat pipe from the transformer 34 of 275 amperes at 1.9 volts. This high temperature prevents the condensation of the working fluid in the orifice which would be expelled from the heat pipe at a high rate. With only vapor in the nipple, the rate of loss of working fluid can be controlled to a degree by the temperature of the nipple. The temperatures referred to are associated with the use of lithium as a working medium. Where other working media having operating temperatures other than about 1400° C. are used, the temperatures referred to should be modified to preserve the ratio of such temperatures to the operating temperature as indicated in the foregoing.

The higher temperature at the nipple 14 is desirable to prevent condensation of the working medium therein, particularly in the annular orifice region defined by the wire 19 and the nipple 14. Such condensation would increase the outflow of working medium through the orifice to an objectionable degree.

For closing the annular orifice referred to, the output of the transformer 34 is increased to 400 amperes at 3 volts. This softens the wall of the nipple 14 and causes it to form a meniscus that bridges the annular space between the wire 19 and the inner surface of the nipple. When the temperature of the nipple is subsequently reduced to a value below the softening point of the nipple 14, the meniscus hardens and forms a permanent seal.

During operation of the heat pipe 10, the amount of working medium therein should be sufficient to fill the capillary lining 12. This assures maximum efficiency of the device. Therefore, in practicing my novel method, the initial charge 13 of lithium is in sufficient quantity to permit loss of working medium through the annular orifice 16 during the evacuation and outgassing of the heat pipe, and yet leave a sufficient quantity of working medium in the heat pipe to fill the capillary lining thereof after the orifice 16 has been sealed. In one example, the quantity of lithium as the working medium required to fill the capillary lining 12 is 6 grams and the amount of the initial lithium charge 13 is 10 grams. The charge 13 therefore includes an excess of 4 grams of working medium above that required for high efficiency operation of the device.

My novel method provides a means for determining accurately when the aforementioned excess of working medium has been permitted to escape through the orifice 16 during the outgassing and evacuating operation. As shown in FIG. 2, this determination may be effected with the aid of receptacle 36 having an opening 38 positioned slightly above the orifice 16. Around the opening 38 is an upturned lip 39 having a function to be described. The receptacle 36 is supported adjacent to one end of a lever 40 fulcrumed at 42 and having a weight 44 adjacent to

the other end. A pointer 46 fixed to the lever 40 is adapted to traverse an indicator 48 when the lever is annularly moved on fulcrum 42. The indicator has calibrations thereon indicating the magnitude of angular deflection of the lever 40. The weight 44 is equal in magnitude to the sum of the weight of the receptacle 36 when empty and the weight of the excess working medium that is permitted to be lost from the pipe 10 during its outgassing and evacuation.

As working medium vapor escapes from the orifice 16 during a practice of my method, it rises into the receptacle 36 and condenses on the walls thereof. The condensate may flow to the bottom of the receptacle where it is prevented from escape through the opening 38 by the upturned lip 39. The working medium so accumulated in the receptacle 36 adds to the weight thereof.

When the total weight of the receptacle 36 and the working medium collected therein equals the value of the weight 44, the pointer 46 moves to a position opposite a calibration on indicator 48 indicating such equality. At this time, all of the excess working medium has been lost from the heat pipe. To prevent further loss, the transformer 34 is adjusted to provide electrical power of 400 amperes at 3 volts to the heat utilization zone 32 that is sufficient to soften the nipple 14 and to produce a meniscus bridging the space between it and the wire 19. The transformer 34 is then adjusted to a lower power output which results in a hardening of the meniscus and sealing of the device.

If the pressure of the working fluid within the device exerts a force on the meniscus greater than the capillary force associated with the material forming the meniscus, the material will be forced out of the orifice preventing a closure. If this happens it is necessary to reduce the temperature of the heat pipe until the pressure exerted on the meniscus by the working fluid is less than the capillary force. To obtain the best possible vacuum in the heat pipe it is desirable to close the orifice when the heat pipe is at its operating temperature. This is not necessary however if a higher pressure of the impurity gases can be tolerated, since the orifice can be closed in the same manner even if no other heat is applied to the heat pipe than that by the orifice heater.

It will be appreciated from the foregoing that I have provided a novel and advantageous method of outgassing, evacuating and sealing a vapor device.

I claim:

1. Method of outgassing and evacuating a vapor device having an envelope, said envelope including a heat input region and a heat dissipation region and containing a vaporizable heat transfer medium, said envelope at said heat dissipation region including walls defining an orifice for venting gases from said envelope, said method comprising:

(a) evacuating said envelope,

(b) heating said heat input region to a first temperature that is at least as high as that required for vaporizing said heat transfer medium, whereby said heat transfer medium urges said gases through said orifice,

(c) heating said heat dissipation region to a second temperature higher than said first temperature but below a third temperature at which a wall of said orifice softens, whereby that portion of said heat transfer medium passing through said orifice is preserved in the vapor state for preventing excess loss of said medium through said orifice, and

(d) heating said heat dissipation region to said third temperature, whereby said wall of said orifice softens and closes said orifice.

2. A method according to claim 1 and wherein said softened wall of said orifice is hardened for effecting a permanent seal of said orifice.

3. A method according to claim 1 and wherein the difference between said first temperature and said second temperature is about 400° C.

4. A method according to claim 1 and wherein said first temperature is about 200° C. higher than the operating temperature of said vapor device.

5. A method according to claim 1 and wherein said first temperature is about 15% higher than the operating temperature of said device, said second temperature is about 30% higher than said operating temperature, and said third temperature is equal to the meniscus forming softening temperature of a wall defining said orifice.

6. A method according to claim 1 and wherein said heating steps are effected by electric current losses in portions of the walls of said vapor device and in the walls defining said orifice.

7. Method of outgassing and evacuating the envelope of a vapor device comprising:

(a) introducing into said envelope a heat vaporizable heat transfer medium in an amount in excess of that required for operation of said device,

(b) simultaneously evacuating said enevelope and heating said medium at least to its vaporization temperature, whereby a portion of said medium is evacuated from said device, and

(c) stopping evacuation of said envelope when the weight of said evacuated portion of said medium equals the weight of said excess of said medium.

8. In a method of outgassing and evaculating a vapor device having an excess of vaporizable working medium therein comprising:

(a) outgassing and evacuating gases and a portion of said working medium from said device,

(b) collecting and weighing the evacuated portion of said working medium, and

(c) stopping the evacuation of said device when the weight of said collected portion of said working medium substantially equals the weight of said excess of said medium.

9. Method of sealing an evacuated device having a wall of relatively low melting point metal defining an elongated passageway terminating in an orifice, comprising:

(a) inserting in said passageway a wire made of a relatively high melting point metal and having a diameter for nearly bridging opposite walls of said passageway,

(b) heating said wall to a temperature to cause said wall to soften and contact all sides of said wire while preserving said wire from softening, and

(c) cooling said wall for hardening the same including the portion thereof contacting said wire, for sealing said orifice.

10. A method according to claim 9 and wherein a meniscus is formed between and contacting said wire and wall when said wall is heated to said temperature.

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THOMAS H. EAGER, *Primary Examiner.*

U.S. Cl. X.R.

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