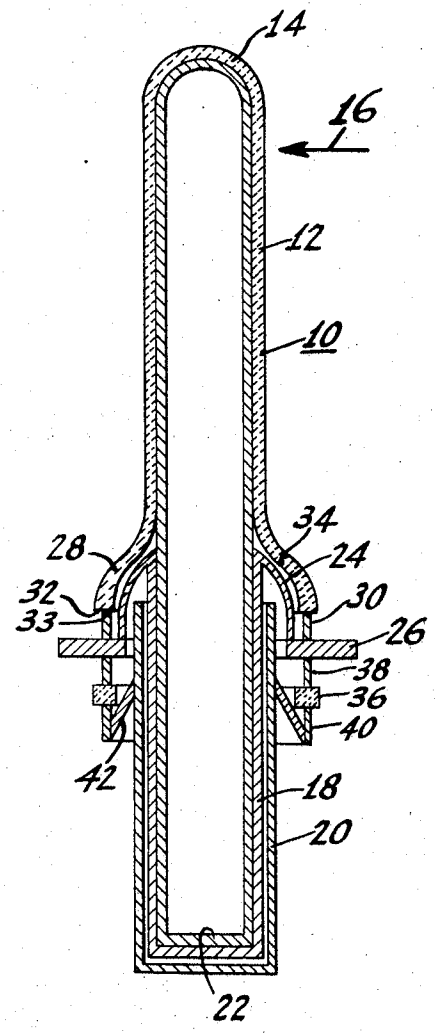
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HEAT-SENSITIVE SEAL FOR THERMIONIC CONVERTERS

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HEAT-SENSITIVE SEAL FOR THERMIONIC CONVERTERS

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ABSTRACT OF THE DISCLOSURE

Means for protecting a heat sensitive seal from detrimental temperatures, including a channel of capillary dimensions extending from the region of the seal to a region of high temperature. The channel serves to retain, by capillary action, a liquid medium which achieves a thermal gradient decreasing in the direction of the seal.

Our invention relates to heat-sensitive seals and particularly to heat pipes comprising metallic and ceramic envelope portions joined in a seal that is thermally isolated from operating heat of the heat pipe.

A heat pipe is a heat exchange apparatus comprising a structure including an elongated envelope containing a vaporizable heat transfer or working medium. One portion of the envelope is associated with a source of heat and constitutes a heat zone, and another portion of the envelope comprises a heat utilization zone. The inner wall of the envelope is lined with a material having capillary openings therein, such as sintered tungsten or one or more layers of wire mesh. The function of the capillary lining is to return to the heat zone a heat transfer medium condensed at the heat utilization zone. The heat transfer medium is selected to have a sufficient vapor pressure at the operating temperature so that the rate of evaporation is sufficiently high to transfer the quantity of heat desired. The heat transfer medium is also selected so as to be compatible with the material of which the heat pipe is made. Where this material is a ceramic such as aluminum oxide, and an operating temperature of about 1400° C. is desired, the heat transfer medium may be sodium, for example. Other materials may also be used that conform to the foregoing requirements with respect to vapor pressure and compatibility with the materials of which the heat pipe is made.

This type of heat transfer apparatus effects heat transfer from the heat zone to the heat utilization zone by causing the heat transfer medium to vaporize at the heat zone for permeating at least a portion of the envelope wall adjacent to the utilization zone, with the heated vapor. If the envelope portion adjacent to the heat utilization zone is sufficiently cool, the heated vapor of the heat transfer medium condenses thereon. Such condensation releases to the heat utilization zone the heat of evaporation of the heat transfer medium.

A heat pipe may be used advantageously for heating thermionic cathodes of electron tubes, such as thermionic energy converters. When a heat pipe is associated with the cathode of a thermionic energy converter it is desirable to employ a portion of the heat pipe envelope as a heat utilization zone for heating the cathode. The heat pipe envelope at such zone may effectively serve as a cathode. However, for such service it is desirable that this portion of the heat pipe envelope be constituted of a refractory metal such as molybdenum. The portion of the heat pipe constituting the heat input zone should be made of a material compatible with the heat source employed. Where this heat source is a fossil fuel flame, it is desirable that the heat input portion of the heat pipe envelope be constituted of a material that resists corrosion by the flame. One material that may be used is ceramic.

Since the material of the heat pipe envelope employed at the heat utilization zone is different from the material employed at the heat input zone when a corrosive heat source is used, it is necessary to provide a seal between the regions of the heat pipe made of the different materials.

One problem associated with such seal resides in the fact that a heat pipe is characterized by a substantially uniform temperature throughout its length. Therefore, when the portion of the heat pipe envelope serving as a cathode is operated at 1400° C., for example, the remainder of the heat pipe is also at this temperature. This relatively high temperature precludes the use of available sealing materials for effecting a seal between the two portions of the heat pipe made of different materials.

Accordingly, it is an object of the invention to provide a desired temperature gradient between an operating structure, e.g., a heat pipe, and a heat sensitive seal in said structure.

A further object is to provide a seal between ceramic and metal portions of a device, e.g., a heat pipe, in which the seal is kept at a lower temperature than the heat pipe in operation.

Another object is to provide a heat pipe having a metallic portion for service as a thermionic cathode joined in a thermally isolated seal to another portion made of corrosion resistant material for heating by a corrosive heat source.

In one embodiment as described herein, an elongated tubular heat pipe comprises an envelope having one end portion made of a corrosion resistant material such as aluminum oxide. This portion constitutes the heat input zone of the heat pipe and may be heated advantageously by a fossil fuel flame. The other end portion of the heat pipe envelope is made of a metal such as molybdenum and serves as a cathode. This end portion of the heat pipe envelope constitutes the heat utilization zone of the pipe. In an application wherein the cathode constitutes an element of a thermionic energy converter, the cathode may be operated at about 1400° C. for desired efficiency.

To protect a seal region between the two envelope end portions of the heat pipe from the operating heat of the device, the seal region is spaced from the inner ambient of the heat pipe and isolated from the high temperature heat pipe envelope by a channel of capillary dimension into which the heat transfer medium in liquid form is adapted to enter by surface tension. When the heat transfer medium in liquid form completely fills the channel, a temperature gradient is established in the several elements intermediate the high temperature heat pipe envelope and the seal. These elements may comprise a conical section of flame resistant material, a conical metal flange and liquid heat transfer medium trapped in the annular space between the conical section and flange. The temperature gradient is produced by heat flowing through the three heat flow paths provided by the aforementioned three elements, from the high temperature heat pipe envelope to the seal region.

The heat is removed at the seal region by any suitable means, such as normal radiation from the exposed outer surfaces. The heat dissipation should be sufficient to maintain the seal region at a temperature below the maximum temperature tolerated by the seal during operation of the heat pipe. In one example, the heat pipe was operated at 1400° C. and the seal region had a temperature of about 550° C.

The foregoing temperature gradient is produced by thermal resistivity only. If the annular space between conical portions referred to is not maintained completely full with the heat transfer medium in liquid form, such

medium in vapor form will permeate the annular space, give up its latent heat of vaporization, and defeat the accomplishment of a desired temperature gradient. Thus, an important feature resides in the fact that the liquid heat transfer medium in the annular space referred to forms an effective seal that prevents the heat transfer medium in vapor state from entering the annular space.

It is not feasible to isolate the seal region from the working medium in the vapor phase by a surface engagement of the two conical portions defining the annular space communicating with the seal region. However, by permitting the heat transfer medium in the liquid form only, to enter the annular space aforementioned, we avoid the high temperature vapor heat transport to the seal region, and in fact substantially preserve the heat gradient normally provided by the thermal flow through the conical members defining the annular space.

In the drawing to which reference is now made for a description of an exemplary embodiment of the invention, the sole figure is an elevation in section of a heat pipe having a heat utilization zone comprising a cathode of a thermionic energy converter.

The heat pipe also comprises a cylindrical end portion **12** made of a material that is resistant to corrosion, such as aluminum oxide. This cylindrical end portion has a closed end **14**, and may be heated by a fossil fuel flame indicated by the arrow **16**.

The heat pipe also comprises a cylindrical end portion **18** made of a metal such as molybdenum for advantageous service as the cathode of a thermionic energy converter. The thermionic energy converter includes an anode or collector **20** made of molybdenum for example, and closely spaced from the cathode **18**. The space between the cathode and collector may include a small amount of cesium for contributing to efficiency of operation of the converter.

The inner wall of the heat pipe **10** is provided with a continuous lining **22** having openings therein of capillary size. The lining may be made of any material that is compatible with the temperature involved in operation of the heat pipe and with the heat transfer or working medium employed. Where the operating temperature is about 1400° C. and the working medium is sodium, exemplary materials of which the lining **22** may be made are sintered tungsten having interconnecting pores of capillary size, and a molybdenum wire mesh having openings of capillary size.

The cathode **18** of the thermionic energy converter is fixed at one end in a suitable manner to a conical flange **24** which may be made of molybdenum. The end of flange **24** remote from cathode **18** is suitably fixed to an annular disc **26** which may be made of molybdenum. ceramic heat pipe portion **12** is flared outwardly to provided by electron beam welding.

The terminal region **28** remote from the end **14** of the ceramic heat pipe portion **12** is flared outwardly to provide a conical portion and its end **32** is butt sealed to a metal ring **30** made of molybdenum, for example. The seal **33** between the ring **30** and the end **32** of ceramic portion **12** may be effected by using available sealing materials. One of such materials may comprise a layer of tungsten powder including 2% by weight of titanium fired to the end **32**. The resultant metallizing of the end **32** of the ceramic portion **12** of the heat pipe permits convenient brazing of the end **32** to an end of metal ring **30**. The brazing material used may be an iron-palladium alloy consisting by weight of 47% iron and 53% palladium. The assembly produced by fixing the flange **24** to the disc **26** and by fixing the ring **30** to the end **32** of the ceramic portion **12** and to the disc **26**, results in the formation of an annular space **34** involving a spacing of about 10 mils from the inner surface of the flared portion **28** and the outer surface of the flange **24**. While this spacing may be of capillary dimension with respect to a heat transfer medium such as sodium, it may be supplemented by a lining or filling of capillary material such as molybdenum wire mesh having openings of capillary size. The terms capillary dimension and capillary size are intended to denote a space in which surface tension of a liquid results in transport of the liquid and retention of the liquid in a terminal region of the capillary means. When the heat pipe **10** is charged with sodium in an amount to saturate the capillary lining **22** and to fill the annular space **34**, and the device is heated to an operating temperature such as 1400° C., sodium will condense in and fill the space **34**. It is found that liquid sodium will pass through the lining **22** for entrance into the space **34**. The condensed sodium in the space **34** acquires a temperature of 500° C. to 600° C. in the space adjacent to the seal **33** and a temperature of 1400° C. adjacent to the operating portion of the heat pipe. The temperature of the condensed sodium in the space **34** adjacent to the seal **33** is therefore sufficiently low to preserve from harm the ceramic-to-metal seal between ceramic end **32** and the metal ring **30**. The ceramic-to-metal seal **33** can reliably withstand 800° C. in operation.

The resultant thermal isolation of the ceramic-to-metal seal **33** from the operating heat of the heat pipe **10**, permits of the advantageous heat pipe-cathode construction which may utilize a fossil fuel flame without adverse effects.

The converter portion of the heat pipe structure is completed by fixing the anode **20** to the ring **26**. This fixing is accomplished by sealing ceramic ring **36** to metal rings **38, 40**, using the ceramic-to-metal sealing technique described before herein. Ring **38** is fixed as by electron beam welding to the disc **26** and ring **40** is fixed as by electron beam welding to the conical metal flange **42** which in turn is fixed as by electron beam welding to the outer surface of the anode **20**.

The ceramic ring **36** serves effectively to electrically insulate the cathode **18** from the anode **20** of the converter. The output may be taken conveniently across the disc **26** and the exposed anode **20**.

The heat pipe structure assembled as described in the foregoing is then loaded with the working fluid (sodium) and evacuated through an opening not shown, to a pressure of about 10^{-6} torr to remove most of the gases therein. Gas within the heat-pipe envelope is objectionable in that it may collect adjacent to a portion of the heat pipe wall and insulate such portion from the heat transfer medium. However, a relatively small amount is tolerable in view of its tendency to collect at a region including a relatively small area of the capillary lining **22**. After most of the gas has been removed the device is heated to its operating temperature which may be 1400° C. and further outgased through the opening referred to. Some of the working fluid is lost during the process but the initial loading is of sufficient quantity to take care of such loss. Thus sufficient sodium is available to completely fill the capillary lining **22** and the annular space **34**. The opening is then sealed and the device is in condition for operation.

What is claimed is:

1. Means for isolating a seal region tolerating only a relatively low temperature from an adjacent region operated at a relatively high temperature, said means comprising:

(a) a passageway defining a capillary space between said seal region and said adjacent region, and

(b) a liquid retained in said passageway by capillary force, said liquid having a temperature gradient decreasing from said adjacent region to said seal region, said gradient being achieved by virtue of the thermal resistivity of said liquid.

2. Means according to claim **1** and wherein said passageway includes material defining interconnected openings of capillary size.

3. A heat pipe comprising a cylindrical structure having:

(a) an end portion made of ceramic,

(b) an end portion made of metal,
(c) an annular seal region joining said end portions,
(d) said end portions being adapted to be operated at a higher temperature than is tolerable by said seal region, and
(e) liquid means for thermally isolating said seal region from said end portion.

4. A device having an envelope comprising:
(a) a ceramic portion,
(b) a metal portion,
(c) a seal between said ceramic and metal portions,
(d) said envelope being adapted to be operated at a temperature harmful to said seal, and
(e) means for thermally isolating said seal from said envelope,
(1) said means comprising a passageway defining a space extending from said enevelope to said seal, and
(2) a liquid substantially filling said space.

5. A heat pipe comprising a cylindrical structure,
(a) a first portion of said structure defining a heat input zone,
(b) a second portion of said structure defining a cathode for an electron tube,
(c) a continuous lining of capillary material engaging the inner walls of said first and second portions, and
(d) a seal between said first and second portions thermally isolated from said portions.

6. A heat pipe according to claim 4 and wherein said first portion is made of ceramic and said second portion is made of a refractory metal.

7. A heat pipe comprising a cylindrical structure having:
(a) a first end portion made of ceramic and constituting a heat input zone,
(b) an electron tube having a metal cathode and an anode surrounding said cathode,
(c) said cathode constituting the second end portion of said structure and the heat utilization zone of said heat pipe,
(d) a seal between said first and second end portions, and
(e) means for thermally isolating said seal from said first and second end portions.

8. A heat pipe according to claim 7 and wherein said means comprises an annular passageway having opposite walls defined by adjacent portions of said first and second end portions, said walls defining an annular space extending to said seal, and a liquid retained in said space by capillary force.

9. A heat pipe comprising a cylindrical structure having:
(a) a first end portion made of a first material resistant to corrosion by a corrosive heat source,

(b) a second end portion made of a second material different from said first material,
(c) adjacent portions of said first and second end portions defining an annular channel having an opening communicating with the interior of said cylindrical structure,
(d) a seal between said first and second end portions,
(e) said channel extending from said opening to said seal,
(f) a capillary structure within said cylindrical structure and bridging said opening, and
(g) a heat transfer medium within said cylindrical structure,
(1) said capillary structure being pervious to said heat transfer medium for passage of said medium into said channel in liquid form,
(2) at least a portion of said liquid form of said heat transfer medium having a substantially lower temperature than the form of the heat transfer medium within said portions, whereby said seal is thermally isolated from said portions.

10. A heat pipe according to claim 9 and wherein said second end portion comprises a cathode of a thermionic energy converter.

11. A thermionic energy converter comprising:
(a) a cylindrical cathode
(b) a lining of capillary material engaging the inner wall of said cathode,
(c) a heat transfer medium adjacent to said cathode adapted to condense on said capillary lining,
(d) heating means adjacent to said cathode for heating said medium to its vapor phase, and
(e) heat impedance means between said heating means and said cathode.

12. A thermionic energy converter according to claim 11 and wherein said heating means comprises an axial extension fixed to said cathode at a region thermally isolated from said cathode.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,426,220 February 4, 1969

Fred G. Block et al.

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

Column 3, line 23, "also" should read -- 10 --; line 52, after "molybdenum." insert -- The fixing means in all metal-to-metal joints may be --; line 53, cancel "ceramic heat pipe portion 12 is flared outwardly to".

Signed and sealed this 24th day of March 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents