July 22, 1969 W. J. LEVEDAHL 3,457,436

HEAT PIPES WITH UNIQUE RADIATOR CONFIGURATION IN COMBINATION WITH THERMIONIC CONVERTERS

Filed Nov. 7, 1966 2 Sheets-Sheet 1

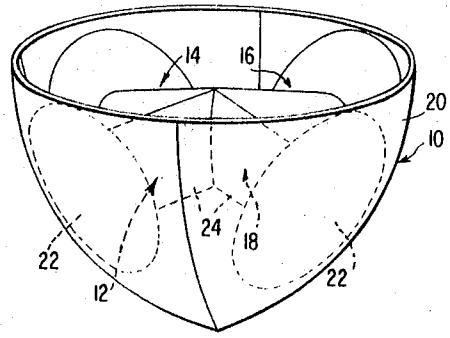


FIG. 1

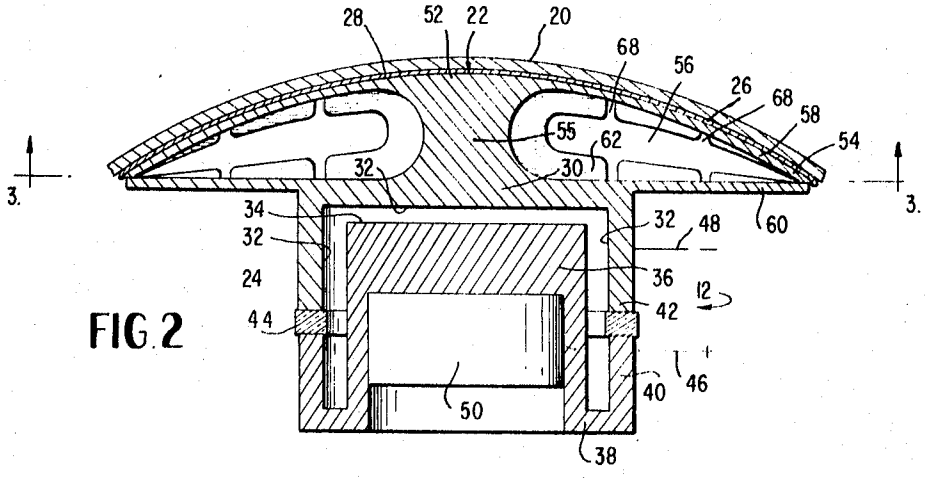


FIG. 2

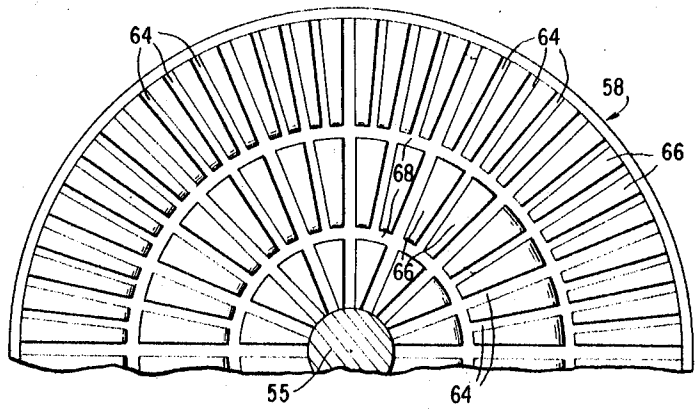


FIG. 3

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FIG. 4

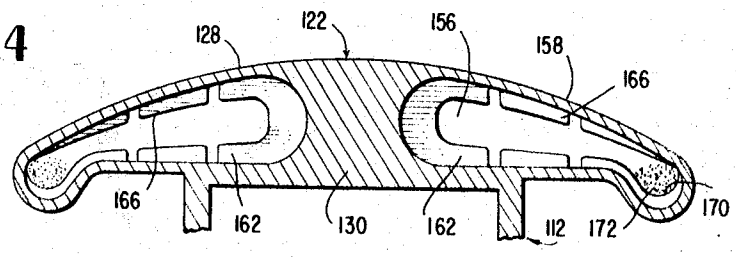
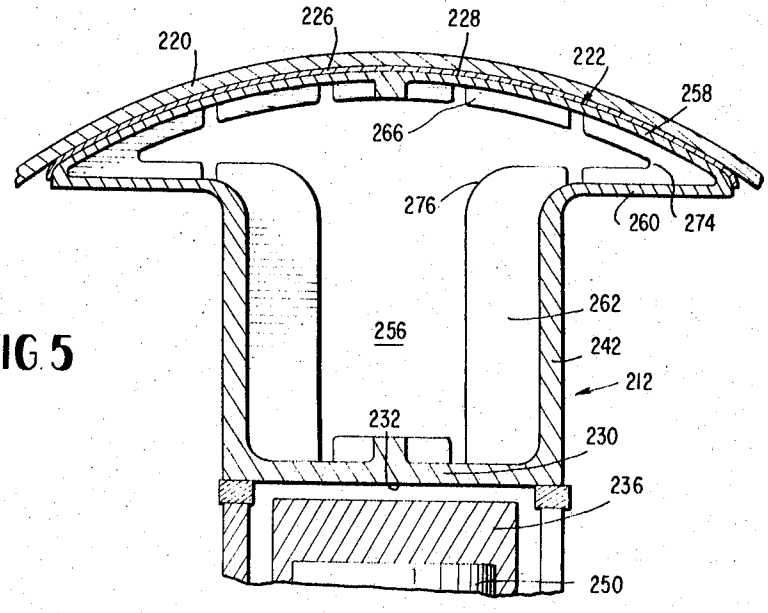


FIG. 5



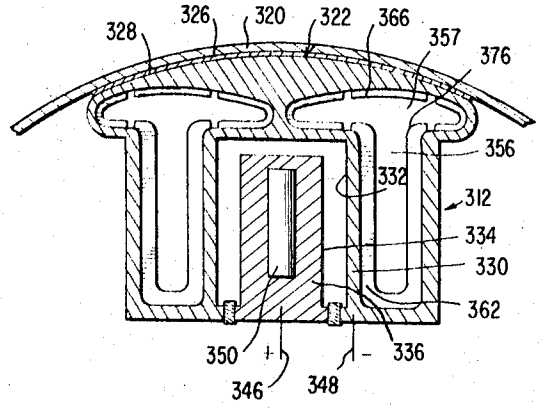


FIG. 6

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HEAT PIPES WITH UNIQUE RADIATOR CONFIGURATION IN COMBINATION WITH THERMIONIC CONVERTERS

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Int. Cl. H02n 3/00; H01j 45/00
U.S. Cl. 310—4 8 Claims

ABSTRACT OF THE DISCLOSURE

A heat pipe with unique radiator configuration particularly applicable to a thermionic electrical converter in which the collector surface spaced from the emitter surface functions as the waste heat receiving member for a heat pipe with the heat rejecting surface of the heat pipe being greatly in excess thereto. Multiple converter assemblies of mushroom-shape cross-section may be readily positioned within a metallic module shell for maximum heat dissipation, although electrically insulated therefrom.

This invention relates to heat pipes, and more particularly, to heat pipes having unique radiator configuration. The invention further relates to thermionic diodes of the type generally powered by radioisotopes, and more particularly, to a collector-radiator structure operating as a heat pipe to obtain maximum efficiency in rejecting waste heat.

Heat pipes are a recent innovation and in their simplest form comprise a container, normally metallic, employing on the inner surface a capillary structure which is essentially saturated with a vaporizable fluid. The heat pipe acts to transfer heat, almost isothermally, from one point on the external surface to any other point by a vaporization-condensation cycle. The heat pipe means employed in the present invention is based on the principles set forth in copending application Ser. No. 592,363, filed No. 7, 1966, entitled, "Heat Pipe For Low Thermal Conductivity Working Fluids," assigned to the common assignee.

In thermionic diodes, such as those powered by radioisotopes of short half life, the quantity of heat rejected varies greatly with time, and the radiator and the collector surface may vary more sharply than is desired if normal conduction radiation charactistics are used. Moreover, the temperature drop between the collector surface and the radiator may be excessive if the heat-conduction path is long and the radiator surface is poorly utilized. Conventionally, thermionic diodes have incorporated a heat sink comprising a relatively large mass of metal or other heat conductive material thermally bonded to the metallic collector surface, whereby thermal energy, not utilized by the thermionic conversion means, is dissipated by radiation and/or convection from the outer surface of the heat sink radiator. Such conventional heat sink radiators have been unsatifactory due to sizable thermal and mechanical stresses set up within the heat sink member itself as a result of temperature differences therein.

It is therefore a primary object of this invention to provide an improved heat pipe structure involving unique radiator configuration at the condenser end of the heat pipe which allows a variation in surface area between the heat input and in the heat rejection and of the heat pipe.

It is a further object of this invention to provide an improved heat pipe configuration which incorporates a change in direction of both the vapor and liquid flow paths within the heat pipe enclosure.

It is another object of this invention to provide an improved thermionic collector-radiator structure in which the temperature difference between the collector surface and the radiator is effectively zero.

It is a further object of this invention to provide an improved thermionic collector-radiator structure in which the entire radiator surface is nearly isothermal when full heat rejection capability is desired.

It is a further object of this invention to provide an improved collector-radiator structure involving heat pipe principles to isothermally transfer heat between the collector surface and the radiator to thereby permit maximum control of the rate of change of collector temperature with input power, to lighten the structural weight of the diode-radiator combination and to provide a highly compact thermionic converter.

It is a further object of this invention to provide an improved thermionic converter module which allows the use of series-connected multiple diodes which will function under varying loads without destructive thermal and mechanical stresses to the radiator or module shell supporting the same.

Other objects of this invention will be pointed out in the following detailed description and claims and illustrated in the accompanying drawings which disclose, by way of example, the principle of the invention and the best modes which have been contemplated of applying that principle.

In the drawings:

FIGURE 1 is a perspective view of a multiple diode thermionic converter module incorporating a plurality of improved thermionic diodes of the present invention.

FIGURE 2 is an elevational view, in section, of one embodiment of the improved thermionic diode of the present invention.

FIGURE 3 is a bottom plan view of a portion of the heat pipe condensing section of the device shown in FIGURE 2 taken about lines 3–3.

FIGURE 4 is an elevational view, in section, of a diode forming a second embodiment of the present invention.

FIGURE 5 is an elevational view, in section, of a diode forming yet a third embodiment of the present invention.

FIGURE 6 is an elevational view, in section, of a diode forming yet another embodiment of the present invention.

In general, the invention is directed to a heat pipe having unique radiator configuration involving an enclosure having spaced heat rejecting and heat receiving surfaces, a working fluid carried within the enclosure having liquid and vapor phase in equilibrium and capillary transport means carried by the spaced, inline heat receiving and rejecting surfaces. Heat input to the heat receiving surface causes the liquid phase to vaporize with the vaporized working fluid tending to migrate to the heat rejecting surface and condense thereon to effect isothermal heat transfer between the surfaces. The condensed liquid is returned to the heat receiving surface by the capillary transport means with the area of the heat rejecting surface being substantially greater than the area of the heat receiving surface. In a preferred form the heat rejecting and heat receiving surfaces are generally annular in plan configuration and spaced from each other along a common axis with a portion of the capillary transport means extending perpendicular to the common center line between the opposed surfaces such that the vapor and liquid flow paths change from an inline direction between opposed heat receiving and heat rejecting surfaces to a direction at right angles thereto.

The present invention is further directed to an improved

thermal to electrical converter assembly characterized by a uniform temperature heat rejecting surface with the assembly including a source of thermal energy and electrical conversion means operatively coupled to the thermal energy source. Excess thermal energy dissipating means in the form of a "heat pipe" is thermally coupled to the electrical converter for receiving waste thermal energy and includes a heat receiving surface and a spaced heat rejecting surface forming a heat pipe enclosure. A working fluid is carried within the enclosure having liquid and gaseous phases in equilibrium with capillary means carried by the surface, whereby vaporized working fluid migrates to the heat rejecting surface and condenses thereon to effect isothermal heat transfer therebetween with the condensed working fluid returning to the heat receiving surface by capillary transport.

Multiple converter assemblies may be readily positioned within a metallic module shell with the isothermal heat rejecting surfaces bonded to the shell but electrically insulated therefrom, thereby allowing electrical series connection of the converters without resultant destruction of the mechanical bond between the shell and the assemblies due to the elimination of a thermal gradient across the heat rejecting surface.

The invention is particularly applicable to radioistope-powered thermionic converters and a noncondensable gas may partially fill the heat pipe working chamber to effectively control the rate of heat rejection under low load operating conditions.

Thermionic diodes powered by radioistopic fuel sources have long been utilized for converting thermal energy into electrical form. Only a portion of the thermal energy released by the radioisotopic fuel source is actually converted into electrical energy and the remaining thermal energy must be released to the atmosphere, in most cases by radiation or convection from a converter module.

Referring to FIGURE 1, the improved thermionic diode of the present invention has great applicability to a multiple diode converter module, such as hemispherical module **10**. Module **10** consists, in this case, of four thermionic diode converters, **12**, **14**, **16** and **18** (shown by the dotted lines), which are more or less radially positioned, with their axes extending inwardly and intersecting at a common point centrally of the outer semispherical shell **20**. Semispherical denotes a portion of a sphere. While a single radioisotopic fuel source (not shown) may be employed as a common thermal energy supply for all four thermionic diode converters, each of the diodes **12**, **14**, **16** and **18** may incorporate their own radioisotopic fuel source in the manner shown in the embodiments of FIGURES 2 through 6, inclusive. The individual thermionic diode converters are mushroom-shaped in configuration having large annular caps **22** and cylindrical bases **24**. The outer semispheric shell **20** may be formed of stainless steel with the annular hemispheric caps **22** or collector-radiator structures being formed of heat conductive metal, such as aluminum. Caps **22** are electrically insulated from the stainless steel shell **20** by a thin coating of metal oxide or the like. The aluminum caps **22** of the mushroom-shaped thermionic converter assemblies, in essence, form the thermal radiator sections of the thermionic converters and, therefore, the heat must pass readily from the outer surfaces of the caps **22** to the hemispherical shell **20** where it is then radiated into space or passed to the surrounding atmosphere by convection. The comator caps should be shaped as spherical triangles for theoretical perfection. The advantages of the module assembly of FIGURE 1 will become more apparent as the description of each embodiment of the improved thermionic diode of the present invention proceeds.

Referring to FIGURES 2 and 3, each of the thermionic diode converters, such as **12**, **14**, **16** and **18**, may be of the type and configuration shown. For instance, the mushroom-shaped thermionic converter **12** has its semispherical cap portion **22** in the thermal abutting relationship to outer stainless steel shell **20**, separated by electrical insulation layer **26**. If the cap portion **22**, for instance, is formed of a good conductive material, such as aluminum, a thin layer of aluminum oxide or alumina **26** may be provided to allow heat to readily pass from the radiator cap **22** to the stainless steel shell **20**. The aluminum oxide layer may be "hard-coated" onto the outer surface **28** of the aluminum cap **22** in the manner set forth in U.S. Patent 2,692,851. The aluminum oxide coating, therefore, acts effectively as an electrical insulator but readily allows thermal energy to pass by conduction between the two members **20** and **22**. An electrical potential difference is set up between two conductive surfaces which are spaced from each other as a result of electrons passing from a first surface known as an emitter surface to a second surface known as a collector surface. Cesium vapor or other ionizable gas may be present in the cavity formed thereby. In the embodiment shown in FIGURES 2 and 3, a metallic collector section or portion **30** of the aluminum cap **22** is provided with collector surfaces **32** spaced slightly from emitter surfaces **34** formed on the outside of emitter member **36**. The emitter member may also be formed of aluminum and may include a U-shaped base portion **38** which has a reverse turned section **40** in line with, but electrically isolated from thin wall base **42** of the collector portion **30**. An annular glass ring **44** electrically isolates the emitter **36** from the collector **30** in conventional thermionic converter fashion.

Appropriate electrical leads **46** and **48** connect the electrical thermionic converter sections to an electrical load in either series or parallel fashion, as desired. As shown, lead **48** is at negative potential while the lead **46** is at positive potential. In order to generate the electrons which pass from an emissive surface **34** to collector surface **32**, a heat source must be provided. In this case, a convention radioisotopic fuel source **50** is shown in block form, in thermal contact with emitter **36**. In addition to the collector portion **30** acting as a collector for released electrons, it also functions as the waste heat receiving member allowing the waste heat to be rejected exterior of the module assembly. In conventional practice, the semispherical cap **22** is solid with a relatively large thermal gradient existing between collector surface **32** and the cap outer surface. This not only would set up undesirable thermal stresses within the cap itself, but the central portion of this surface **52** would be at a higher temperature than the tip portion **54** of the same dissipating surface. Obviously, if the thermionic conversion device were bonded to the outer shell **20**, as a result of the temperature difference between center portion **52** and the outer tip portion **54** of the heat dissipating surface, sufficient mechanical stress would be set up due to unequal thermal expansion which would rupture the bond between the shell and the cap end of the thermionic converter.

In the present invention, while the center **55** of the cap **22** is solid, an annular "heat pipe" cavity **56** extends radially outward of the cap center line formed by spaced upper thin wall **58** and lower thin wall **60**. The hollow collector-radiator structure or cap **22** is provided with a grooved interior surface which acts as capillary means for a vaporizable liquid, such as metal, which essentially fills the groove but leaves the central areas **56** void. The grooves are formed in the lower section of chamber **56** by the series of radially directed fins **62** while the upper thin wall section **58**, forming the main radiator portion of cap **22**, is provided with a plurality of capillary grooves **64** formed by spaced, short fin sections **66**. Circumferential grooves **68** separate the radial fin sections **66**, there obviously being more fins **66** near the outer periphery of the chamber **56**. By providing sufficient liquid metal (not shown) within chamber **56** to essentially fill the grooves, the liquid evaporates from the grooves near the collector surface **32**, and the vapor will condense on the fin surfaces **66** adjacent to the radiator fin wall **58**. The condensed liquid passes, by means of the

capillary grooves, back to the heat input or evaporator region defined by the lower thin wall **60**, especially near the center post **55** of the cap member.

Under basic "heat pipe" principles, the entire structure can thereby be made essentially isothermal giving a "fin efficiency" of nearly 1.0 to the structure even though its dimensions are large. The radiator area is thus minimized, thermal stresses are minimized, and the size of the entire system is reduced. Weight is reduced both because the system is smaller and because the structure is thin and hollow. Thermal streses are not possible in the structure shown, since being isothermal, all points surrounding the heat pipe chamber **56** are essentially at the same temperature. This eliminates the problem of prior art solid radiator desings in which hot spots often occur due to the failure of portions of the radiator to release heat. Since heat transfer is isothermal, and there are no thermal stresses, there are no resultant mechanical stresses. There is no temperature gradient across the outer surface **28** of the heat rejector or radiator. Thus, a good mechanical bond can be maintained between the outer surface **28** of the collector-radiator structure or cap **22** and the metallic sheet or stainless steel housing **20**. While the embodiment has been described as comprising an aluminum cap member **22**, other metals may appropriately be used. In a multiple diode converter module assembly such as that shown in FIGURE 1, with the thin wall electrical insulator between the isothermal heat dissipating surface **28** of the radiator and the mechanically contacting stainless steel casing **20** and the stainless steel casing bonded thereto, the diodes can be readily connected in electrical series.

Referring next to FIGURE 4, an alternate configuration is shown. In the FIGURE 4 embodiment, the variation of collector temperature with total heat input can be readily controlled. Normally, the radiator temperature varies essentially as the fourth root of the heat rejection rate and the difference between the collector and radiator temperature is approximately proportional to the heat rejection rate. For optimum thermionic operation, it is often desirable to have less sensitivity of the collector temperature to the heat rejection rate. This reduction in sensitivity can be achieved using an inert (non-condensable) gas in the hollow grooved structure and arranging a sizeable void volume at the extremes of the system. The employment of such inert gas within a heat pipe broadly is set forth in copending United States patent application Serial No. 506,206, by Walter B. Beinert et al., entitled "Thermal Control and Power Flattening for Radioisotopic Thermodynamic Power System," filed Nov. 3, 1965.

Referring to FIGURE 4, only a portion of the thermionic converter **112** is shown which includes principally the collector-radiator structure or cap **122** involving collector portion **130**, collector fins **162**, radiator surface **128** and radiator fins **166**. The annular heat pipe chamber **156** and the heat pipe configuration is identical to the embodiment shown in FIGURE 2 with the exception of an enlarged volume, depressed chamber section **170** at the radial extremity of chamber **156** which is filled with noncondensable inert gas cloud **172**. In line with copending application Ser. No. 506,206, at high heat rates, the metal vapor (or other vaporizable heat pipe liquid) is at high pressure and dynamically drives the inert gas **172** into the void chamber section **170** which is outside of the radiator-condensing region, thus allowing the entire condenser surface formed by fins **166** to operate in a normally essentially isothermal manner. Thus, at full load, the entire annular heat rejecting surface **128** operates essentially isothermally.

At lower heat rates, the collector **130** should be somewhat cooler. The corresponding lower metal-vapor pressure of the heat pipe vaporizable liquid carried within chamber **156** permits the inert gas at **172** to expand and blanket a portion of the thin wall radiator surface **128**. Thus, the blanketed portion of the radiator will reject little heat and the unblanketed portion must carry virtually the entire load and will operate at a higher temperature than would an isothermal radiator. Obviously, since there is then a thermal gradient along the heat rejection surface **128** of the radiator, the embodiment of FIGURE 4 would not operate satisfactorily in a multiple thermionic converter module assembly, such as FIGURE 1. The desired rate of change of collector temperature with heat load can be obtained by properly selecting the void volume and depression configuration at **170** and the mass **172** of inert gas carried thereby.

FIGURE 5 shows a third embodiment of the improved thermionic converter of the present invention. The mushroom-shaped thermionic converter **212** incorporates a radioisotopic fuel source **250** thermally coupled to emitter **236** which is spaced axially from collector portion **230** of the collector-radiator structure **222**. Radiator surface **228** is formed in this case of a continuous thin wall radiator section **258** provided with spaced fins as at **266**. Collector fins **262** extend radially inwardly along collector thin wall portion **260** and downwardly toward collector portion **230** to form a large T-shaped working chamber **256**. While the continuation of the fin at the point **274** of juncture between radiator fins and collector fins is very sharp, a rounded surface **276** must be given to the collector fin at the point where it changes from horizontal orientation adjacent collector thin wall portion **260** to vertical orientation along vertical collector wall **242** to ensure liquid flow. A metal oxide thin film **226** separates the radiator surface **288** from the stainless steel sheath **220** of the thermionic module. The grooved interior surface between the fins **262**, **266** contains sufficient vaporizable liquid, such as liquid metal, to essentially fill the groove. The liquid will, of course, evaporate from the grooves near the collector surface **232** and the vapor will move through the central void region **256** condensing on the exposed surfaces of fins **266** providing heat transfer from the collector portion **230** to the radiator surface **228** in an isothermal fashion.

In the previously described embodiments, the gap existing between the emitter and collector surfaces has been oriented horizontally. FIGURE 6 shows an alternate embodiment in which the radioisotopic fuel block **350** is vertically oriented in line with the axis of mushroom-shaped thermionic converter **312**. The emitter, therefore, constitutes a concentric, cylindrical member **336** which surrounds the fuel block **350** providing a vertically oriented, peripheral emitter surface **334** which is concentrically spaced slightly from collector surface **332** carried by concentric collector **330**. With this portion of configuration, there is provided an annular heat pipe chamber **356** which is concentric of the assembly and is generally T-shaped in cross-section having an enlarged upper chamber portion **357**. Continuous fins are provided having radiator fin sections **366** and collector fin sections **362** and are again provided with the rounded corners **376** in like manner to the embodiment of FIGURE 5. A potential difference is thus created across positive and negative leads **346** and **348**, respectively, coupled to the emitter and collector conductive sections of the assembly. The collector must, of course, be electrically insulated from the emitter (by means not shown) otherwise the metallic members making up the assembly would short the electrical circuit. Of course, the electrical insulator **326** between the collector-radiator member **322** and the outer metal shell **320** must not act as a thermal barrier to prevent ready transfer of heat from the collector **336** to the collector fins **362** for vaporization of the heat pipe liquid. With the heat pipe liquid filling the grooved interior surfaces between the fins, the liberation of waste heat from the isotopic fuel source **350** will cause vaporization of the vaporizable liquid carried within the heat pipe chamber, the vapor passing through the central void to the radiator fins **366** and condensing thereon. Condensed liquid travels via the

capillary grooves formed between the fins back to the heat input or evaporator regions defined by fin sections **362** forming the capillary grooves adjacent collector section **330**. Again, the temperature across the annular heat rejecting surface **328** of the radiator is constant and is at the same temperature of collector portion **330**, providing near isothermic heat transfer and eliminating thermal and mechanical stresses between the outer shell **320** and the mushroom-shaped thermionic converter which is bonded thereto.

From the above, it is seen that the improved thermionic converter of the present invention in the forms shown constitutes a lightweight and compact assembly. By providing isothermal heat transfer from the collector to the radiator sections, the radiator has a uniform temperature quite close to collector temperature with the radiator being smaller, lighter and having lower thermal stresses. In this regard, it is important to note that the heat pipe portion of said converter is of unique configuration involving two basic principles. First, the heat pipe configurations provide for a change in direction from axial to radial flow for both the vapor and liquid path. Secondly, the heat input surface area forming the evaporator portion of the heat pipe is much smaller than the heat rejecting surface area of the condenser portion. While the thermal to electrical converter in the embodiments is radioisotope fueled, the application of the "heat pipe" principles for the purposes of readily dissipating waste thermal energy has broad application to many types of thermal to electrical converters, such as thermoelectric devices. Obviously, where the radiator surface area is much greater than the cross-sectional area of the conversion means, under conventional heat transfer principles, a thermal gradient must be created not only axially of the unit but also radially of the unit axis toward the tip extremity of the enlarged surface area radiator. Maximum heat transfer efficiency is achieved isothermally with the heat pipe providing this function. While the overall configuration of the improved thermionic converter is mushroom-shaped in all embodiments, the collector and radiator structure may be of any shape, including flat, spherical, cylindrical and conical. The capillary grooves may have any cross-section and may be arranged in radial and circumferential lines, criss-crosses or any other configuration. Obviously, in line with the conventional "heat pipe" practice, the capillary grooves may be replaced by porous screen or other wick material; however, the capillary grooves offer minimum flow interference for the condensed liquid as it moves back to the evaporating region. Further, while the materials forming the emitter-collector-radiator in the examples have been stated as being of aluminum, like material may be readily used, such as tungsten, tantalum, molybdenum, rhenium and niobium.

A complete spectrum of working fluids is available depending upon the temperature of the heat source. For instance, water at a temperature of approximately 100° C. will provide a desired isothermal heat transfer function. Silver at temperatures near 2000° C., lithium near 1000° C., as well as liquid metals, such as sodium near 700° C. are acceptable. In employing the embodiment of FIGURE 4, with water used as the working fluid, the noncondensable gas may comprise one of the following: hydrogen, oxygen, nitrogen and all the noble gases. However, where liquid metal acts as the working fluid, noble gases form the noncondensable cloud **172**.

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

What is claimed is:

1. An improved thermionic converter assembly comprising a source of thermal energy, emitter means operatively coupled to said source of thermal energy, a combined collector and radiator structure spaced from and electrically insulated from said emitter means with said collector acting as a spaced heat receiving surface, a heat rejecting surface spaced from said heat receiving surface and forming an enclosure therebetween, a working fluid within said enclosure having liquid and vapor phases in equilibrium and capillary means carried by said spaced heat receiving and heat rejecting surfaces whereby waste heat passing to said collector causes said liquid phase to vaporize with said vaporized working fluid migrating to said heat rejecting surface and condensing thereon to effect substantially isothermal heat transfer therebetween and with said condensed liquid returning to said heat rejecting surface by said capillary means, and a limited mass of noncondensing gas within said enclosure whereby; said noncondensing gas tends to concentrate adjacent the heat rejecting surface with the area of the heat rejecting surface in heat transfer relation with the vapor phase of the working fluid increasing with increased threshold temperature.

2. The improved thermionic converter assembly as claimed in claim **1** wherein said working chamber formed by said enclosure is donut-shaped and includes an enlarged volume section at the outer periphery which acts to receive said noncondensing gas cloud to thereby expose completely said heat rejecting surface to said vaporized working fluid under full thermal load conditions.

3. A thermal to electrical energy conversion module comprising an outer metallic shell, a plurality of thermal to electrical energy conversion assemblies, means for spacing said assemblies from each other and in thermal contact with said module shell, each of said converter assemblies including thermal energy rejecting surfaces bonded to the inner surface of said module shell and isothermal heat transfer means between said thermal energy converter and said heat rejecting surface to eliminate thermal and mechanical stresses within each converter assembly and to thereby prevent destruction of said bond between said heat rejecting surfaces and said common module shell.

4. The module as claimed in claim **3** wherein said shell is semispherical and each of said thermionic conversion means is mushroom shaped in configuration including a heat rejecting surface of semispherical configuration, uniformly bonded to said inner surface of said shell.

5. The improved thermionic converter assembly as claimed in claim **3** wherein each converter includes a mushroom-shaped enclosure with a fuel source, an emitter, a spaced collector and heat rejecting surface and a spaced heat receiving surface being coaxially positioned in order within said enclosure in the direction toward said shell with said heat rejecting surface being of much greater area than said heat receiving surface.

6. An improved, mushroom-shaped thermionic converter assembly comprising: concentrically arranged in order; a radioisotopic fuel source, cylindrical emitter means including a peripheral emitter surface, cylindrical collector means spaced from said cylindrical emitter means and having an inner peripheral collector surface and an outer peripheral heat receiving surface; a spaced heat rejecting surface and forming in conjunction with said heat receiving surface a heat pipe enclosure, a working fluid carried within said enclosure having liquid and gaseous phases in equilibrium and capillary means carried by said heat receiving and heat rejecting surfaces whereby waste thermal energy is radiated from said radioisotopic fuel source toward said collector heat receiving surface to vaporize the liquid phase in contact therewith with said vaporized working fluid tending to migrate to said heat rejecting surface and condensing thereon to effect isothermal heat transfer therebetween.

7. The thermionic converter assembly as claimed in claim **6** wherein said heat rejecting surface is of much greater area than said heat receiving surface.

8. The apparatus as claimed in claim **6** wherein said

capillary means comprises closely spaced grooves, said grooves carried internally of said enclosure adjacent said heat receiving and heat rejecting surfaces.

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