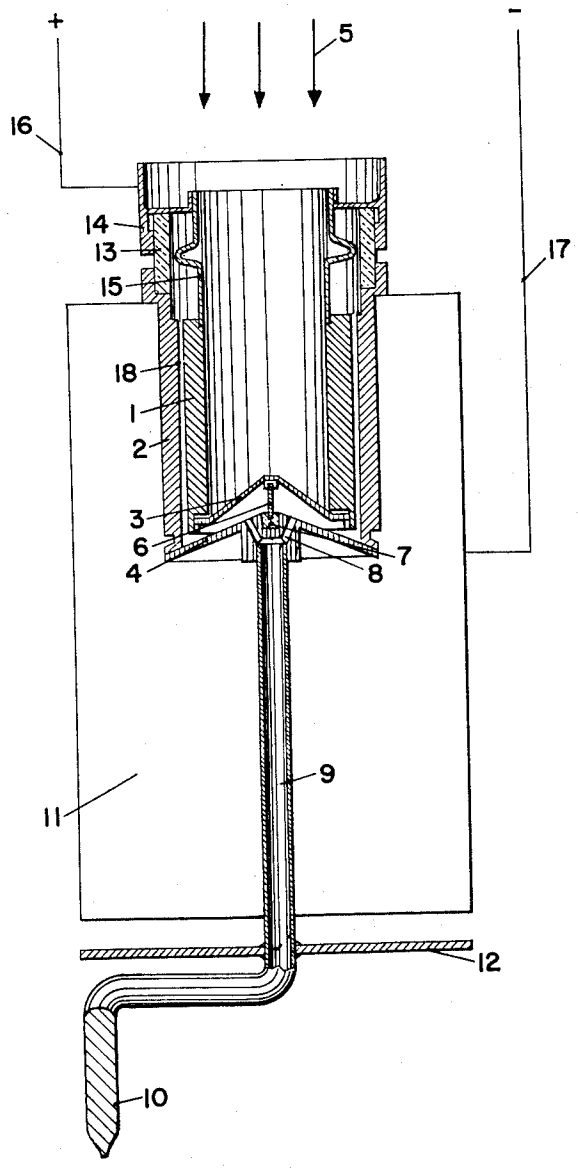
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ENERGY CONVERTER

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ENERGY CONVERTER

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The present invention relates to direct thermoelectronic converters which convert thermal energy directly into electrical energy.

It is known that, in its simplest form, such a converter comprises a pair of electrodes, particularly an electron emitter and an electron collector, disposed within a vacuum-tight enclosure or incorporated within the walls of such an enclosure, the distance between these electrodes being preferably equal to or less than the free mean path of the electrons within the medium filling the enclosure. No external voltage source is normally applied between these electrodes. However, when heat is applied to the emitter, the energy of certain electrons of the emissive material increases beyond the working potential, whereupon these electrons leave the emitter and proceed in the direction toward the collector, dispositions being eventually taken to annul or reduce the inter-electrode space-charge which would oppose such movement. If the working potential of the material of the collector is less than that of the emitter, the portion of the energy of the electrons captured by the collector, corresponding to the working potential thereof, is dissipated in the form of heat, whereas the remaining portion, corresponding to the difference of the working potentials of the two electrodes, represents the difference of contact potential and will appear between the emitter and the collector in the form of an electric voltage which may be applied to a suitably matched load resistance.

The known, prior art constructions of these diodes utilize generally spacers which assure a fixed spacing or gap between the emitter and the collector in order to provide a well-defined width of the inter-electrode space. However, experience has indicated that these spacers as used in the prior art cause loss, by conduction, of an appreciable quantity of heat which is the greater the smaller the distance or gap between the electrodes and the higher the difference in temperature between the emitter and the collector.

The present invention aims at eliminating this shortcoming of which the influence on the correct and proper functioning of the converter is important, and, with this aim, proposes to realize a diode of the type described hereinabove, either of the vacuum-type or filled with a metal vapor such as cesium or another alkaline metal ionized by contact with the hot electrode, of a structure such that the need for any spacer is completely eliminated.

The structure of the converter according to the present invention is cylindrical, the electrodes having the shape of two coaxial cylinders with the emitter on the inside and the collector on the outside thereof. Such a form is already generally known, per se, in the prior art but has utilized heretofore spacers between the two electrodes as is also the case with other known prior art constructions.

According to the present invention, the two cylinders are realized in such a manner as to slide, when cold, one over the other substantially without play, whereas the metals utilized for the manufacture thereof are selected, independently of the properties required to form, respectively, an emitter and a collector, in such a manner that the absolute expansion of the emitter situated on the inside is, at its normal operating temperature and with respect to its diameter in the cold state thereof, smaller than the absolute expansion of the collector located on the outside, also at its normal operating temperature and with respect to its diameter in the cold state thereof; additionally, centering elements are provided for each of the cylinders to maintain the coaxiality thereof in the hot state when the gap necessary between the electrodes has been established by the differential expansion.

As examples of metals that are suitable, both from the point of view of electrical property and expansion, may be cited, for the emitter, columbium, tantalum, molybdenum, and tungsten, and for the collector, titanium, beryllium, and copper.

Accordingly, it is an object of the present invention to provide a direct thermoelectronic energy converter of the type described hereinabove which effectively eliminates the shortcomings and disadvantages of the prior art by simple means.

It is another object of the present invention to provide a thermoelectronic energy converter directly converting thermal energy into electrical energy which, for a given structure, reduces the heat losses and therewith assures increased efficiency of operation of the device.

A still further object of the present invention resides in the provision of a direct energy converter of the type described hereinabove which entails simplification in the mechanical construction thereof and which, in particular dispensed with the necessity of utilizing spacers to assure the proper spacing and positioning of the electrode elements thereof.

These and other objects, features and advantages of the present invention will become more obvious from the following description when taken in connection with the accompanying drawing which shows, for purposes of illustration only, in the single figure thereof, an axial cross sectional view of one representative embodiment according to the present invention incorporating the principles of a cesium vapor converter.

Referring now to the drawing, which illustrates a diode type direct energy converter, reference numeral **1** designates therein an internal cylinder forming the emitter of the converter. The cylinder **1**, constituting the emitter, may be made, for example, of molybdenum. The converter additionally comprises an external cylinder **2** constituting the collector and may be made, for example, of copper. The external diameter of the cylinder **1** and the internal diameter of the cylinder **2** are adjusted in such a manner that, in the cold state, the cylinder **2** may slide over the cylinder **1**. The two cylinders **1** and **2** are independently centered on two conical pieces **3** and **4**, the external surface of the cone **3** forming, on the inside of cylinder **1**, a heat reflector for the heat applied in the direction of and schematically indicated by arrows **5**. The two conical members **3** and **4** may be, for example, made respectively of the same metals as the cylinders **1** and **2**, that is of molybdenum for the conical member **3** and of copper for the conical member **4**. The conical

member 3 is centered on an insulating shaft or pin 6 encased within an insulating bearing member 7 secured within the axis of the conical member 4. The conical piece 4 comprises a series of channels 8 to place into communication the inside of the converter with a tubular member 9 connected to a cesium reservoir 10.

A radiator provided with fins 11 is attached to the collector 2 and a thermal screen 12 is interposed between the converter and the reservoir 10 in order to prevent an excessive temperature of the cesium within the reservoir 10 as a result of the radiation of heat by the fins 11.

An insulating ring 13, for example, made of alumina, to which are secured, on the one hand, the collector 2 and, on the other, an annular member 14, for example, made of titanium, insulates electrically these two elements 2 and 14 with respect to each other. The annular member 14 is connected to the emitter 1 by means of a flexible membrane 15, for example, made of tantalum which completes the vacuum-tight envelope. The output connections 16 and 17 are connected, respectively, to the member 14 and to the collector 2 or the fins 11 attached thereto.

As already indicated hereinabove, there is substantially no play between the cylinders 1 and 2 when in the cold state. In contrast thereto, when in the hot state, that is when each of the electrodes attains its normal operating temperature, an inter-electrode space 18 will be formed between the cylinders 1 and 2 by reason of the respective expansions due to the choice of materials indicated. For example, when the temperature of the emitter 1 reaches about 2000° K., and that of the collector 2 reaches a temperature of about 1000° K., there will be established an inter-electrode space 18 of approximately 60 microns if the external diameter of the cylinder 1 is about 40 millimeters.

The electrodes 1 and 2, nevertheless, remain coaxial since they are centered on members 3 and 4 which expand in the same manner as the corresponding cylinders, the conical form thereof entailing the additional advantage of not buckling during heating thereof. The ring 13 expands with the cylinder 2 and passes on its expansion onto the piece 14 but the difference in expansion between piece 14 and the emitter 1 is absorbed by the deformation of the membrane 15.

There is established, therefore, in the hot state, a converter structure which operates, in principle, as other known converters but with improved performances as a result of the absence of any spacer between the emitter and the collector.

While we have shown and described one embodiment in accordance with the present invention, it is understood that the same is not limited thereto, but is susceptible of many changes and modifications within the spirit and scope thereof. For example, the present invention is not limited to the particular type of converter described herein, but is equally applicable, for example, to vacuum-type converters. Furthermore, the present invention also permits numerous modifications in the structural details thereof as known to a person skilled in the art.

Thus, it is obvious that the present invention is susceptible of numerous modifications and changes without departing from the spirit thereof, and we, therefore, do not wish to be limited to the details shown and described herein, but intend to cover all such changes and modifications thereof as are encompassed by the scope of the appended claims.

We claim:

1. An energy converter comprising electron emitting means of solid material operable to emit electrons upon the application thereto of heat energy, electron collecting means of solid material, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means being substantially of coaxial shape of such dimension as to fit closely one upon the other in the cold state of said converter, the respective materials of said electron emitting and collecting means being chosen in such a manner that upon application of heat energy both said last-mentioned means thermally expand to provide a gap therebetween.

2. An energy converter comprising electron emitting means adapted to emit electrons upon application thereto of heat energy, electron collecting means, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween, said gap being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

3. An energy converter comprising electron emitting means adapted to emit electrons upon application thereto of heat energy, electron collecting means, an independent centering piece for each of said emitting means and said collecting means, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween, said gap being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

4. An energy converter comprising electron emitting means adapted to emit electrons upon application thereto of heat energy, electron collecting means, an independent centering piece for each of said emitting means and said collecting means, said centering pieces being of substantially conical shape, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween, said gap being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

5. An energy converter comprising electron emitting means adapted to emit electrons upon application thereto of heat energy, electron collecting means, an independent centering piece for each of said emitting means and said collecting means, said centering pieces being of substantially conical shape, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the apices of said substantially conical centering pieces being directed towards the interior of said hollow cylinders, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween, said gap being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

6. An energy converter comprising electron emitting means operable to emit electrons upon the application thereto of heat energy, electron collecting means, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means being substantially of coaxial shape of such dimension as to fit closely one upon the other in the cold state of said converter, the respective materials of said electron emitting and collecting means being chosen in such a manner that upon application of heat energy both said last-mentioned means thermally expand to provide a gap therebetween, the material of said emitting means being selected from the group consisting of columbium, tantalum, molybdenum and tungsten, and the material of said collecting means being selected from the group consisting of titanium, beryllium and copper.

7. An energy converter comprising electron emitting means adapted to emit electrons upon application thereto of heat energy, electron collecting means, an independent centering piece for each of said emitting means and said collecting means, said centering pieces being of substantially conical shape, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the apices of said substantially conical centering pieces being directed towards the interior of said hollow cylinders, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween, the material of said emitting means being selected from the group consisting of columbium, tantalum, molybdenum and tungsten, and the material of said collecting means being selected from the group consisting of titanium, beryllium and copper, said gap being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

8. An energy converter having electron emitting means of solid material adapted to emit electrons upon application of heat energy, and electron collecting means of solid material, said emitting and collecting means being of substantially complementary coaxial shape substantially devoid of any play therebetween in the cold state of said converter, the respective materials of said emitting and collecting means being chosen in such a manner that upon application of heat energy the differential thermal expansion therebetween provides a gap forming the predetermined inter-electrode space.

9. An energy converter comprising electron emitting means adapted to emit electrons upon application thereto of heat energy, electron collecting means, an independent centering piece for each of said emitting means and said collecting means, said centering pieces being of substantially conical shape, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the apices of said substantially conical centering pieces being directed towards the interior of said hollow cylinders, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween.

10. An energy converter having electron emitting means adapted to emit electrons upon application of heat energy, and electron collecting means, said emitting and collecting means being of substantially complementary coaxial shape substantially devoid of any play therebetween in the cold state of said converter, the respective materials of said emitting and collecting means being chosen in such a manner that upon application of heat energy the differential thermal expansion therebetween provides a gap forming the predetermined inter-electrode space, and means for centering said emitting and collecting means substantially independently of one another including first centering means for said emitting means and second centering means for said collecting means.

11. An energy converter having electron emitting means adapted to emit electrons upon application of heat energy, and electron collecting means, said emitting and collecting means being of substantially complementary coaxial shape substantially devoid of any play therebetween in the cold state of said converter, the respective materials of said emitting and collecting means being chosen in such a manner that upon application of heat energy the differential thermal expansion therebetween provides a gap forming the predetermined inter-electrode space, and means for centering said emitting and collecting means substantially independently of one another including first centering means for said emitting means and second centering means for said collecting means, said first and second means having substantially the same thermal coefficients of expansion as said emitting means and collecting means, respectively.

12. An energy converter comprising electron emitting means adapted to emit electrons upon application of heat energy, electron collecting means, and means for collecting electrical energy between said electron emitting and collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the respective materials of said cylinders being chosen in such a manner that upon application of heat energy both said cylinders thermally expand to provide a gap therebetween, the material of said emitting means being selected from the group consisting of columbium, tantalum, molybdenum and tungsten, and the material of said collecting means being selected from the group consisting of titanium, beryllium and copper, said gap being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

13. An energy converter having electron emitting means adapted to emit electrons upon application of heat energy, and electron collecting means, said emitting and collecting means being of substantially complementary coaxial shape substantially devoid of any play therebetween in the cold state of said converter, the respective materials of said emitting and collecting means being chosen in such a manner that upon application of heat energy the differential thermal expansion therebetween provides a gap forming the predetermined inter-electrode space, and means for centering said emitting and collecting means substantially independently of one another including first centering means for said emitting means and second centering means for said collecting means, said first and second means having substantially the same thermal coefficients of expansion as said emitting means and collecting means, respectively, and said first and second means being effectively provided with means preventing buckling during thermal expansion thereof.

14. An energy converter having electron emitting means, electron collecting means, means for applying heat energy to said electron emitting means thereby causing said electrons to be emitted, and means for collecting electrical energy between two output connections connected directly respectively to said electron emitting and said collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the respective materials of said cylinders being chosen in such a manner that on application of said heat energy both said cylinders thermally expand and thereby provide a gap therebetween, said gap

being incorporated in an evacuated enclosure, means being provided for filling said enclosure with low pressure gas, and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

15. An energy converter having electron emitting means, electron collecting means, means for applying heat energy to said electron emitting means thereby causing said electrons to be emitted, and means for collecting electrical energy between two output connections connected directly respectively to said electron emitting and said collecting means, both said emitting and collecting means having substantially the shape of coaxial hollow cylinders closely adjusted one upon the other in the cold state of said converter, the respective materials of said cylinders being chosen in such a manner that on application of said heat energy both said cylinders thermally expand and thereby provide a gap therebetween, said gap being incorporated in an evacuated enclosure and the width of said gap being substantially equal to the free mean path of said electrons in said gas.

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