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July 7, 1970 E. D. DAVIS 3,519,854

THERMIONIC CONVERTER WITH HALL EFFECT COLLECTION MEANS

Filed Feb. 20, 1967 2 Sheets-Sheet 1

FIG.1

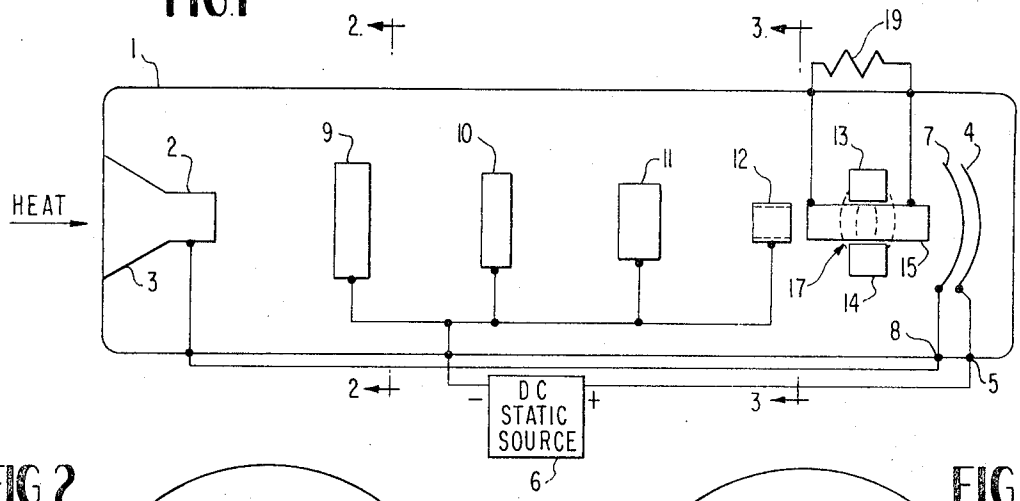


FIG.2

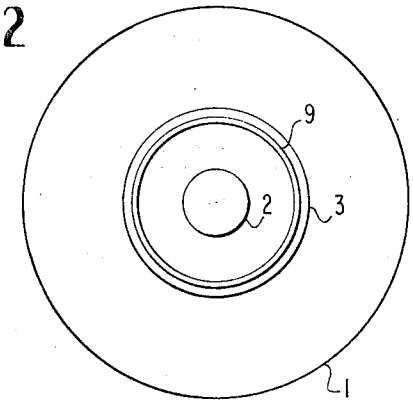
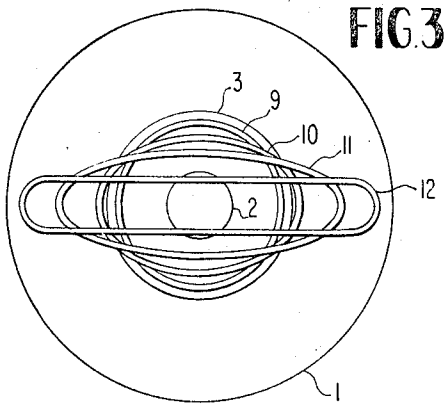


FIG.3



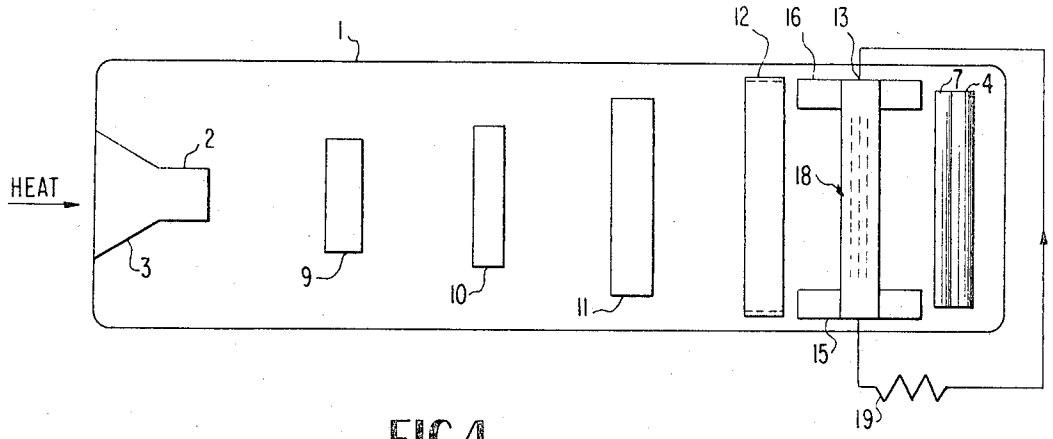


FIG.4

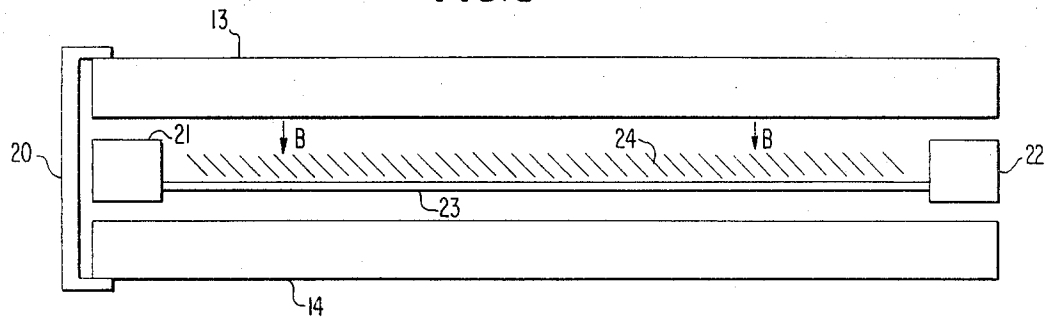
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FIG. 5



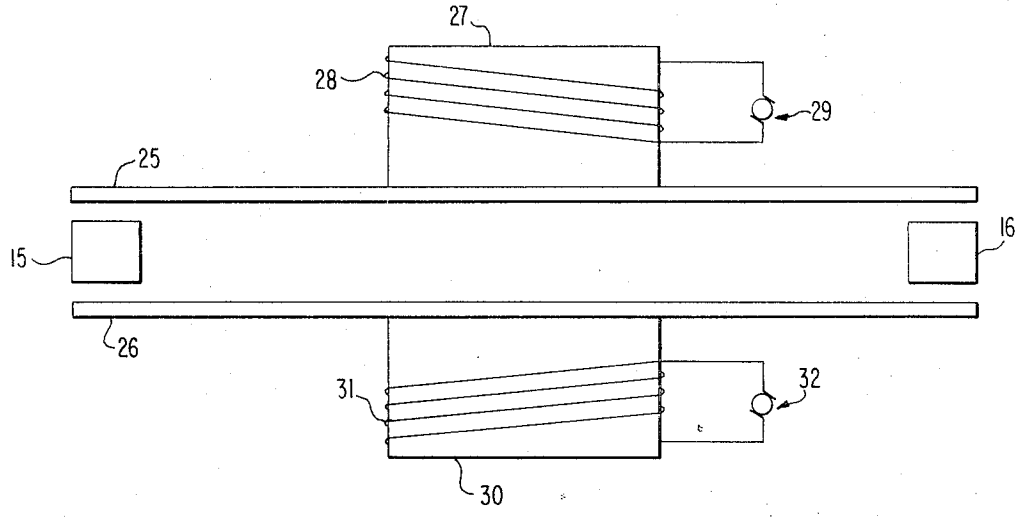


FIG. 6

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THERMIONIC CONVERTER WITH HALL EFFECT COLLECTION MEANS

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U.S. Cl. 310—4 8 Claims

ABSTRACT OF THE DISCLOSURE

A thermionic converter utilizes the Hall effect for current collection. A plurality of electrostatic electrodes shape the electron beam prior to collection, and either permanent magnet or electromagnetic means may be used to provide the transverse magnetic field for the Hall plates.

This invention relates to thermionic converters and, more specifically, to apparatus for converting thermal energy into energy in the form of an electron stream from which an electrical current is produced, the current being usable to energize a load device.

In my copending U.S. patent application Ser. No. 369,931, filed May 25, 1964, now Pat. No. 3,328,611 reference is made to prior patents which discuss the problems of obtaining efficient thermal-electrical conversion, and a solution is presented therein.

One object of the present invention is to provide a further and different solution to these problems using a longitudinal structure having a relatively linear high velocity electron path and novel means for collecting usable current and delivering it to a load.

Another object is to provide an apparatus which can convert heat generated by any source, such as radiant energy, nuclear energy and the like, directly to usable electrical current.

Briefly described, the invention includes an envelope which can be evacuated, the envelope advantageously being in the shape of an elongated cylinder such as in an electron multiplier or a cathode ray tube. A cathode having an electron emissive surface is located near one end of the envelope with heat conductive means suitably placed to conduct heat from any convenient source. An anode is placed near the other end of the envelope and is supplied with a high positive potential to attract electrons emitted from the cathode. Focusing elements are placed in the line of electron travel between the cathode and anode, each element having an opening shaped to form the electrons into a well defined beam having a predetermined cross-sectional shape.

Between the focusing means and the anode, magnetic field producing means are located so as to produce a field which is in the nature of a veil or sheet and which crosses the path of electron beam. Electrically conductive members are placed near the edges of the field to collect current produced by the interaction of the magnetic field produced by the magnet means with the field produced by the moving electron stream.

In order that the manner in which the foregoing and other objects are attained in accordance with the invention can be understood in detail, particularly advantageous embodiments thereof will be described with reference to the accompanying drawings, which form a part of this specification, and wherein:

FIG. 1 is a schematic diagram showing a side elevation of one apparatus incorporating the invention;

FIGS. 2 and 3 are vertical sections of FIG. 1;

FIG. 4 is a schematic plan view of the apparatus of FIG. 1;

FIG. 5 is a detail elevation of a structure usable in the apparatus of FIGS. 1 and 4; and

FIG. 6 is a detail elevation showing an alternate magnetic structure usable with the apparatus of FIGS. 1 and 4.

Referring now to FIG. 1, it will be seen that the apparatus includes an envelope or casing **1**, which can be made of plastic, metal or other material which can be rendered air tight so that it can be evacuated and so that a vacuum created therein will remain substantially unchanged with time. A cathode **2** is mounted near one end of envelope **1**, the cathode being connected to heat conducting means **3** which can be placed in good heat conducting relationship to any convenient source of heat. Cathode **2** is provided with an electron emissive coating of a suitable type so that, when heat is applied to the cathode, electrons will be released from the emissive surface.

Near the other end of envelope **1** is located a positively charged anode **4** which is shown in FIG. 1 as a semi-circular member, but which can be in the shape of a portion of a sphere or any convenient shape, depending upon the envelope shape and the distances involved. Anode **4** is connected through an air tight connection **5** to the positive terminal of a source of DC potential **6** which is adapted to provide a static potential of great magnitude, on the order of tens of thousands of volts. Thus anode **4**, being charged to the high positive potential, will operate to attract electrons emitted from cathode **2** through the length of envelope **1**. By using a high voltage, the electrons emitted from cathode **2** are given substantial kinetic energy.

An electron recovery member **7** is located near the anode between the anode and cathode to intercept the majority of electrons attracted from the cathode. Recovery member **7** is connected, also through an air tight connector **8**, to cathode **2**, thereby returning the electrons to the source. Recovery member **7** can advantageously be a fine screen or a member composed of a semiconductor material.

Focusing members **9**, **10**, and **11** are mounted within envelope **1** in a line between cathode **2** and anode **4**, each focusing member having an opening therein shaped to form the electrons passing between cathode **2** and anode **4** into a stream of predetermined shape. Focusing members **9**, **10**, and **11** are all connected, through an air tight fitting, to the negative terminal of a DC static source, which may be source **6** to which the anode is connected. By negatively charging the focusing members, it will be seen that the individual electrons will be repelled therefrom, and will tend to remain near the center of the openings in the focusing members. A focusing member **12**, also connected to the negative DC static source, performs the final focusing operation, shaping the stream properly to pass it between a magnetic field producing apparatus including magnets **13** and **14**. Magnets **13** and **14** can be permanent magnets of a conventional type, having unlike poles facing each other so that a substantially planar field is established between the two closest faces. After passing through the field produced by magnets **13** and **14**, the electron stream impinges upon recovery member **7**.

As will be recognized by one skilled in the art, an electron stream can be regarded as a current flowing in a wire, and will product a magnetic field which travels circularly about the axis of the stream. In the area between magnets **13** and **14**, the magnetic field produced by the electron stream interacts with the field produced by the magnetic members, indicated generally by dotted lines **17** in FIG. 1, thereby inducing a current, essentially a stream of free electrons, which is collected by pick-up members **15** and **16**, only one of which can be seen in FIG. 1. Members **15** and **16** are connected, through conductors **17** and **18**, to an external load device shown in FIG. 1 as a resistor **19**.

The arrangement of the magnets and pick-up members

can more clearly be seen in FIG. 4, which is a plan view of the same apparatus as in FIG. 1. In FIG. 4, the same identifying numerals have been used as in FIG. 1 for clarity.

It will be seen that pick-up members **15** and **16** are disposed on either side of the electron stream and are vertically spaced between magnets **13** and **14** to collect the current produced by the field interaction, indicated generally by dotted lines **18**.

In order to obtain the most efficient interaction of the fields and therefore the most efficient thermoelectric conversion, it is desired that the electron stream be focused into a relatively flat wide beam before it passes between magnets **13** and **14**. This is accomplished by shaping successive focusing members **9**, **10**, **11** and **12** to gradually shape the beam to the desired form. Referring to FIG. 2, it will be seen that cathode **2** is substantially circular in cross section, and that the opening in focusing member **9** is of substantially the same shape and acts to initially combine the electrons into a well-grouped beam. Although focusing member **9** is shown as an annular member, it will be recognized that member **9** can be made in the form of a sheet extending transversely within envelope **1** with a circular opening therein to perform the same function as the interior of member **9** as shown in FIG. 1.

In FIG. 3 it will be seen that members **10**, **11** and **12** tend increasingly to assume the final shape of the desired beam, member **10** being wider and shorter than member **9**, and member **11** being still wider and shorter. Member **12** is then substantially rectangular with the width dimension being substantially greater than the height, the electron beam obviously taking the shape of a relatively wide flat sheet as it passes through focusing member **12**. This increase in width can also be seen in FIG. 4.

It will be recognized that the various members within envelope **1** can be mechanically mounted therein in any convenient fashion, such as by insulating support members extending radially inwardly from the inner walls of envelope **1**. These structural supports have been omitted for simplicity in the drawings.

Referring now to FIG. 5, it will be seen that the current collecting members can assume an alternate structure, the primary pick-up members **21** and **22** being disposed as before on either side of the gap between magnets **13** and **14**. In this structure an electrically conductive member **23** extends between members **21** and **22** and adjacent the lower edge electron stream, the location and general shape of the stream being indicated by the shading at **24**. In some magnet arrangements it is also desirable to have a connecting member **20** to complete a magnetic circuit between magnets **23** and **24**, member **20** being of a highly permeable material such as soft iron.

FIG. 6 shows an alternative magnet structure usable in the apparatus of FIGS. 1 and 4, in which pick-up members **15** and **16** lie between the lateral edges of magnet face plates **25** and **26**. Plate **25** is connected to a core **27** of magnetic material which is provided with a plurality of windings **28**, the ends of winding **28** being connected to a source of voltage indicated schematically at **29**. Likewise, plate **26** is secured to a core member **30** which is provided with a plurality of windings **31**, the ends of which are connected to a suitable voltage source indicated generally at **32**. The electromagnetic apparatus thus formed can advantageously be substituted for permanent magnets **13** and **14** in any of the embodiments shown and suggested above.

While certain advantageous embodiments have been chosen to illustrate the invention, it will be understood by those skilled in the art that various changes and modifications can be made therein without departing from the scope of the invention as defined in the appended claims.

I claim:

1. Thermoelectric conversion apparatus comprising the combination of

envelope means for defining an evacuated volume having an elongated shape;

a cathode having a surface including an electron emissive material, said cathode being located near one end of said envelope means;

means for heating said cathode to a temperature above the emission temperature of said electron emissive material to free electrons from said material;

positively charged means within said envelope means longitudinally spaced from said cathode means for imparting high kinetic energy to said freed electrons by attracting said electrons longitudinally through the volume;

means for focusing said freed electrons into an electron stream of predetermined shape;

magnet means for creating a magnetic field transversely of said stream between said means for focusing and said positively charged means; and

pickup means adjacent said magnet means for collecting current produced by the fields of said magnet means and said electron stream.

2. Apparatus according to claim **1** wherein said means for focusing said freed electrons comprises

a plurality of negatively charged members spaced between said cathode and said magnet means,

said members having openings therethrough through which said electrons can pass, the one of said members nearest said cathode having a substantially circular opening, and the one of said members nearest said magnet means having a substantially rectangular opening.

3. An apparatus according to claim **1** and further comprising

means for collecting said electrons near said positively charged means.

4. Apparatus according to claim **1** wherein said positively charged means comprises a semi-spherical surface the concave surface of which faces said cathode; and

said apparatus further comprises

means for generating a high unidirectional voltage, the positive output terminal of said means being connected to said positively charged means.

5. Apparatus according to claim **1** wherein

said magnet means comprises first and second permanent magnets contained within said envelope between said focusing means and said positively charged means,

said first and second magnets being disposed with unlike poles facing each other across said electron stream.

6. Apparatus according to claim **1** wherein said magnet means comprises

at least one electromagnet having first and second unlike poles, said poles being disposed on opposite sides of said electron stream to create a magnetic field transversely of and through said electron stream.

7. Apparatus according to claim **1** wherein said pick-up means comprises

first and second electrically conductive members enclosed within said envelope on opposite sides of said electron stream,

said conductive members both being in a plane which passes through said electron stream and is substantially perpendicular to the field created by said magnet means.

8. Apparatus according to claim **7** wherein said pick-up means comprises

a third electrically conductive member lying in said plane, said third member being elongated and hav-

ing the ends thereof in good electrical contact with said first and second members.

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