

March 11, 1969

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3,432,690

THERMIONIC CONVERSION OF MICROWAVE ENERGY TO DIRECT CURRENT

Filed Aug. 31, 1966

Sheet 1 of 2

Fig. 1.

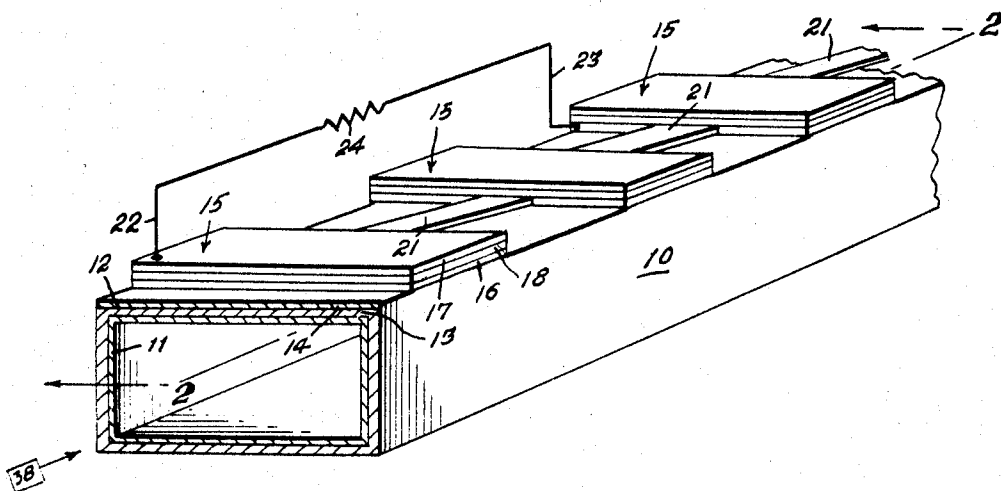


Fig. 2.

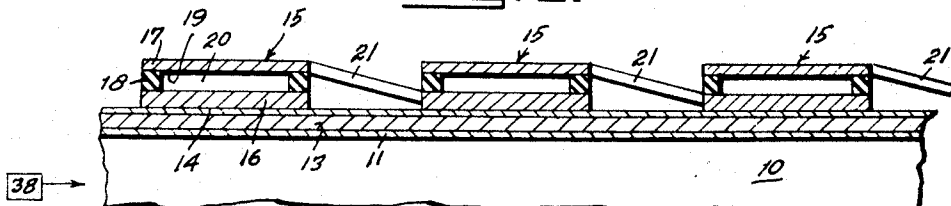
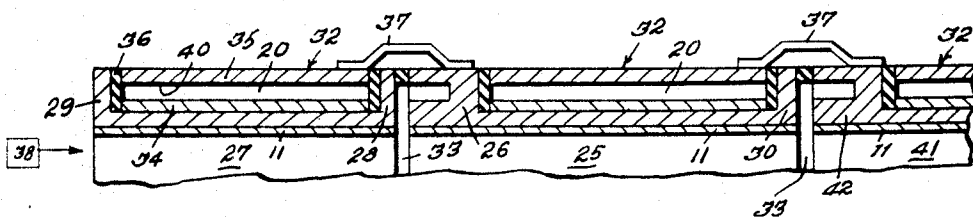


Fig. 3.



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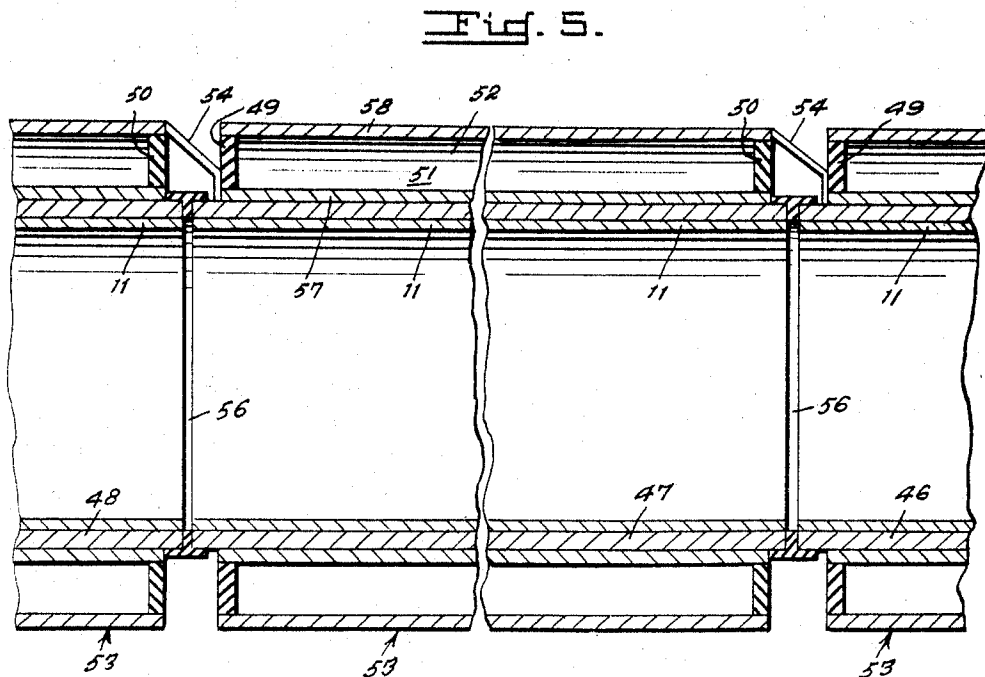
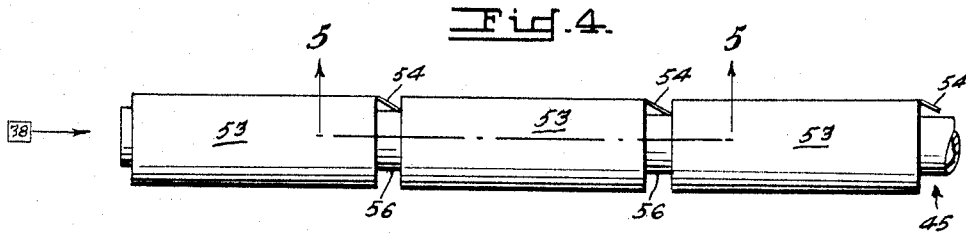
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Sheet 2 of 2



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**THERMIONIC CONVERSION OF MICROWAVE
ENERGY TO DIRECT CURRENT**Alan E. Blume, Scotia, N.Y., assignor to the United States
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4 Claims

ABSTRACT OF THE DISCLOSURE

A device for converting microwave energy to direct current by use of thermionic emission consisting of a waveguide having the inner surface thereof lined with a lossy material whereby the microwave energy exciting the waveguide is converted into heat and a refractory material affixed to the outside surface of the waveguide which serves as the cathode for a thermionic device. The refractory material when heated emits electrons causing current to flow in the thermionic device.

This invention relates to devices for changing electromagnetic energy to direct current and more particularly to apparatus and method for converting microwave energy to direct current by the use of thermionic emission.

An object of the invention is a converter means for changing electromagnetic energy to direct current.

Another object of the invention is the utilization of microwave energy to heat the wall of a waveguide and by heat conduction activate the cathode of a thermionic converter attached thereto whereby a direct current is produced.

The invention will be more fully understood and its objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawings in the several figures of which like numerals identify like elements and in which:

FIGURE 1 is an isometric view, partly in section, illustrating one embodiment of the invention;

FIGURE 2 is a fragmentary sectional view taken along line 2—2 of FIGURE 1; and

FIGURE 3 is a fragmentary longitudinal sectional view illustrating another embodiment of the invention.

FIGURE 4 is a plan view of another embodiment of the invention utilizing a circular waveguide.

FIGURE 5 is a fragmentary sectional view taken along line 5—5 of FIGURE 4.

In FIGURE 1 there is shown one form which my invention may take and wherein 10 indicates a section of rectangular waveguide lined with a lossy material 11 such as carbon or a high resistance metal alloy. Block 38 indicates a source of microwave energy for energizing waveguide 10. The outside surface 12 of the top wall 13 is provided with a layer of a metalloid oxide coating 14 such as beryllia which has a high electrical resistivity at 2000° C. to electrically isolate the waveguide 10 from the serially connected thermionic cells 15. Each thermionic cell 15 consists of a cathode 16 of refractory material affixed to the surface of the beryllia layer 14, a metallic anode 17 in spaced relationship with cathode 16 by means of insulator 18 so as to form a hermetically sealed container having a chamber 19 containing cesium vapor 20 under low pressure. An electrical conductor means 21 connects the anode of one of the thermionic cells to the cathode of an adjacent thermionic cell to place said cells in series connection. Lead 22 of the anode of the first of said series connected cells and lead 23 of the cathode of the last of said series connected cells provide means for connection to a load 24. It is to be understood that any number of

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such cells may be connected in series or parallel in accordance with the electrical circuit requirement. Further, it is also to be understood that the thermionic cells may be formed to completely embrace the peripheral surface of the waveguide.

In operation microwave energy is fed into the waveguide 10, the inner surface of which is coated with the lossy material 11, whereby the waveguide walls are heated and thus by heat conduction the cathode of the thermionic cell is heated causing it to emit electrons to obtain a current flow in the cell and connected circuits.

In FIGURE 3 there is illustrated another embodiment of the invention wherein waveguides formed with waveguide chokes are employed. In this embodiment, a waveguide section 27 provided with a flange at each end is coupled to a waveguide section 25 by means of a choke joint. As indicated by waveguide sections 25 and 41 any number of waveguide sections may be coupled to each other through means of the waveguide choke method. Waveguide section 27 is provided at one end with flange 29 for coupling the waveguide to the source of microwave energy 38 and its opposite end is also provided with a similar flange 28 for coupling to an adjacent waveguide. Waveguide section 25 is formed at one end with a choke plate 26 and coupled to waveguide section 27 by means of flange 28 and choke plate 26 whereby a choke joint is formed. A spacer ring 33 of insulating material prevents electrical contact between choke plate 26 and flange 28. The use of the choke joint eliminates the need for insulation such as beryllia on the peripheral surface of the waveguides. Waveguide section 25 is also provided with a flange 30 for coupling to waveguide section 41 through choke plate 42 separated by a spacer ring 33 as heretofore described in conjunction with the choke joint between sections 27 and 25. Each of the waveguide sections are lined with lossy material 11. It is to be understood that in this embodiment of the invention the waveguide utilized may for example consist of waveguide section 27 and any number of waveguide sections such as sections 25 and 41 coupled by means of choke joints as illustrated in FIGURE 3 and wherein each of said sections carry a thermionic cell as described in the following, resulting in a battery of series connected thermionic cells. Thermionic cells 32 are of substantially the same construction as thermionic cells 15 except that the edges of cathode 34 and anode 35 are hermetically sealed to insulator 36 comprising the vertical wall of the cell and whereby chamber 40 is formed which contains the cesium vapor 20 under low pressure. This constructing prevents shorting of the anode 35 to the waveguide. Thermionic cells 32 extend between the flanges of the first section and between the choke joints and flanges of the respective adjacent sections of waveguides with their cathodes directly affixed to the peripheral surfaces of the waveguide sections. An electrical conductor means 37 connects the anode of one cell to choke plate of the adjoining waveguide whereby the cells are connected in series. It is also to be understood that the cells 32 may be of any geometric configuration and may completely embrace the peripheral surfaces of the related waveguides.

In another embodiment of the invention, FIGURES 4 and 5, a circular waveguide is employed. In particular, the use of the TE₀₁ mode in the circular waveguide is advantageous. Since there are no longitudinal currents accompanying this mode, the waveguide can simply be divided into longitudinal sections with a thin insulation between adjacent sections whereby the choke joints shown in FIGURE 3 are eliminated. Furthermore, the circumferential currents accompanying the TE₀₁ mode in the circular waveguide are constant with angle around the waveguide and the heating of the waveguide will then

not vary with angle resulting in a more uniform heating of the cathode of the thermionic converter. Now, with reference to FIGURES 4 and 5 wherein is shown the aforementioned embodiment and wherein for the purpose of illustration is shown a circular waveguide 45 divided into three sections 46, 47 and 48, it being understood that the waveguide may consist of any number of sections. The ends of adjacent sections are separated by a thin ring insulator spacer 56 adapted to fit the ends of the adjacent sections. The interior surfaces of the waveguide sections in this instance are also coated with lossy material 11. The thermionic converter 53 comprises a cylindrical cathode 57 of refractory material adapted to fit the peripheral surface of cylindrical waveguide 45 and a concentric cylindrical metallic anode 58 which is held in spaced relationship to cathode 57 by means of insulator ring end closures 49 and 50 in hermetically sealed relationship with cathode 57 and anode 58 to form annular chamber 51 which contains cesium vapor 52. The length of each thermionic converter may extend approximately the length of the related waveguide section. To provide a battery of series connected thermionic converters, and electrical conductor 54 bridges each of the related insulator rings whereby the anode of one thermionic converter is connected to the cathode of the adjacent thermionic converter. In FIGURES 3 and 5 the waveguide may serve as the cathode terminal and electrical conductors 37 or 54 as the anode terminal when a single thermionic converter is employed or conductors 37 or 54 of the anode of the last thermionic converter of a battery of series connected thermionic converters may be utilized as the anode terminal.

While certain forms of the invention have been shown and described for the purpose of illustration, it will be understood that modifications may be made in the practice of the invention without departing from the spirit or scope of the following claims. For instance, the power converted into heat will fall off exponentially, to a first approximation, with distance down the waveguide. To overcome this the diameter of the waveguide can be decreased or the resistivity of the inner surface metal can be increased.

I claim:

1. A device for generating direct current comprising in combination a waveguide, a source of microwave energy for energizing said waveguide, a lossy material lining the inner surfaces of said waveguide, electrical insulating means consisting of a metalloid oxide coating formed on the peripheral surfaces of said waveguide, a thermionic converter consisting of a cathode of refractory material and metallic anode elements spaced by means of a wall of insulating material to form a hermetically sealed chamber, cesium vapor in said chamber, said cathode being affixed to said metalloid oxide coating, electrical terminal means affixed in said cathode, and electrical terminal means affixed in said anode.

2. The invention in accordance with claim 1 wherein said waveguide has affixed to said metalloid oxide coating a multiplicity of said thermionic converters connected in series and longitudinally spaced from each other.

3. A device for generating direct current comprising in combination a waveguide consisting of a first waveguide section provided with a flange at each end thereof, a series of waveguide sections, each of said series of waveguide sections provided with a choke plate at one end and a

flange at the opposite end whereby a choke joint is formed between each of said series of waveguide sections, the first of said series of waveguide sections being coupled to said first waveguide section through the choke plate thereof and a flange of said first waveguide section whereby a choke joint is formed therebetween, a centrally perforated insulator spacer positioned between the choke plate and flange of each of said choke joints preventing electrical contact between the flange and choke plate of each of said choke joints, a lossy material lining the inside surfaces of each of said waveguide sections, a thermionic converter positioned between the flanges of said first waveguide section, a thermionic converter positioned between the choke plate and flange of each of said series of waveguide sections, each of said thermionic converters consisting of a continuous wall of insulation supporting within its confines in hermetically sealed relationship a cathode of refractory material in spaced relationship to an anode to form a chamber, cesium vapor in said chamber, the cathode of each of said thermionic converters being affixed to the peripheral surface of the respective waveguide sections, electrical conductor means bridging each of said choke joints whereby the anode of one thermionic converter is connected to the cathode of the adjacent thermionic converter forming a battery of series connected thermionic converters, and microwave energy generating means coupled to said waveguide for exciting said waveguide.

4. A device for generating direct current comprising in combination a circular waveguide consisting of a number of circular waveguide sections, the adjacent ends of each of said waveguide sections spaced in butted relationship by a thin ring insulator, a lossy material lining the inner surfaces of each of said waveguide sections, a thermionic converter encircling each of said waveguide sections intermediate the ends thereof, each said thermionic converter comprising a cylindrical cathode of refractory material affixed to the peripheral surface of the related waveguide section, a concentric metallic anode surrounding said cathode, an insulator ring positioned at each end of said cathode and anode in hermetically sealed relationship therewith forming an annular chamber, and cesium vapor in said annular chamber, electrical conductor means bridging each said thin ring insulator whereby the anode of one thermionic converter is connected to the cathode of the adjacent thermionic converter forming a battery of series connected thermionic converters, and microwave energy generating means coupled to said waveguide for exciting said waveguide.

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U.S. Cl. X.R.

324—106; 333—81