June 3, 1958 E. G. LINDER 2,837,666

RADIOACTIVE VOLTAGE SOURCE EMPLOYING A GASEOUS DIELECTRIC MEDIUM

Filed July 24, 1953

Fig. 1.

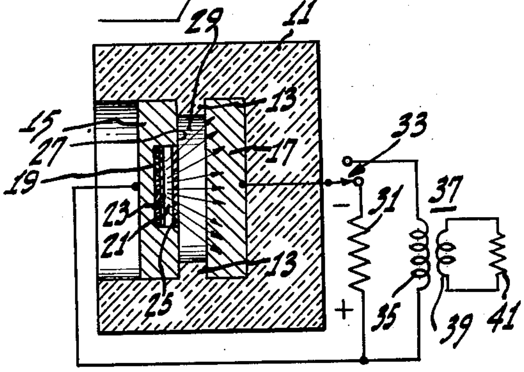


Fig. 2.

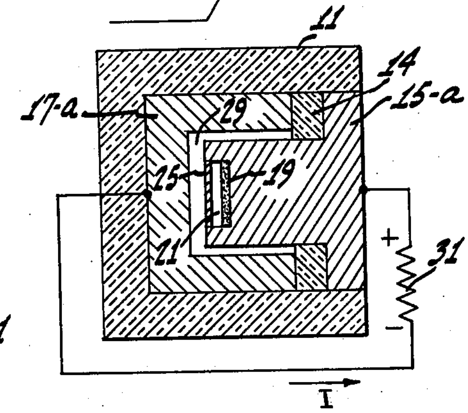


Fig. 3.

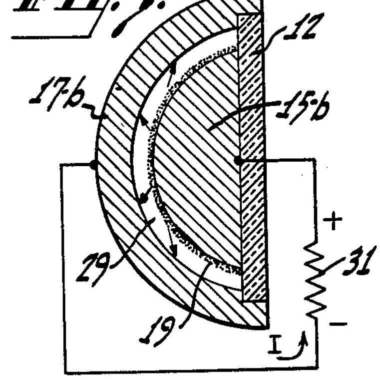


Fig. 4.

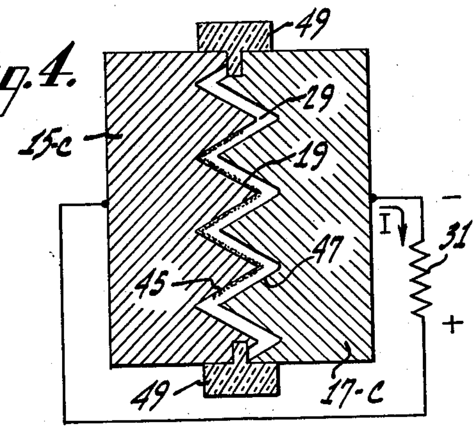
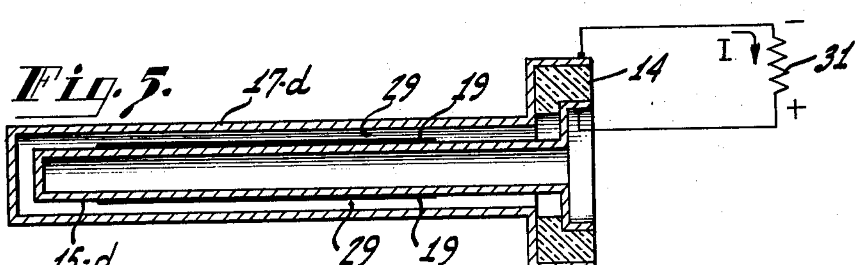


Fig. 5.



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RADIOACTIVE VOLTAGE SOURCE EMPLOYING A GASEOUS DIELECTRIC MEDIUM

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Application July 24, 1953, Serial No. 370,125

13 Claims. (Cl. 310—3)

This invention relates generally to the conversion of the energy of nuclear radiations into useful electrical energy. Particularly the invention relates to an improved radioactive primary type of voltage charging or voltage generating device for generating either unidirectional or alternating voltages.

In my U. S. Patent No. 2,517,120 voltage generating apparatus is described in which a radioactive source of charged particles is located within an evacuated device. The radiation source emits high energy charged particles, for example, positively-charged alpha particles or negatively-charged beta particles, which are collected to establish a potential with respect to the source. The energy of the potential thus established is used to supply current to a load circuit. The device is evacuated so that substantially no gas molecules are present between the source and the collector which would be ionized by the high energy radiations. Such ionization, if it were permitted to occur, would cause a substantial if not complete discharge of the accumulated electrical charge. The patented device produces a unidirectional voltage and charges to some final voltage which may be of the order of several hundred thousand volts.

My copending application Serial No. 177,015, filed August 1, 1950, now abandoned, describes different voltage generating apparatus, also employing a radioactive isotope, which permits D.-C. voltage charging in air or other media at or near atmospheric pressure rather than in a vacuum. In the devices described in said application, a solid dielectric material is interposed between the radiation source and the collector. The dielectric member is substantially permeable to the primary high energy particles and permits the particles to be collected to generate a useful direct current voltage. The dielectric member, however, is not permeable to the reverse current flow of low energy ions. These ions tend to reduce the potential to which the device finally charges. Since some reverse ion current does flow through the irradiated dielectric, the maximum potential to which this device may charge is lower than that of the device previously described and is of the order of several thousand volts.

It has been found that when the solid dielectric member of the latter device is subjected to radioactive emissions for an extended period of time, the conductivity of the dielectric material changes from its original value. This change in conductivity is one form of radiation damage and causes a change in the terminal voltage of the device. Although it may require several years for the conductivity of the dielectric to change appreciably, the voltage change may be undesirable since the half life of the radioactive isotope employed by the voltage source may be twenty-five years or greater.

An object of the present invention is to provide an improved radioactive voltage generating device.

Another object of the invention is to provide a substantially constant voltage-constant current energy source employing a radioactive isotope.

Another object of the invention is to obviate the effects

of radiation damage in voltage generating devices employing radioactive isotopes.

A further object of the invention is to provide an improved radioactive voltage generating device which is operable at or near normal atmospheric pressures.

A further object of the invention is to provide an improved voltage generating device which is capable of producing either a unidirectional voltage output or an alternating voltage output.

A still further object of the invention is to provide an improved voltage generating device which does not require a solid dielectric member for preventing the flow of a reverse ion current.

The foregoing objects may be accomplished in accordance with the invention by spacing the radioactive charged particle emission source a predetermined distance from the collector electrode. The medium between the emission source and the collector electrode is a gaseous medium at or near atmospheric pressure rather than a solid dielectric member as discussed heretofore. The electrode spacing is made less than the mean free path for ionization of gas molecules by collisions with the high energy radioactive charged particles. With the electrodes so spaced little or negligible ionization of gas molecules occurs, and the collector electrode collects the emitted high energy particles to establish a potential relative to the emission source. The substantially unionized gaseous medium present between the emitter and collector affords high resistance insulation therebetween and obviates the effects of radiation damage which occur when using a solid dielectric material.

In one mode of operation the electrode spacing and/or the value of the load impedance for the device are chosen so that the voltage gradient across the gaseous medium is sufficiently low that appreciable cold charged particle emission from the collector electrode does not result. Cold emission occurs when the voltage gradient is great enough that electrons are pulled from the surface of the collector electrode and flow in a direction which is opposite to that of the radioactive charging current. Cold emission would cause a partial or complete discharge of the device. With the electrode spacing and load impedance suitably chosen the device charges to a desired constant voltage, there is substantially no cold emission, and a constant output current is provided.

In a different mode of operation, the electrode spacing and/or load impedance are selected so that the device operates in this critical region where cold charged particle emission does occur. The device charges either negatively or positively (depending on the type of radioactive emitter material employed) and continues to charge until the terminal voltage reaches such a value that either the voltage gradient between emitter and collector is sufficient for cold emission to occur or the gaseous medium breaks down and the device discharges. When the device breaks down the terminal voltage of the device drops to substantially zero volts. The repetitive charging and discharging of the device in this manner results in the generation of a pulsating voltage.

The invention will be described in greater detail with reference to the accompanying drawing in which:

Figure 1 is a sectional view and schematic diagram of a radioactive energy source, according to the invention;

Figure 2 is a sectional view of an embodiment of the invention in which improved shielding is provided for structure which is utilized to maintain the spaced relation of the emission source and collector electrode;

Figures 3 and 4 are sectional views of further embodiments of the invention; and

Figure 5 is a sectional view of another embodiment of the invention in which cylindrical electrode geometry is employed.

Similar reference characters are applied to similar elements throughout the drawing.

Referring to Figure 1, a first embodiment includes an electrode holder 11, annular in shape and formed, for example, of an insulating material such as polystyrene or mica. The holder includes an inwardly projecting portion 13 which supports a pair of electrically conductive electrodes 15 and 17 in a predetermined spaced relation. Electrodes 15 and 17 may be of aluminum. The electrode spacing (determined by the width of projecting portion 13) is critical and is determined as described hereinafter.

The electrode 15 is a support electrode for a radioactive material 19 which is capable of emitting high energy radioactive charged particles. For present purposes it is assumed that the emitter material 19 is strontium^{90}, an emitter of negatively-charged beta particles. However, other beta particle emitters or, alternatively, emitters of positively-charged alpha particles may be used. The material 19 is deposited at the bottom of a recessed portion 21 of the support electrode 15. The depth of the recessed portion 21 is made sufficiently great that substantially few charged particles, emitted tangentially or at low emission angles, strike the insulating spacer portion 13.

A thin window 23, for example of aluminum foil, permeable to the charged particle emission, may be employed to provide physical support for the radioactive emitter 19. A second window 25, also permeable to charged particle emission, is positioned across and seals off the recessed region 21. This second window 25 is mounted flush with the surface 27 of the support electrode 15 so that uniform spacing is maintained between electrodes 15 and 17.

The emitter material 19 preferably is mixed with a binder so that the mixture is self-supporting and adheres to the surface of the region 21 whereon it is deposited. For example, strontium^{90}, in powdered form, may be mixed in a liquid solution of polystyrene and the mixture coated or evaporated onto the desired surface. If the emission source is made self-supporting in this or in a similar manner the support window 23 may be omitted.

The electrode 17 collects charged particles emitted by the radioactive emitter 19. The thickness of the collector electrode 17 is dependent on the penetration power of the high energy radiation and should be sufficient to absorb substantially all the radiation incident thereon.

A gaseous medium 29 occupies the space between the electrodes 15 and 17. The medium 29 is maintained at or near atmospheric pressure and may be air or some other gas such as helium or neon which have high ionization potentials.

The critical spacing mentioned heretofore is selected to be less than the mean free path for ionization of molecules of the gaseous medium 29 by collisions with the emitted radioactive charged particles. In air, for example, at atmospheric pressure, a typical beta emitter such as the previously mentioned strontium^{90} isotope produces particles having ranges of the order of 400 centimeters. The total number of ion pairs formed by collisions of these particles with air molecules is approximately 20,000. The average distance for the production of one ion pair then is 0.02 centimeter or eight mils. This figure represents the maximum electrode spacing for the instant device for a typical beta emitter and an air dielectric medium at or near atmospheric pressure. The minimum electrode spacing is partially determined by mechanical considerations and is of the order of one mil.

The range of voltages which is attainable with electrode spacings of between one and eight mils is of the order of several hundred volts to 20,000 volts. The maximum output voltage attainable for any selected electrode spacing is determined by the voltage gradient between the electrodes 15 and 17. If this voltage gradient exceeds a critical value cold charged particle emission from the collector electrode 17 results and the voltage across the device breaks down. The value of the voltage gradient which causes cold emission from most metals is approximately 10^6 volts per centimeter. Thus if the spacing of electrodes 15 and 17 is 0.0025 centimeter (one mil), the maximum voltage which the device may develop before breaking down is 0.0025 times 10^6 or 2500 volts. If the electrode spacing is 0.02 centimeter (eight mils), the maximum terminal voltage of the device is 20,000 volts. Various intermediate electrode spacings yield breakdown voltages which vary between 2,500 volts and 20,000 volts.

Where the device is to be utilized as a constant voltage-constant current energy source, the collector electrode 17 is connected to one terminal of the load circuit 31 via a single pole-double throw switch 33. As a practical matter the collector electrode 17 usually is directly connected to the load circuit 31 rather than by means of the switch 33. However, since the device may be operated to generate either unidirectional or alternating current, the two modes of operation may be described more simply with reference to a single figure of the drawing which includes the switch. The other terminal of the load circuit 31 is connected to the emitter material support electrode 15.

For D.-C. operation the value of load circuit impedance is chosen so that the voltage gradient between electrodes 15 and 17 is less than 10^6 volts per centimeter whereby cold emission from the collector electrode does not result. If, for example, a constant-current device having a one mil electrode spacing is desirable, the terminal voltage developed across the load 31 is dependent on the internal impedance of the device and the load impedance connected to the device and must be some value less than 2500 volts. If, for example, constant current at 1000 volts is desired, maximum power may be delivered to the load circuit 31 when its impedance is equal to the internal impedance of the radioactive device. If one-sixth of a curie of strontium^{90} is used, the load impedance for maximum power transfer may be of the order of 10^{12} ohms. For different electrode spacings the load impedance may be selected accordingly. The criteria to be observed are that the terminal voltage of the device be less than the critical value for producing cold emission, and preferably that the load impedance be matched to the impedance of the generator.

Where the instant device is to be operated as an alternating-current generator rather than a direct-current generator, it is essential that either the device operate in the region where cold emission occurs or that the spacing of the emitter support and collector electrodes be great enough that a few random ionizations occur. In the latter case, however, the electrode spacing is still made less than the mean free path for substantial ionization. When the device has charged to some desired potential the electrostatic field across the gaseous medium 29 causes the randomly generated ions to collide with other gas molecules, cumulative ionization occurs, and the device breaks down. For A.-C. generation the load impedance, for any given electrode spacing, is selected so that the voltage gradient between electrodes 15 and 17 is greater than 10^6 volts per centimeter. Under such conditions the collector electrode 17 charges to develop a potential with respect to the emission source. The potential of the collector electrode is negative with respect to the emitter when a beta particle emitter is employed. The collector continues to charge until the 10^6 volts per centimeter voltage gradient is exceeded. At that time either the electrostatic field between electrodes 15 and 17 is sufficiently great that electrons are pulled from the surface of the collector electrode 17 or randomly produced ions cause cumulative ionization of the medium 29 and the device discharges. The charging cycle then begins again and continues until cold emission again occurs, the device then discharging. A pulsating output voltage thus is provided.

In this A.-C. mode of operation the arm of the switch 33 is thrown to the other of its two positions so that the collector electrode 17 is connected to a terminal of one winding 35 of a transformer 37. The other terminal of the winding 35 is connected to the support electrode 15. The transformer secondary winding 39 is connected to the terminals of the selected A.-C. load impedance 41.

While the transformer 37 may be either a step-up or step-down transformer, a step-down transformer is herein employed so that low currents at high voltages may be converted or transformed into higher values of current at lower voltages. The use of the transformer also facilitates matching the impedance of the load 41 to the relatively high internal impedance of the generator. This is true since the load impedance as seen by the voltage generator appears greater than its actual value by a factor of the square of the turns ratio of the transformer 37.

The frequency of the alternating-current signal generated in this manner largely is determined by the rate at which the device charges. This rate is dependent upon the capacity between the support electrode 15 and the collector electrode 17, the quantity of radioactive emitter material used, the type of radioactive emitter, the gas employed, and the gas pressure.

Referring to Figure 2, an embodiment of the invention is shown in which improved shielding is provided for the spacing member used for maintaining the spaced relation between the emitter support and collector electrodes. The spacing member comprises an apertured annular ring 14 of polystyrene or other suitable insulating material. The ring 14 is interposed between the emitter support electrode 15–*a* and the collector electrode 17–*a*. The ring has sufficient thickness that charged particles traversing the gaseous medium 29 between these electrodes 15–*a* and 17–*a* travel distances in the medium less than the mean free path for ionization of molecules of the gas by collisions with the charged particles. The emitter support electrode 15–*a* is made sufficiently thick that charged particles which are emitted in the reverse direction, i. e., away from the collector electrode 17–*a*, are absorbed and do not bombard the insulating and spacing ring 14. The insulator thus effectively is isolated from particle emission.

Figure 3 shows a device in which curved electrode geometries are employed. In this embodiment the shape of the emitter support electrode 15–*b* is plano-convex, the emitter material 19 being deposited on the convex surface. The collector electrode 17–*b* is complementarily curved with respect to the curvature of the convex surface of electrode 15–*b*. An annular insulating ring 12 maintains the aforementioned desired spacing between electrodes 15–*b* and 17–*b*. One of the advantages of the curved geometry is that the path lengths through the gaseous medium 29 of charged particles having low emission angles are considerably reduced.

Figure 4 shows another embodiment of the invention in which electrode geometries are designed to reduce the path lengths of particles emitted tangentially or at low emission angles. In this embodiment the adjacent surfaces of the emitter support electrode 15–*c* and the collector electrode 17–*c* are corrugated or have a zig-zag contour. The surfaces 45 and 47, respectively, are equidistantly spaced. Insulating plugs 49 are provided for maintaining the spaced relation of the electrodes.

In Figure 5 a device is shown in which cylindrical electrode geometry is provided. An inner cylinder 15–*d* provides mechanical support for a radioactive source 19 capable of emitting charged particles. Surrounding the support electrode 15–*d* and coaxial therewith is a cylindrical collector electrode 17–*d*. The electrodes similarly are spaced from each other a distance less than the mean free path for ionization of the medium 29 which is located between the electrodes. The spacing means comprises an insulating ring 14 which is located at one end of the spaced electrodes. The ring 14 is positioned so that relatively few of the emitted radioactive particles strike the ring. The principal advantage to be gained in employing cylindrical support and collector electrode is that relatively large quantities of emitter material may be used with a high degree of particle collection efficiency.

While the embodiments described with reference to Figures 2, 3, 4, and 5 have not been illustrated to show the switch illustrated in Figure 1, these devices may be operated in the same manner to produce either a direct or an alternating current output. It is essential that the electrode spacing for all the above devices, either for A.-C. or D.-C. operation, be less than that value which would result in ionization of the gaseous medium by the radioactive particles. The maximum voltage produced by each of the devices depends on the electrode spacing and/or the impedance of the load circuit connected thereto. For A.-C. operation these factors are chosen so that the device operates at a voltage gradient where cold emission occurs. For D.-C. operation the device is operated at voltages yielding lower gradients so that cold emission does not occur.

What is claimed is:

1. A primary source of electrical energy comprising, a source capable of emitting radioactive charged particles, a collector electrode spaced from said source for collecting said radioactive charged particles to establish a potential relative to said source, and a gaseous medium occupying a space between said emission source and said collector electrode, the geometry of the space occupied by said gaseous medium being such that charged particles traversing said medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

2. A primary source of electrical energy comprising, a source capable of emitting radioactive charged particles, a collector electrode spaced from said source for collecting said radioactive charged particles to establish a potential relative to said source, an insulating member for maintaining a predetermined spacing between said emission source and said collector electrode, and a gaseous medium occupying a space between said emission source and said collector electrode, the geometry of the space occupied by said gaseous medium being such that charged particles traversing said medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

3. A primary source of electrical energy comprising, a source capable of emitting radioactive charged particles, a collector electrode spaced from said source for collecting said radioactive charged particles to establish a potential relative to said source, an insulating member for maintaining a predetermined spacing between said emission source and said collector electrode, said insulating member being substantially shielded from said particle emission, and a gaseous medium occupying a space between said emission source and said collector electrode, the geometry of the space occupied by said gaseous medium being such that charged particles traversing said medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

4. A primary source of electrical energy comprising, a material capable of emitting radioactive charged particles, an electrically conductive electrode for supporting said radioactive emitter material, a collector electrode spaced from said support electrode for collecting charged particles emitted by said material to establish a potential relative to said support electrode and said material, an insulating member for maintaining a predeter-

mined spacing between said support and collector electrodes, and a gaseous medium occupying a space between said electrodes, the geometry of the space occupied by said gaseous medium being such that charged particles traversing said medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

5. Apparatus as claimed in claim 4 wherein said conductive support member includes a recessed portion within which said emitter material is located, the depth of said recessed portion being sufficiently great that said insulating member is substantially shielded from said particle emission.

6. Apparatus as claimed in claim 1 wherein said charged particle emission source comprises a source of negatively charged beta particles.

7. Apparatus as claimed in claim 1 wherein said gaseous medium is at a pressure of the order of atmospheric pressure.

8. A primary source of electrical energy comprising, a material capable of emitting radioactive charged particles, a convex shaped electrode for supporting said emitter material, a complementarily shaped collector electrode equidistantly spaced from said support electrode for collecting charged particles emitted by said material to establish a potential relative to said material and support electrode, and a gaseous medium occupying the space between said material and collector electrode, the spacing between said material and said collector electrode being such that charged particles traversing said medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

9. A primary source of electrical energy comprising, a material capable of emitting radioactive charged particles, an electrode having a zig-zag shaped surface for supporting said emitter material, a collector electrode having a zig-zag surface complementary with respect to said support electrode surface and spaced equidistantly therefrom, said collector electrode collecting charged particles emitted by said material to establish a potential relative to said material and support electrode, and a gaseous medium occupying the space between zig-zag surfaces, the spacing between said material and said collector electrode being such that charged particles traversing said gaseous medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

10. A primary source of electrical energy comprising, a material capable of emitting radioactive charged particles, a cylindrical electrode for supporting said material on a surface thereof, a cylindrical collector electrode coaxial with respect to said support electrode and spaced equidistantly therefrom, said collector electrode collecting charged particles emitted by said material to establish a potential relative to said material and cylindrical support electrode, and a gaseous medium occupying the space between said coaxial electrodes, the spacing between said material and collector electrode being such that charged particles traversing said gaseous medium travel a distance which is less than the mean free path for ionization of molecules of said medium by collisions with said charged particles.

11. Apparatus as claimed in claim 10 including an insulating member for maintaining the spaced relation of said coaxial electrodes, said insulating member being substantially shielded from said particle emission.

12. Apparatus as claimed in claim 1 including a load circuit coupled between said charged particle emission source and said collector electrode, the impedance of said load circuit being so related to the internal impedance of said primary energy source and the spacing between said charged particle source and collector electrode to produce a pulsating current through said load.

13. Apparatus as claimed in claim 12 including means for converting said pulsating current into alternating current.

No references cited.