May 29, 1951 J. H. COLEMAN 2,555,116

VARIABLE POTENTIAL ELECTRICAL GENERATOR

Filed Oct. 30, 1948

Fig.1.

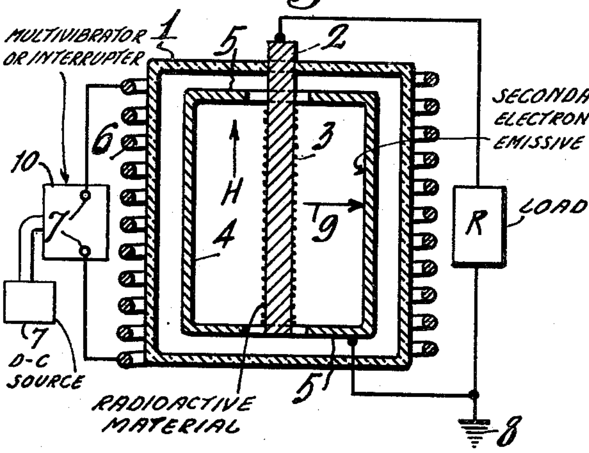


Fig.3.

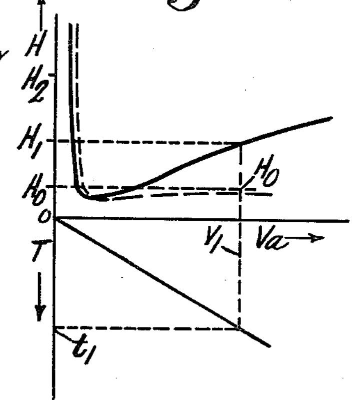


Fig.2.

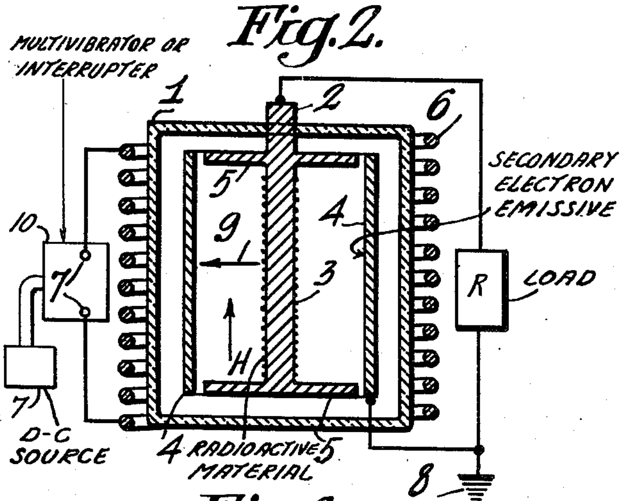


Fig.4.

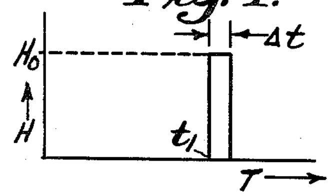


Fig.5.

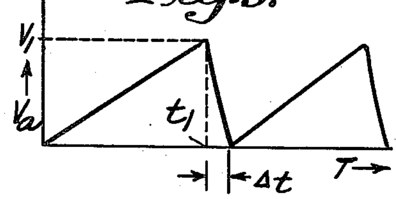


Fig.6.

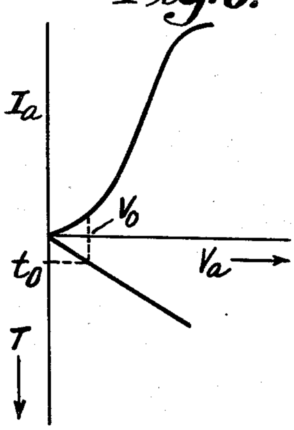
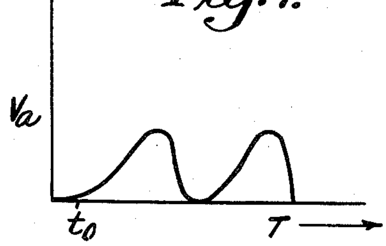


Fig.7.



INVENTOR
John H. Coleman
BY J. L. Whittaker
ATTORNEY

Patented May 29, 1951 2,555,116

UNITED STATES PATENT OFFICE

2,555,116

VARIABLE POTENTIAL ELECTRICAL GENERATOR

John H. Coleman, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 30, 1948, Serial No. 57,463

15 Claims. (Cl. 322—2)

1

This invention relates to electrical generators and more particularly variable potential nuclear electrical generators.

It is known that certain isotopes are radioactive and emit nuclear charged particles at known rates over known periods of time and over a range of energy values or levels expressed in electron volts. Some emissions consist of positively charged or alpha particles, others of negatively charged or beta particles and others both alpha and beta particles.

When nuclear charged particles bombard or strike other substances, the particles cause secondary electron emission or other forms of secondary radiation or the particle may be captured or elastically reflected depending upon the energy and character of the particle, the angle of incidence of individual bombardments and the character of the bombarded substance itself.

Secondary electron emission is in random directions and at velocities usually much less than that of the bombarding particles. The paths of the secondary emission electrons depend upon their energies and the electrostatic and magnetic field values in the region in which they move.

The change in potential of the radioactive source resulting from its radiation depends upon the charge sign of the radiated particles and intensity of the radiation. When a beta particle or electron is emitted from a source, whether by primary or secondary emission the potential of the source with respect to the collector is positively increased. On the other hand, when an alpha particle is emitted, the potential of the source with respect to the collector is increased negatively.

These general principles are applied in a novel combination to generate variable electrical potentials by using the emission of charged particles to build up a difference of potential between a radioactive source and an electrode to a desired amount and when the difference in potential has risen to the desired and predetermined amount, a discharge of the potential is effected by impressing a magnetic field upon the medium between the source and the electrode. This discharge is accomplished by the magnetic field causing ionization of the medium, with attending flow of conduction currents of charged particles across the medium and thereby neutralizing the difference in potential between the source and the electrode. These differences in potentials are utilized by connecting the source and the electrode to an external or load circuit.

Among the objects of the invention are to provide new methods of and means for generating variable electric potentials.

2

Another object of the invention is to build up at predetermined rates differences in potentials between a radioactive source and an electrode by the emission and capture of nuclear charged particles and to discharge the built-up potentials at predetermined values and at predetermined times and rates.

Other objects will be apparent from the description of the invention as hereinafter set forth in detail and from the drawings made a part hereof in which Figure 1 is a schematic sketch of a vertical cross section of an embodiment of the invention as applied to a beta emitter radioactive source; Figure 2 is a schematic sketch of a vertical cross section of an embodiment of the invention as applied to an alpha emitter radioactive source; Figure 3 is a graph showing the relation between the values of the magnetic field impressed upon the medium between the radioactive source and the collector electrode to the values of the potentials between the source and the electrode to satisfy the condition that the medium is just non-conducting and a graph showing the relation between the difference in potential between the source and the electrode and time; Figure 4 is a graph showing the relation between the strength of the magnetic field and time; Figure 5 is a graph showing the relation of the potential across the device to time; Figure 6 is a graph showing the relation between the current across the device to the voltage across the device for a fixed value of magnetic field strength and a graph showing the relation of the voltage across the device to time; and Figure 7 is a graph showing the relation of the voltage across the device in relation to time.

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

Referring to Figure 1, 1 represents the envelope of the device, which may be of glass or other material permeable by a magnetic field and capable to maintaining a high vacuum the rarified residual gaseous medium having a pressure not exceeding 10^{-3} mm. Hg, for example. The "medium" specified throughout the specification and claims is intended to refer to said residual gaseous medium. Rod 2 is mounted in the vertical axis of the envelope and has deposited thereon the radioactive material 3. As this figure represents the embodiment of the device as applied to a beta emitter, the radioactive material may be phosphorus^{32}, which is a pure beta emitter with energies of the particles ranging up to about

1 m. e. v. The radioactive material and the rod support 2 will be referred to throughout the specification and claims as the "source" and identified by the numeral 3.

Coaxial with source 3 is mounted the target or collector electrode 4 which is generally cylindrical in shape, with end plates 5 at each end extending inward. Collector 4 is made of some non-magnetic metal which is also secondary electron emission responsive to beta radiation. Aluminum has been found to be satisfactory for this purpose.

Surrounding envelope 1 is solenoid 6, which is connected to a source of direct current 7 in the circuit of which is connected a conventional controlled interrupter 10, such as a multi-vibrator.

Between source 3 and collector 4 is connected the load circuit of the device, a part of which circuit is a load having an impedance R. The load circuit and collector 5 are grounded at 8.

In operation, and referring to Figures 1 and 3, when there is no magnetic field impressed upon the medium of the device, the beta particles are emitted from source 3 in random directions as illustrated by arrow 9. Because of the shape of electrode 4 with its end plates 5, practically all of the particles bombard or strike electrode 4. The end plates 5 are not absolutely necessary to the operation of this embodiment of the device, but they increase the efficiency of electron trapping as will be hereinafter explained.

As each beta particle leaves source 3, a unit positive charge remains on source 3 and as each beta particle is captured by electrode 4, the charge on the collector 4 is decreased correspondingly. There will be some secondary electron emission from collector 4 and these electrons will be repelled by collector 4, thus tending to slightly decrease the potential difference between collector 4 and source 3. Some of these electrons will be accelerated to source 3, because source 3 is of positive potential. However, there will not be any ionization of the medium of the device as the mean free path of the electrons for collision with the molecules of the medium is much less than the mean path between molecules of the medium. Thus for low differences of potentials across the device compared with the maximum energy of the charged particle emission (1 m. e. v. for phosphorus^{32}) the charging rate of source 3 will be determined by the capacity constant of the system and the radioactive current or

$$Va=\frac{i}{c}T \qquad (1)$$

where Va is the voltage across the device, i is the radioactive current, c is the capacity of the system and T is time. The small currents, due to secondary emission are subtracted from the radioactive current to determine the effective generated currents. The plot of this relation is shown in the lower half of Figure 3.

When a magnetic field is impressed upon the medium of the device, as indicated by the arrow H, for certain values of H and Va the secondary electrons are cut off from reaching source 3 by being so deflected in their paths that they pass by source 3 and strike electrode 4 again and again. They are thereby trapped within the medium and their paths are lengthened beyond the mean free path ionization by collision and ionization of the medium occurs. With ionization, further or cumulative ionization occurs because of the creation of a large number of ion pairs and large conductive currents flow across the medium.

The conditions for cut off have been calculated to be

$$H=\frac{Rs}{Rc^2}\sqrt{\frac{8m}{e}}\sqrt{Va} \qquad (2)$$

where Rs is the radius of source 3, Rc is the radius of electrode 4, m is the mass of the particle, e is the charge of the particle and Va is the potential of source 3, all in c. g. s. units (see Hull, Physics Review 1921, volume 18, page 35).

In the upper part of Figure 3, there has been plotted by the dash curve the observed conditions, of a particular tube, of cut off for various values of H and Va. The lower part of this curve corresponds closely to the mathematical analysis of the reactions as set forth in Equation 2.

Thus, if after an interval of time, t_1, Va will have risen to the value of V_1 and if a magnetic field is impressed upon the medium at the time instant of t_1 and equal to or greater than H_0 (see Figure 4), the medium becomes conductive (see Figure 3) and Va will drop through the conduction region to near zero in the time interval Δt. This discharge period is determined by

$$\Delta t=R'C \qquad (3)$$

where R′ is the effective resistance of the conduction region and C is the total effective capacity of the system.

If the solenoid circuit is broken at the end of the period Δt, H becomes zero and the device will begin to recharge again at a constant rate as hereinbefore described.

In Figure 4 is shown a typical magnetic pulse, which is a function of the current through the solenoid. It is obvious that this pulse may be biased by a magnetic field equal to any value below that of H_0.

The plot of the Va versus time is shown in Figure 5.

The device shown in Figure 2 is used when the radioactive material is an alpha emitter. The arrangements of the two devices are generally the same except that the plates forming the ends of the conductive region for the alpha emitter are essential and are made part of the central electrode instead of the outer electrode, as in the case of a beta emitter. It was found that no trapping or ionization occurred within the medium, with attending conduction currents, if the locations of the end plates were reversed, that is, if the plates were secured to the electrode 4 in an alpha emitter device, and vice versa.

In Figure 2, 1 is the envelope, 2 is the central rod or electrode upon which is deposited the radioactive material. Polonium^{210} is a suitable alpha emitter, with radiated particles reaching maximum energy values of about 2 m. e. v.

At each end of electrode 2 are positioned the end plates 5. 4 is the collector electrode and is cylindrical in shape. The solenoid 6, supplied by direct current from source 7, surrounds the envelope 1. The load circuit R is connected between source 3 and electrode 4 and is grounded at 8.

In operation, the reactions are the same in general as those described for the device of Figure 1. Alpha particles are emitted from source 3 and bombard electrode 4, causing secondary electron emission which are immediately returned to the collector by the electric field. The delta electrons emitted from the source tend to be attracted to the positive collector 4.

The generation of large conduction currents upon the impressing of a magnetic field upon the medium occurs in the same manner as hereinbefore described, except that the delta electrons and ionization electrons flow to the electrode **4** and therefore flow through the medium and the load circuit in a direction opposite to that when a beta emitter is used as the radioactive source.

The solid curve in Figure 3 is a plot of the relation between the magnetic field H and the voltage across the device, when the device is just non-conducting. The value of the magnetic field to cause the generation of conduction currents when V_a reaches the value of V_1, is determined from the graph as H_1. The sawtooth voltage-time curve in Figure 5 applies to both types of devices.

To define the relation between a time interval of charging the device and the minimum required magnetic field for discharge of the device at the end of that time interval, it will be noted from the form of the lower boundary of the alpha (solid line, Figure 3) cut-off curve that

$$H=K\sqrt{Va} \qquad (3')$$

where K is a constant determined by the geometry of the elements of the device.

It has been seen that

$$Va=\frac{i}{c}\cdot t \qquad (1)$$

and as i and c are constants determined by the amount of radioactive material deposited on electrode **2** (disregarding the half life of the radioactive material) and the capacity of the system, respectively, Equation 1 becomes

$$Va=\frac{i}{c}\cdot t=K'\cdot t \qquad (4)$$

and

$$H=K_2\sqrt{t} \qquad (5)$$

for the alpha case where $K_2=K\sqrt{K'}$.

For the beta device, where $V>V_0$, $H=H_0$=a constant.

As another method of operation (see Figures 6 and 7), the magnetic field is held constant at some value, for example, H_2, Figure 3. Referring to Figure 6 there is plotted again in the lower part of the figure, the charging curve (a straight line) of Va versus time.

When the charging voltage Va reaches the value V_0 at time (t_0) a small amount of current (i_0) will begin to flow across the device. As Va increases the effective resistance across the device becomes less and less and the current increases rapidly, as plotted in the upper part of Figure 6. With the larger currents flowing the voltage across the device, Va, drops almost to zero, as shown in Figure 7, in which is plotted the relation between Va and time (T).

It is of course apparent that a wide range of desired outputs both as to voltage values and the form of the voltage-time curves can be obtained by selecting different amounts of radioactive material and selecting the geometry of the elements of the device.

Likewise, in selecting a biasing magnetic field, its value may approach the lower cut off value and, in such cases, the secondary electrons emitted from the collector electrode (beta emitter case) returned by the magnetic field to the collector and the delta electrons (alpha emitter case) are returned to the source. In both cases, the charging rate is increased.

There is thus disclosed an invention for providing variable potentials of desired values and wave forms by utilizing the potential charges on particles emitted from a radioactive isotope and controlling the flow of accumulated charges by a magnetic field.

What is claimed is:

1. The method of creating variable electric potentials comprising: providing a source of nuclear charged particle radiation in a rarified gaseous medium, exposing to said radiation a secondary electron emissive material, whereby differences of potentials are created between said source and said material by the emission of the said particles from the source and the capture of said particles by the said material, and imposing a magnetic field upon said medium at intervals of time, whereby the medium becomes conductive and the said created potentials are neutralized.

2. The method of creating variable electric potentials comprising: providing a quantity of a radioactive isotope in a rarified gaseous medium, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particles by the said material, and imposing a magnetic field upon said medium at intervals of time, whereby the medium becomes conductive and the said created potentials are neutralized.

3. The method of creating variable electric potentials comprising: providing a quantity of radioactive isotope in a rarified gaseous medium, the quantity of said isotope being in proportion to the desired rate of increase in potentials of said variable potentials, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particles by the said material, and imposing a magnetic field upon said medium at intervals of time, whereby the medium becomes conductive and the said created potentials are neutralized.

4. The method of creating variable electric potentials comprising: providing a quantity of a radioactive isotope in a rarified gaseous medium, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particles by the said material, imposing a magnetic field upon said medium at intervals of time, whereby the medium becomes conductive and the said created potentials are neutralized by the flow of conduction currents between said isotope and said material, and adjusting the electrical characteristics of the circuit in which the said conduction currents flow to control the rate of said flow and thereby the rate of neutralization of said created potentials.

5. The method of creating variable electric potentials comprising: providing a quantity of a radioactive isotope in a rarified gaseous medium, the quantity of said isotope being in proportion to the desired rate of increase in potentials of said variable potentials, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in

potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particles by the said material, imposing a magnetic field upon said medium at intervals of time, whereby the medium becomes conductive and the said created potentials are neutralized by the flow of conduction currents between said isotope and said material, and adjusting the electrical characteristics of the circuit in which the said conduction currents flow to said control the rate of said flow and thereby the rate of neutralization of said created potentials.

6. The method of creating variable electric potentials comprising: providing a source of nuclear charged particle radiation in a rarified gaseous medium, exposing to said radiation a secondary electron emissive material, whereby differences of potentials are created between said source and said material by the emission of the said particles from the said source and the capture of said particles by the said material, and imposing a constant magnetic field upon said medium, whereby the medium becomes conductive upon the said potentials rising to predetermined values and the said created potentials are neutralized.

7. The method of creating variable electric potentials comprising: providing a quantity of radioactive isotope in a rarified gaseous medium, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particles by the said material, and imposing a constant magnetic field upon said medium, whereby the medium becomes conductive upon the said potentials rising to predetermined values and the said created potentials are neutralized.

8. The method of creating variable electric potentials comprising: providing a quantity of radioactive isotope in a rarified gaseous medium, the quantity of said isotope being in proportion to the desired rate of increase in potentials of said variable potentials, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particles by the said material, and imposing an ionizing constant magnetic field upon said medium, whereby the medium becomes conductive upon the said potentials rising to predetermined values and the said created potentials are neutralized.

9. The method of creating variable electric potentials comprising: providing a quantity of radioactive isotope in a rarified gaseous medium, the quantity of said isotope being in proportion to the desired rate of increase in potentials of said variable potentials, exposing to the charged particle radiation of said isotope a secondary electron emissive material, whereby differences in potentials are created between said isotope and said material by the emission of the said particles from said isotope and the capture of said particle by the said material, imposing a constant magnetic field upon said medium, whereby the medium becomes conductive upon the said potentials rising to predetermined values and the said created potentials are neutralized by the flow of conduction currents between said isotope and said material, and adjusting the electrical characteristics of the circuit in which the said conduction currents flow to control the rate of said flow and thereby the rate of neutralization of said created potentials.

10. Apparatus for creating variable electrical potentials comprising: a magnetic field permeable envelope enclosing a rarified gaseous medium, a source of nuclear charged particle radiation in said envelope, a secondary electron responsive electrode positioned adjacent said source, a solenoid surrounding said envelope and connected to a source of direct current sufficient to provide a magnetic field to ionize said medium, means to supply said current at predetermined intervals to said solenoid, and a load circuit connected between said source and said electrode.

11. Apparatus for creating variable electrical potentials comprising: a magnetic field permeable envelope enclosing a rarified gaseous medium, a source of nuclear negatively charged particle radiation being cylindrical in shape and positioned along the axis of said envelope, a secondary electron responsive electrode positioned adjacent said source, a solenoid surrounding said envelope and connected to a source of direct current sufficient to provide a magnetic field to ionize said medium, means to supply said current at predetermined intervals to said solenoid, and a load circuit connected between said source and said electrode.

12. Apparatus for creating variable electrical potentials comprising: a magnetic field permeable envelope enclosing a rarified gaseous medium, a source of nuclear positively charged particle radiation being cylindrical in shape and positioned along the axis of said envelope, a secondary electron responsive electrode positioned adjacent said source, a solenoid surrounding said envelope and connected to a source of direct current sufficient to provide a magnetic field to ionize said medium, means to supply said current at predetermined intervals to said solenoid, and a load circuit connected between said source and said electrode.

13. Apparatus for creating variable electrical potentials comprising: a magnetic field permeable envelope enclosing a rarified gaseous medium, a source of nuclear negatively charged particle radiation positioned along the axis of said envelope, a secondary electron responsive electrode positioned adjacent said source, the said electrode being cylindrical in shape and coaxial with said source and having end plates extending toward said source, a solenoid surrounding said envelope and connected to a source of direct current sufficient to provide a magnetic field to ionize said medium, means to supply said current at predetermined intervals to said solenoid, and a load circuit connected between said source and said electrode.

14. Apparatus for creating variable electrical potentials comprising: a magnetic field permeable enclosing a rarified gaseous medium, a source of nuclear positively charged particle radiation, the said source being cylindrical in shape and positioned along the axis of said envelope, the said source having at each end lateral flanges that extend outward from the source toward said envelope, a secondary electron responsive electrode positioned adjacent said source, a solenoid surrounding said envelope and connected to a source of direct current sufficient to provide a magnetic field to ionize said medium, means to supply said current at predetermined intervals to

said solenoid, and a load circuit connected between said source and said electrode.

15. Apparatus for creating variable electric potentials comprising an envelope containing a rarified gaseous medium, a source of nuclear charged particle radiation enclosed therein, a secondary-electron-emissive electrode within said envelope exposed to said radiation, whereby in operation differences of potentials are created between said source and said electrode by the emission of said particles from said source and capture of said particles by said electrode, and means for applying a magnetic field to said medium at intervals of time, whereby the medium becomes conductive and the said created potentials are neutralized.

JOHN H. COLEMAN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,108,830	Skellett	Feb. 22, 1938
2,128,408	Grenier	Aug. 30, 1938
2,492,313	Okress	Dec. 27, 1949

OTHER REFERENCES

"The Electrician," Oct. 31, 1924, page 497.