APPARATUS EMPLOYING RADIOACTIVE ISOTOPES

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This invention relates to electrical apparatus employing radioactive isotopes and particularly to an improved device utilizing a radioactive isotope and having a controllable output voltage.

In the prior art, voltage charging or voltage generating devices have been devised in which a radioactive source of charged particles is positioned in a vacuum and produces high energy charged particles which subsequently are collected to establish an electric potential. The use of a vacuum was necessary to prevent gas ionization between the radiation source and a collector electrode for collecting the charged particle radiations. Such ionization would cause a substantial if not complete reduction of the electrical charge desired.

However, in my foregoing application, Serial No. 177,015, filed August 1, 1950, radioactive voltage charging apparatus is described and claimed wherein such charging conveniently may be achieved at substantially higher gas pressures. In said apparatus, a dielectric sheet is interposed between the radiation source and the collector. The dielectric material prevents the flow of low energy particles between the source and the collector which tend to discharge the device but does not stop the high energy particles used for voltage charging. While a device thus fabricated affords voltage charging in air or other atmospheres, the device inherently charges to some final voltage which is a function of various factors including, for example, the quantity and type of radioactive isotope used, and the conductivity and thickness of the dielectric sheet.

It is desirable to provide some means for readily controlling the output voltage of the charger over a wide range of voltages. One voltage control arrangement is disclosed and claimed in my foregoing application Serial No. 312,477, filed October 1, 1952, now Patent No. 2,768,313 by Paul Rappaport wherein an aperture in the dielectric sheet provides an electrical charge leakage path comprising an ionized column of gas effectively shutting the charger. By utilizing a manually adjustable dielectric probe adapted to traverse the aperture and control its geometry, the equivalent resistance of the ionized gas column effectively shutting the charger may be controlled so that its output voltage is varied correspondingly.

According to the instant invention, an improved radioactive voltage source having a controllable output voltage is provided wherein the device output voltage is modulated and controlled not by mechanically changing the aperture geometry but by impressing modulation signals on an electrically conductive electrode positioned in the ionized medium. These modulation signals control the magnitude of an ion current which is produced in the ionized region which effectivly flows in opposition to the high energy charged particle current. By thus controlling the ion current magnitude in response to signal intelligence the device may be charged or discharged to a voltage greater or less than a given value in accordance with the polarity and amplitude of the modulation signal. Since the voltage control thus is basically electrical and does not require ad-

justable probes or other moving parts, the device is structurally simple and relatively easy to fabricate.

Further in accordance with the invention, it has been found that the above device, and modifications thereof, in addition to being utilized as a controllable voltage source, may be suitably biased to a point on its characteristic curve whereby the invention may be utilized to provide signal amplification, signal mixing, and the like.

An object of the invention is to provide novel electrical apparatus employing radioactive isotopes.

Another object of the invention is to provide an improved voltage source employing a radioactive isotope.

Another object of the invention is to provide an improved radioactive voltage charging device having a controllable output voltage.

Another object of the invention is to provide an improved radioactive voltage charging device in which a wide range of output voltages readily are attainable.

A further object is to provide a radioactive voltage source which is simple in structure and inexpensive to manufacture.

A further object of the invention is to provide a radioactive voltage charging device having an output voltage controllable in response to electrical signal intelligence applied thereto.

A still further object is to provide improved apparatus employing radioactive isotopes useful for amplifying and/or mixing electrical signal intelligence.

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

Figure 1 is a schematic diagram of apparatus including an improved voltage charging device having a controllable output voltage, according to the invention;

Figure 2 is a schematic diagram of a cylindrical embodiment of the device of Figure 1;

Figure 3 is a schematic diagram of a double-triode radioactive amplifier, according to the invention; and

Figures 4 and 5 are schematic diagrams of further embodiments of the invention.

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

Referring to Figure 1, a source capable of emitting high energy radioactive charged particles is indicated at 11. In the present example, it will be assumed that the radioactive isotope employed is strontium90, a beta particle emitter. It will be recognized, however, that other beta particle emitters and other types of charged particle emitters also may be used. Spaced from the source 11 is a collector electrode 13 of some suitable beta-ray absorbing material such as aluminum. Disposed intermediate the radioactive source 11 and the collector electrode 13 is a dielectric material 15 comprising, for example, a sheet of mica or polystyrene having an aperture 17 extending between the source and the collector. The aperture 17 is located in the travel path of a portion of the beta particles emitted by the source 11 such that an ionizable medium 19 contained therein is subjected to the high energy radiation. The ionizable medium 19 may comprise either a solid, a liquid, or a gas. For the present illustration it will be assumed that this medium is air.

In operation: The high energy negatively charged beta particles emitted by the source 11 pass through the dielectric sheet 15, which has low beta ray absorption, to the collector electrode 13 where they are collected to charge electrode 13 negatively with respect to the source. The collector electrode 13 increasingly becomes more negative with time until the output voltage is sufficiently great to repulse additional beta particles traveling toward the collector. A portion of the high energy radiation providing this charging action also penetrates the medium 19 defined by the aperture 17, such that the medium ionizes to produce relatively slow moving low energy pos-
itive and negative ions. Since these lower energy charged particles tend to partially discharge the device (i.e., the negatively charged particles flow toward the source 11 and the positively charged particles flow toward the collector 13), it may be said that an ion current is produced which effectively flows in opposition to the high energy charged particle emission. The net output voltage thus developed by the charger is

\[ V = iR = (i_i - i_b)R \]

where \( i \) is the net charging current, \( i_i \) is the equivalent high energy charged particle current, \( i_b \) is the effective reverse ion current, and \( R \) is the equivalent resistance of the device and load circuit to be connected thereto.

In accordance with the invention, an electrically conductive control electrode 21 is positioned in the ionizable medium. The electrode may comprise, for example, a mesh grid supported by the dielectric sheet 15 and mounted transversely to the charged particle radiation. Coupled to the control electrode 21 is a signal source 23 which provides signals for impressing an electric field on the ionized medium. Since the "reverse current" mentioned above primarily is attributable to positive ions and negative ions produced in response to ionization of the medium 19 and since the magnitude of this current determines the terminal voltage of the charger, variations in the electric field impressed on the medium control the reverse current flow and cause corresponding variations in the terminal voltage. Because of the extremely high energies possessed by the beta particles the grid 21 exerts negligible control thereon and controls only the reverse current. Thus the modulation signals, depending on their amplitude and polarity, cause the device either to charge to a potential greater than the potential to which it normally charges with zero control voltage or to discharge to a potential less than that potential. The electric energy of the potential thus derived may then be used to supply current to a load or utilization circuit 25.

While the device described above preferably is used as a voltage source capable of readily supplying a wide range of output voltages in response to different amplitudes and polarities of signals supplied by the source 23, the device may be employed with equal facility as a cold cathode amplifier. In the event that it is desirable to so adapt the device, a bias battery 27 is used to bias the device to operate in the non-linear portion of its operating characteristic curve. Under such conditions alternating-current signals applied to the device from the source 23 are amplified and supplied to the load circuit 25. While the ion transit time through the aperture is of the order of 10\(^{-9}\) seconds and indicates an upper frequency limit of 10\(^9\) cycles per second, the upper limit actually may be less than this value. This is true since the RC time constant of the charger imposes an upper frequency limit which may be less than the limit imposed by the ion transit time.

Referring to Figure 2, a cylindrical embodiment of the device of Figure 1 is shown. The radioactive source 11 provides high energy charged particles which are collected by a cylindrical collector electrode 13 surrounding and spaced from the source by an apertured dielectric cylinder 15. A cylindrical or other suitably shaped control electrode 21 may be positioned in the aperture and, in response to control signals impressed thereon, controls the output voltage of the device in a manner substantially identical to that described with reference to Figure 1. This arrangement may be particularly desirable since the cylindrical configuration enables the high energy charged particles to be collected more efficiently than by using plane collectors. The instant device also may be used either as a voltage source or as an amplifier.

In Figure 3 a further embodiment of the invention is illustrated which comprises a double-triode cold cathode amplifier adapted for push-pull operation. In accordance with this feature of the invention the radioactive source is positioned across and divides the aperture 17 into two smaller apertures 17' and 17". Positioned in each aperture 17' and 17" are control electrodes 21 and 21', respectively, which are connected to opposite ends of the secondary winding 29 of a modulation transformer 31. The charged particle source 11 is connected to the center tap of the modulation transformer secondary winding 29 via a bias battery 27. In response to modulation signals developed across the transformer primary winding 33 oppositely poled signals are applied to grids 21 and 21' causing the terminal voltage of one charger unit to rise and the terminal voltage of the other charging unit to decrease. Since the primary winding 35 of an output transformer 37 is connected between the output terminals of each charging unit, a corresponding A.C. current flows through this winding. This current results in an output voltage appearing at the terminals of the output transformer secondary winding 39 which may be utilized as desired. Resistors 41 and 43 preferably are provided to prevent the relatively low impedance of the transformer winding 35 from shorting out the device.

In Figures 4 and 5 further embodiments of the invention are shown. In each of these figures the dielectric member 15 includes a plurality of apertures 17', 17" and 17' extending between the radiation source 11 and the collector electrode 13. These apertures each are provided with conductive electrodes, 21 and 21', respectively, which separately control the reverse current flow therein in response to ionization of the medium contained within the aperture bounds. Devices of this type may be particularly desirable for use as mixers or similar devices. The electrodes 21 and 21' may comprise grids positioned either across the apertures as shown in Figure 4 to provide a longitudinal control field or may comprise pairs of plane electrodes longitudinally positioned as shown in Figure 5 to provide a transverse control field as is desirable.

What is claimed is:

1. Electrical apparatus comprising, a cold source of high energy charged particle emission, a collector electrode for collecting said charged particle emission to establish an electric potential relative to said source, a dielectric member including an apertured portion disposed intermediate said source and said collector electrode, the confines of said dielectric member defining said apertured portion containing a medium capable of being ionized by a portion of said charged particle emission to produce a current effectively flowing in opposition to said high energy emission, and electrode means positioned in said medium for controlling the flow of said current.

2. Electrical apparatus comprising, as a source of high energy charged particle emission, a collector electrode for collecting said charged particle emission to establish an electric potential relative to said source, a dielectric member including an apertured portion disposed intermediate said source and said collector electrode, the confines of said dielectric member defining said apertured portion containing a medium capable of being ionized by a portion of said charged particle emission to produce a current effectively flowing in opposition to said high energy emission, and connection means for a source of modulation signals for applying said modulation signals to said conductive electrode for controlling the flow of said current whereby said established potential is modulated in accordance therewith.

3. Apparatus as claimed in claim 2 including means for utilizing the energy of said modulated potential.

4. Apparatus as claimed in claim 2 wherein said medium is a gas.

5. Apparatus as claimed in claim 2 wherein said medium is a liquid.

6. Apparatus as claimed in claim 2 wherein said medium is a solid.

7. Electrical apparatus comprising, a cold source of
5 high energy radioactive charged particle emission, a collector electrode spaced from said source for collectingsaid radioactive charged particle emission to establish an electric potential relative to said source, a dielectric member disposed intermediate and in contact with said source and said collector electrode and having an apertured portion extending therebetween, the confines of said dielectric member defining said apertured portion containing a medium capable of being ionized by a portion of said radioactive charged particle emission to produce a current effectively flowing in opposition to said high energy emission, and a conductive screen transversely positioned across said apertured portion for controlling the flow of said current whereby said established potential is modulated in accordance with signals impressed thereon.

8. Electrical apparatus comprising, a cold source of high energy charged particle emission, a collector electrode spaced from and surrounding said source for collecting said charged particle emission to establish an electric potential relative to said source, a dielectric member disposed intermediate and in contact with said source and said collector and having an apertured portion extending therebetween, the confines of said dielectric member defining said apertured portion containing a medium capable of being ionized by a portion of said high energy emission to produce an ion current effectively flowing in opposition to said charged particle emission, and electrode means positioned in said medium for controlling the flow of said ion current whereby said established potential is modulated in accordance with signals impressed thereon.

9. Apparatus as claimed in claim 8 wherein said conductive electrode is cylindrical in form.

10. Electrical apparatus comprising, a dielectric member having an apertured portion, the confines of said member defining said apertured portion containing an ionizable medium, a cold source of high energy charged particle emission positioned across said apertured portion and capable of ionizing said medium to produce currents effectively flowing in opposition to said high energy emission, a collector electrode bounding each end of said apertured portion for collecting said charged particle emission and said currents for establishing a potential relative to said source, and a conductive electrode positioned in said medium intermediate said source and each of said collector electrodes for controlling the flow of said current whereby said potential is modulated in accordance with signals impressed thereon.

11. Apparatus as claimed in claim 10 including means for applying modulation signals to said conductive electrodes in push-pull relationship.

12. Electrical apparatus comprising, a cold source of high energy charged particle emission, a collector electrode spaced from said source for collecting said charged particle emission to establish an electric potential relative to said source, a dielectric member disposed intermediate said source and said collector electrode and having a plurality of apertured portions extending therebetween, the confines of said dielectric member defining said apertured portions containing media capable of being ionized by a portion of said charged particle emission for producing ion currents effectively flowing in opposition to said high energy emission, and conductive electrode means positioned in each of said media for controlling the flow of said ion currents for modulating said established potential in accordance with signals impressed thereon.

13. Apparatus as claimed in claim 12 wherein said conductive electrode means comprises a grid positioned across said apertured portion.

14. Apparatus as claimed in claim 8 wherein said electrode means provides a longitudinal field for modulating said ion current.

15. Electrical apparatus comprising, a source of radioactive charged particle emission, an electrically conductive electrode spaced from said radioactive source, an ionizable medium located between said radioactive emission source and said conductive electrode, an electrically conductive control electrode positioned in said medium between said radioactive emission source and said first named conductive electrode, connection means to said control electrode for applying modulation signals to said first named conductive electrode for deriving output signals which vary as functions of said modulation signals.

16. Apparatus as claimed in claim 15 wherein said medium is a gas.

17. Apparatus as claimed in claim 15 wherein said medium is a liquid.

18. Apparatus as claimed in claim 15 wherein said medium is a solid.

References Cited in the file of this patent

UNITED STATES PATENTS
2,594,777 Hicks Apr. 29, 1952
2,672,567 Alvarez Mar. 16, 1954