Feb. 16, 1954 E. G. LINDER 2,669,609

ELECTRON DISCHARGE DEVICE

Filed Oct. 30, 1948

Fig. 1

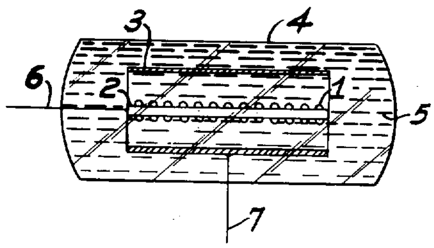


Fig. 2

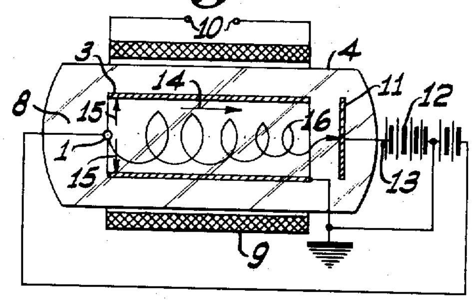


Fig. 3

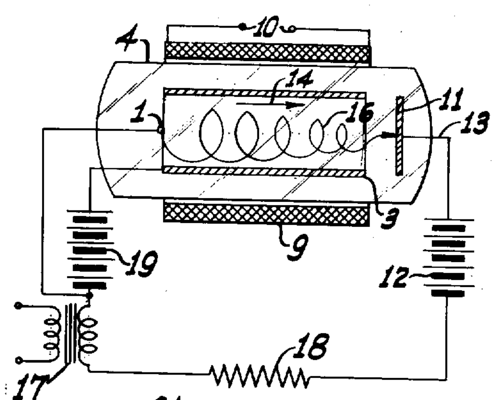
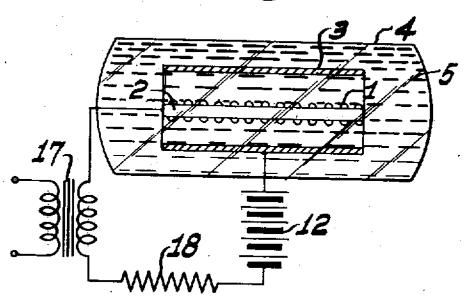


Fig. 4



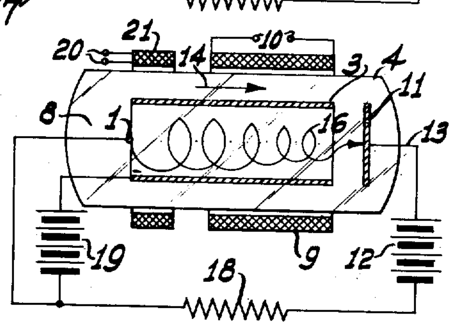


Fig. 5

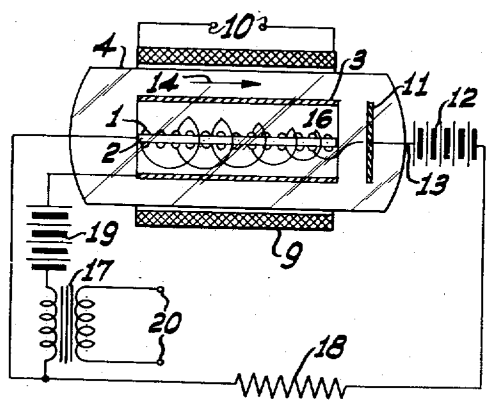


Fig. 6

INVENTOR
Ernest G. Linder
BY
J. L. Whittaker
ATTORNEY

Patented Feb. 16, 1954

2,669,609

UNITED STATES PATENT OFFICE

2,669,609

ELECTRON DISCHARGE DEVICE

Ernest G. Linder, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 30, 1948, Serial No. 57,428

8 Claims. (Cl. 179—171)

This invention relates to electron discharge devices and particularly to such devices in which the medium in which the discharge takes place is a liquid, or a gas near or above atmospheric pressure, or a solid or mixtures or combinations thereof.

The mean free path of an electron in a gaseous medium decreases with lower electron velocities, down to certain values, and increases with lower pressures of the medium. When ionization has been desired heretofore in the conventional electron discharge devices, an accelerating voltage in the form of an electric source had to be made available and applied electrostatically to the electrons in the medium to bring their velocities up to and exceeding ionizing values and the accelerating voltages have had to be of such values that the velocities of the electrons were brought up to the ionizing velocities of the electrons before collisions occurred with molecules of the medium. Because of the lengths of the mean free paths of electrons in gas media of conventional pressures and the accelerating voltages normally available, high vacuum gas media have had to be used.

It is known that certain isotopes are radioactive and emit primary 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 of both alpha and beta particles.

The unique properties of radioactive materials are not affected by temperature or pressure conditions or the physical characteristics of the media into which the particles are radiated. What reactions take place between the primary particles and the molecules of the medium after the particles have left the radioactive source does depend upon the physical characteristics of the medium. The magnetic and electric fields present in the medium affect the directions of movement and velocities of the charged particles.

For example, a beta particle emitted at 1 Mev. normally produces about 10^3 ion pairs. If such radiation takes place in air at atmospheric pressure and the total ionization effect of the radiation is desired to be utilized in an electron discharge device, the envelope of the device would have to have a radius of several meters as the range of a 1 Mev. beta particle in air is about that distance. If, however, the air is confined under pressure, air-medium electron discharge devices of practical dimensions may be utilized, as the mean free path of an electron in that medium is much shorter than that in air at atmospheric pressure.

Likewise, shorter mean free paths and hence shorter ranges may be availed of by selecting some liquid that is normally an insulator, for example an oil, or even a solid, such as a low density hydrocarbon with or without other elements in chemical solution or suspension, or mixtures of liquids, gases or such solids, as the medium to be ionized. Thus a "dense medium" is provided in the electron discharge device of this invention.

With high energy primary charged particles available from a radioactive source as the ionization initiating particles, the emission of secondary electrons per collision will be high, as sufficient energy is available not only to knock out electrons from the outer shells of the molecules but also some electrons from the inner shells will be projected into space.

In this specification and appended claims, a "dense medium" is defined as a medium in which the molecules are spaced relatively close together and includes a liquid or a solid or a gas at or near atmospheric pressure or substantially above atmospheric pressure. Also, a medium is defined as "ionizable" when it has the characteristics of the general class of materials known as "insulators" and the electrons in the outer shells of the atoms making up the molecules are not so tightly bound to the nuclei of the atoms that they can not be knocked out of their orbits by emitted nuclear particles or moving free electrons.

In selecting a radioactive isotope from the large number of choices, consideration may be given to the energy of the primary particles emitted, the half life of the isotopes, the character of the element to which the atoms of the isotope decay, and the general availability and cost of the isotope. Phosphorus^{32} and strontium^{90} are examples of suitable radioactive materials as they are beta emitters with a spread of velocities up to 1 Mev. It will be understood, however, that other suitable emitters are well known in the art, as published in the literature.

In selecting a solid or a liquid or a gas to be used as the medium, consideration may be given to the general availability and cost of the material and, in the case of gas, the pressure to be used to obtain the desired molecular mean free path. The molecular mean free paths in various gases are generally known in the literature.

For isotopes having high energy values and gases having relatively long molecular mean free paths, a magnetic field may be impressed upon the medium and a collecting electrode may be placed in the device near one end of the anode. When this electrode is connected to an electric source, the primary particles and the secondary emission electrons are caused to be drawn into cyclic paths and thus the paths of these particles and electrons are lengthened to and beyond the value of the mean free path of the particles for ionization by collision. It is not to be understood that only the high velocity primary particles cause the initiating of secondary electrons. The lower velocity primary particles likewise collide with the molecules of the medium and cause ionization.

While the velocities of the projected secondary electrons are very much less than those of the high energy primary particles, these secondary electrons, with gains in velocities from the electric fields, have sufficient energy to move through the medium and cause further ionization of the medium by collision with the molecules of the medium and furnish a still further supply of electrons for the conduction currents. These secondary electrons, because of their proportional number, are the principal particles to be considered in the practical use of the device.

This invention is related to the invention disclosed in copending application Serial No. 51,756 filed September 29, 1948, in which application is disclosed and claimed a high vacuum electron discharge device and associated circuits, the associated circuits being generally applicable to the present invention.

Among the objects of the invention are the providing of improved methods of and means for obtaining large electron discharge currents.

Another object is to provide an improved electron discharge device in which the discharge medium is a liquid, a solid, or a gas at pressures approximately at or substantially above atmospheric pressure, or in desired combination or form.

Another object is to provide an improved electron discharge device in which the initiating ionizing source of power is a radioactive material or isotope.

Another object is to provide an improved electron discharge device in which the initiating ionizing source of power is a radioactive isotope and in which the secondary electrons projected from the molecules of the ionized medium by the radioactive radiation have and gain from the electric fields sufficient energy to cause further ionization of the medium and thereby effect cumulative ionization.

Another object is to provide an improved electron discharge device in which the lengths of the paths of the electrons initiated by collision with the molecules of the medium are lengthened beyond the mean free path for ionization by collision to effect further ionization of the medium.

Another object is to provide an improved electron discharge device adaptable for use as a rectifier or a detector.

Another object is to provide an improved electron discharge device adaptable for use as an amplifier.

Other objects will be apparent from the disclosure of the invention as hereinafter set forth in detail and from the drawings made a part hereof in which: Figure 1 is a schematic diagram of a discharge device of the invention in which the medium is a liquid or a solid or a gas under

pressure; Figure 2 is a schematic diagram of a discharge device of the invention in which the medium is a gas and upon which medium is impressed a magnetic field and an electric field; Figure 3 is a schematic diagram of the device shown in Figure 2 incorporated into a rectifier or detector circuit; Figure 4 is a schematic diagram of the device shown in Figure 1 incorporated into a detector circuit; Figure 5 is a schematic diagram of a modification of the device shown in Figure 2 incorporated into an amplifier circuit; and Figure 6 is a schematic diagram of another modification of the device shown in Figure 2 incorporated into an amplifier circuit.

Corresponding numerals throughout the drawings refer to corresponding parts.

Referring to Figure 1, numeral **1** is a radioactive isotope charged particle emission source material deposited on a rod **2** that is positioned in the axis of electrode or anode **3**, which is cylindrical in form. Rod **2** and anode **3** are mounted by any conventional means in an envelope **4**. The envelope is filled with a normally insulating or non-conductive liquid or solid **5** that is ionizable by collision by the charged primary particles from source **1**. Connections to rod **2** and anode **3** are provided with conductor wires **6** and **7**, respectively.

Referring to Figure 2, the radioactive isotope source material **1** is positioned in the axis of and near one end of anode **3** in the envelope **4**, which is filled with some gaseous medium, shown generally at **8**. The envelope **4** is made of some material, such as glass, such that the magnetic field, produced by solenoid **9** when connected to a source connection of direct current **10**, is impressed axially upon the space between anode **3** and source **1**. Near the end of anode **3**, opposite to the end near which the source **1** is positioned, is mounted a collecting electrode **11**. This electrode **11** is connected to the positive pole of a source of electric potential **12** by wire **13**, the negative terminal of said source **12** being connected to the radioactive source **1**, and an intermediate point of potential being connected to the anode **3** and grounded.

The magnetic field is not required to be used in all cases where the ionized medium is a gas. The molecular and electron mean free paths of some gases are so relatively short, and especially at pressures substantially above atmospheric pressure, for example, 2 atmospheres, that devices of practical dimensions may be used without the need of extending the paths of the particles and electrons along the axis of the device.

By the adjustment of the positive potential on collector **11** and by adjusting the strength of the magnetic field indicated by arrow **14**, the particles emitted by the radioactive source **1** and the secondary electrons are deflected from their normal paths, **15**, into paths one which is represented by the spiral **16**. Thus the paths of the particles are lengthened beyond the mean free path for ionization by collision with the molecules of the gaseous medium **8**. Because of the dissymmetry of the electrodes, the conduction is non-linear and the device may be used as a rectifier.

A practical use of the device in a rectifier circuit is shown in Figure 3. Referring to Figure 3, the radioactive material **1** is connected to the one terminal of the secondary of transformer **17**, the other terminal of the secondary being connected to collector electrode **11** through load **18** and electric source **12**. Electrode **11** is connected to the positive terminal of source **12**. Anode **3** is kept positive with respect to source **1** by electrical source 19, which is connected between anode 3 and source 1, the positive terminal of source 19 being connected to anode 3. The primary of transformer 17 is connected to the alternating current to be rectified.

In operation: The primary charged particles are emitted from source 1 in random directions. Under the force of the magnetic field set up by the solenoid 9 and the electric field set up by electric source 12, the particles strike the anode 3 at varying angles of incidence according to their random directions of emission and the effect of the magnetic field 14, and cause secondary emission of electrons. Also, as the paths of the individual primary particles are lengthened by their assuming the form of a spiral under the effect of the magnetic field 14 and the electric field set up by source 12, their lengths become such that ionization occurs by which further secondary electrons are projected from the molecules of the medium. These secondary electrons collide with other molecules of the medium and produce further or cumulative ionization. The mean free path between molecules of the gaseous medium may be selected by choosing certain gases as the medium, the molecular mean free paths of which are generally known. Also, the molecular mean free path of a gas may be shortened by increasing the pressure of the medium.

Electric source 12 is adjusted such that electrode 11 is positive only during one half of the cycle of voltage variations between the two terminals of the secondary of transformer 17. When electrode 11 is positive with respect to source 1, the device is conducting and current will flow through load 18. When electrode 11 is negative with respect to source 1, the device is non-conducting. Electrical source 19 maintains anode 3 positive with respect to source 1. The varying current to be rectified is supplied to the primary of transformer 17.

The useful load to which the circuit is to be applied, is connected as shown as at 18. A resistance may be substituted for this load and the drop of potential along this resistance becomes available for use in circuits outside the circuit disclosed.

Figure 4 shows a detector circuit similar to that in Figure 3, but using the device shown in Figure 1 as a substitute for the device shown in Figure 2. A magnetic field and a collecting electrode are not required as the electron mean free path for ionization by collision of a solid or liquid are very short compared with those in a gaseous medium.

In Figure 4, the rod 2 supporting source 1 is connected to anode 3 through the secondary of transformer 17, load 18, and electric source 12. The source of the current to be rectified is connected to the primary of the transformer 17. The initial ionization by the primary particles, the resulting secondary emission of electrons and the further ionization by collision of the initial secondary electrons with molecules of the medium, take place as previously described.

Figures 5 and 6 illustrate the practical uses of the device in amplifier circuits.

Referring to Figure 5, the modulated currents to be amplified are supplied from their source 20 to a section 21 of the solenoid 9 of Figure 2. For very small currents, section 21 may constitute all of solenoid 9 of Figure 2. The magnetic field, shown as arrow 14, is created by the currents through coil 21 and solenoid 9. The strength of the magnetic field, therefore, follows the characteristics of the current source 20. Source 1 and electrode 3 are connected to the collector electrode 11 through load 18 and biasing electric source 19. Biasing electric source 19 is connected between anode 3 and source 1, the positive terminal of electric source 19 being connected to anode 3.

In operation: As the magnetic field is created by the currents from source 20, variations in such currents change the forms of the spirals 16 and therefore the extent of ionization of the medium 8 and hence cause changes in the currents through load 18, which correspond with the variations in the currents from source 20.

Another amplifier circuit is shown in Figure 6 in which the radioactive material 1 is deposited on rod 2 and extends for some distance along the axis of anode 3. The source of the currents to be amplified is connected to the primary of transformer 17. One terminal of the secondary of the transformer 17 is connected to electrode 3 through biasing electric source 19. The other terminal of the secondary of transformer 18 is connected to rod 2 and to collector electrode 11 through load 18 and electric source 12. The current through solenoid 9, to create the magnetic field 8, is supplied from a direct current source connection 10.

In operation: The variations of the currents in source 20 create through transformer 17 a modulating potential on electrode 3 and also impresses on source 1 and electrode 11 potentials opposite in sign. The effect of these changing potentials is to change the electric field between the electrode 11 and anode 3 and source 1 and hence cause variations in the ionization of both initial secondary electrons ejected from the orbits of the atoms of the gas as well as ionization by collisions of the initial secondary electrons with the atoms of the gas. The collections of electrons by electrode 11 is therefore, changed in accordance with the variations in the currents from source connection 20. The characteristics of the currents through load 18, therefore, correspond to those of source 20.

By extending the length of source 1 along the axis of anode 3, the control effect of the magnetic and electric fields is sharper as the number of primary particles are increased and a greater number of electrons are produced in a shorter time.

This invention, therefore, makes use of the radiation of nuclear particles from radioactive isotopes to initiate secondary electrons by the ionization of a medium, not only by the collisions of the primary particles with molecules of the medium, but also by the further collisions of the projected secondary electrons with molecules of the medium. A cumulative ionization, with large attending currents, is thereby obtained. By controlling the generation of these currents by currents from an independent source, such as a signal, the device is useful as a detector or an amplifier.

I claim as my invention:

1. An electron discharge device comprising: a concentrated radioactive charged particle emission source, a cylindrical anode, the said source being positioned adjacent said anode, a collector electrode also positioned adjacent said anode and substantially separated from said source, an electric source connected to said collector electrode, an envelope surrounding said emission source, said collector and said anode, a dense ionizable gas confined within said envelope, connections for a source of direct current, connections for a source of varying currents, and a solenoid sur-

rounding and coaxial with said anode, a portion of said solenoid being connected to said direct current source connections and a portion to said varying currents source connections, whereby the changes in the magnetic field produced by said solenoid correspond in characteristics to said varying currents and a varying magnetic field is impressed on said medium along the axis of said anode.

2. An electron discharge device comprising, a radioactive charged particle emission source capable of emitting charged particles having energies of the order of one million electron volts, an anode electrode positioned adjacent said source, connection means for a source of electric potential for said anode electrode, an envelope surrounding said emission source and said anode electrode, an ionizable medium comprising matter in which the molecules are spaced relatively close together confined within said envelope, a collector electrode within said envelope positioned adjacent said anode and spaced from said source, and connection means for a source of electric potential for said collector electrode, said medium being adapted to be ionized by charged particles emitted by said source to produce a copious supply of ionization electrons for collection by said anode and collector electrodes.

3. An electron discharge device comprising, an anode, a radioactive charged particle emission source positioned adjacent said anode, a collector electrode positioned adjacent said anode and substantially separated from said source, an electric source connected to said collector electrode, an envelope surrounding said emission source, said collector and said anode, an ionizable medium comprising matter in which the molecules are spaced relatively close together confined within said envelope, terminals for a source of direct current, terminals for a source of varying currents, and a solenoid surrounding and coaxial with said anode, a portion of said solenoid being connected to said direct current terminals and another portion of said solenoid being connected to said varying current terminals, whereby the changes in the magnetic field produced by said solenoid correspond in characteristics to said varying currents and a varying magnetic field is impressed on said medium along the axis of said anode.

4. An electron discharge device comprising, a cylindrical anode electrode, connection means for a source of electric potential for said anode electrode, a support member disposed within said anode electrode and along its axis and having lead-in means, a radioactive charged particle emitting material carried by and distributed along the length of said support member capable of emitting charged particles having energies of the order of one million electron volts, a collector electrode positioned adjacent said anode electrode, lead-in means connected to said collector electrode, an envelope surrounding said emission source, said anode, and said collector electrode, and an ionizable medium comprising matter in which the molecules are spaced relatively close together confined within said envelope, said medium being adapted to be ionized by charged particles emitted by said source to produce a copious supply of ionization electrons for collection by said anode and collector electrodes.

5. An electron discharge device as claimed in claim 2 wherein said medium is a gas.

6. An electron discharge device as claimed in claim 2 wherein said medium is a liquid.

7. An electron discharge device as claimed in claim 2 wherein said medium is a solid.

8. An electron discharge device as claimed in claim 2 wherein said medium is a mixture of materials.

ERNEST G. LINDER.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
770,233	Hewett	Sept. 13, 1904
1,145,735	Ainsworth	July 6, 1915
1,299,356	De Forest	Apr. 1, 1919
1,466,777	Winkelmann	Sept. 4, 1923
1,534,148	Vogt et al.	Apr. 21, 1925
1,618,499	White	Feb. 22, 1927
1,748,386	Loewe	Feb. 25, 1930
2,304,412	Kern et al.	Dec. 8, 1942
2,477,348	Postal	July 26, 1949
2,479,271	Shonka	Aug. 16, 1949
2,520,603	Linder	Aug. 29, 1950
2,531,144	Manley	Nov. 21, 1950

FOREIGN PATENTS

Number	Country	Date
332,734	Great Britain	Aug. 7, 1930

OTHER REFERENCES

Phys. Rev. vol. 35, Nov. 3 (2d) Feb. 1, 1930, page 218.